university of groningen / faculty of philosophy

Tracing the impact of Newton's account of force in early modern British natural philosophy: a quantitative approach

A thesis presented for the degree of
Bachelor of Arts in Philosophy of a Specific Discipline

June 18, 2021

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Word count: 10,357

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1. Introduction

When researching history of philosophy, it is common practice to only focus on the work of a handful of philosophers. However, there are also considerable cases in which a researcher wants to focus on more philosophers. There can be various reasons for this, an important one being that a handful of philosophers might give a too narrow account of the actual philosophical views during that time period. There were many more philosophers active during that period who may be very relevant for your research. But when you are interested in studying the work of such a large group of philosophers, time and resource constraints come into play. To obtain a thorough and nuanced understanding of a philosopher, you have to spend a substantial amount of time reading their works. For a large group of philosophers, this seems simply impossible.

As an example, when talking about the early modern period, you might restrict yourself to seven philosophers: Descartes, Spinoza, Leibniz, Locke, Berkeley, Hume, and Kant. Nevertheless, this was a very rich philosophical period in which a lot more philosophers actively participated. In the past decades, there have been attempts to investigate the works of other less 'canonical' philosophers from this time period (Shapiro, 2016). One of the reasons to do this, is to obtain a more complete and accurate grasp of how a concept was understood during that period. Concepts are always expressed through language which is itself socially constructed (Agha, 2006). Because of this, communication through concepts itself is a social process. Everyone has their own interpretation of a concept and it is difficult to transmit this exact interpretation to others. Therefore, obtaining a complete understanding of a concept is, in some sense, inherently problematic when only analyzing several individuals.

The problem so far is the result of connecting two issues: (1) to study philosopher(s), we need to take into account multiple sources, but quantity is difficult to handle case by case; (2) when we study philosophers we often study concepts, and concepts are determined by how people speak about them, hence we need to take into account multiple voices. Notice that (1) and (2) are different, albeit related. You might say that the quantitative approach used in this essay is a way of combining both: on the one hand, it focuses on how specific concepts are used in a wide population of authors through more or less automated computational procedures, on the other hand, this allows to actually take into account more authors in a feasible way.

Such a quantitative approach is in the secondary literature often referred to as the 'model approach'. This approach provides us a quantitative-oriented study of transitions of concepts in the primary literature. The approach has been promoted by Betti and van den Berg (2013, 2014). They describe these so-called models as 'fully explicit and revisable interpretive frameworks or networks of concepts developed by the historians of ideas themselves'. The main idea here is to apply computational methods to literary data, also referred to as 'distant reading', a term that was introduced by Franco Moretti in his influential article "Conjectures on World Literature" (Moretti, 2000). The preeminent advantage of this model approach is that it allows us to study large corpora without having to read everything. Another significant benefit of this approach is that it makes the background assumptions explicit, which enables a proper discussion of the appropriateness of the model.

This research will focus on the work of English mathematician, physicist, and philosopher Isaac Newton and its impact on British natural philosophy. Newton is widely recognised as one of the most influential scientists of all time and therefore it is highly pertinent to obtain a broader picture of how his work and influence developed in the early modern period. In particular, I will investigate what the impact of Newton's account of force was in British natural philosophy in the late 17th and 18th century. It is well-established in the literature that numerous natural philosophers adopted this Newtonian view (Henry, 2013). In this study, I aim to offer new insights into the rapidness of this development and how much opposition there was. This influence of Newton can be traced through the use of specific new concepts introduced by Newton, such as 'force'. Although Newton did not in fact invent the word 'force', he did place it in the center of his philosophical framework and used it in radically different way than done before. By studying how philosophers did or did not change in their use of the concept of 'force', the impact of Newton on British natural philosophy can be measured. A comparative study which also looked at the reception of Newtonian natural philosophy is given by Ducheyne and van Besouw (2021). The difference with this study is that I focus on a wider timeframe, use a quantitative approach, and focus mainly on the concept of 'force'.

Using the model of this study, I demonstrate that there is substantial difference in the use of 'force' before and after Newton. Firstly, it has been found that the concept of 'force' is used substantially more after Newton. Before Newton, it was used barely and after his most important publication, the *Principia*, it became one of the central terms in natural philosophy. Moreover, I show that natural philosophers started using this concept more in a Newtonian context. Although there was also some opposition, most authors in the corpus adopted the Newtonian conception of 'force'. I therefore argue that Newton had a substantial impact on early modern British natural philosophy. A surprising finding in this research is that the prominence of the Newtonian concept of 'force' also started to decline again.

The remainder of this paper is structured as follows. Section 2 introduces the reader to the work of Newton. Here, the concept of 'force' will also be spelled out in more detail. Afterwards, Section 3 discusses the modelling procedure. First, the corpus used for this model will be discussed. After that, the exact modelling procedure will be specified. Next to that, some model validation will be performed. Subsequently, in Section 4 the results of the model will be offered and interpreted. Since this model approach is quite a controversial topic in philosophy, Section 5 is devoted to philosophical evaluation of the adequateness of the model. Finally, Section 6 draws a conclusion.

2. Newton and his account of force

Isaac Newton was born in 1642 in a small town called Woolsthorpe-by-Colsterworth in England. He entered Trinity College, Cambridge, in 1661. In that period, teaching was mostly based on the Aristotelian framework. Newton supplemented his study with the works of Euclid, Descartes and Galileo. In 1665, the Great Plague hit England and it was during this period that Newton seriously developed his first research on gravitation, calculus and optics. This period is therefore sometimes described as Newton's so-called "annus mirabilis" (Palter, 1970). In the years after, he continued his research and published his first work. Because of his publications and his eminent position at Cambridge, he got into contact with prominent scientists of that time including Robert Hooke and Christiaan Huygens, who both criticized several parts of the work of Newton (Smith, 2008a). In 1684, a visit of astronomer Edmond Halley initiated the most important piece of Newton's work. Halley approached Newton with a question about the trajectories of planets. This led Newton back to his work on gravitational force. From 1684 to 1687, Newton put of all his research into a 500-page work called the '*Philosophiæ Naturalis Principia Mathematica*' (Mathematical Principles of Natural Philosophy) which is commonly referred to as the '*Principia*'. In this work, Newton stated his law of universal gravitation and his laws of motion. This is the basis of modern classical mechanics and it made Newton a leading figure in the field of natural philosophy. Until the arrival of the relativity theory of Einstein in 1905, this Newtonian framework remained the basis for most of the work in natural philosophy. It took some effort for people to accept Newton's work but at the end of the century "no one could deny that [out of the *Principia*] a science had emerged that, at least in certain respects, so far exceeded anything that had ever gone before that it stood alone as the ultimate exemplar of science generally" (Smith, 2008b).

A very important aspect throughout Newton's work is his experimental method. He clearly rejected the method of hypotheses and wanted to inductively generalize from particular phenomena. Therefore, Newton's philosophy was also sometimes called 'experimental philosophy'. He states himself in his fourth rule of Reasoning in Philosophy from the third edition of the *Principia*:

> "In experimental philosophy, propositions gathered from phenomena by induction should be taken to be either exactly or very nearly true notwithstanding any contrary hypotheses, until yet other phenomena make such propositions either more exact or liable to exceptions". (Cohen et al., 2016, p. 1062)

Newton did some very influential experiments during his life so he can clearly be characterized as an empiricist. However, in modern physics, Newton is not only known for his experiments but also for his mathematical work. Newton invented calculus (at the same time as Leibniz) and he provided the groundbreaking laws of motion that still play a crucial role in our current understanding of the world. Thus, Newton's method was mainly to do experiments and to then generalize these experiments to laws. These laws were generally mathematical laws, which is another important feature of Newton's work. There had not yet been a natural philosophy framework that was based so much on mathematics. Because of this, the *Principia* is also known to be a very hard to read as it requires a significant mathematical background (Smith, 2008a).

The *Principia* is also Newton's main contribution to philosophy. For some people 'Newton as a philosopher' might still sound odd. In our current age, most people know Newton as a scientist, physicist or mathematician. This is because he made such immense contributions to these fields, and on top of that, in modern times these fields are so developed that it is hard to be a philosopher next to that. However, in Newton's time, the people who studied the world around us were called 'natural philosophers'. Fields like physics and chemistry did not exist yet and they used a philosophical perspective to understand nature. Therefore, the *Principia* can also be seen as a response to other natural philosophers. One of the first of such natural philosophers was Aristotle, and since the medieval period, a number of scholastic authors developed various forms of Aristotelian natural philosophy. This Aristotelian or 'scholastic' framework was dominating university curricula all over Europe up to Newton's time. In Newton's time, another framework was on the rise, which was the Cartesian, developed by René Descartes. The aim of Descartes was to replace the Aristotelian or "scholastic" framework. Newton criticized both the Aristotelean and Cartesian account and developed his own framework. The title of the *Principia*, *Philosophiæ Naturalis Principia Mathematica*, also indicates the intention to enter into a dialogue with the *Principia Philosophiae* of Descartes.

Newton agreed in general with the Cartesian rejections of Aristotle, but there are still some fundamental differences between the Newtonian and Cartesian accounts. The Cartesian account is clearly a mechanistic one, Descartes saw the world as a large-scale mechanism (like a machine). He was a substance dualist, in which he argued that the world existed of two distinct substances. The first is extended matter and the second is the immaterial mind. Since the mind is immaterial for Descartes, the world around us completely exists of inert matter. Everything should also be explained in terms of this inert matter and its motion or translation from place to place. These particles of matter can only have an impact on each other by physical interaction, like a billiard ball striking another ball that also starts moving as a result of that. Occult forces were unacceptable for Descartes. He explained the trajectories of planets around the sun by swirls of particles that moved along with them, not by forces that exercise their effects on each other (Hakfoort, 2012).

Newton replied to this theory on the trajectories of planets that it was in contradiction with his experiments. From these experiments, he developed his own account of nature in which the concept of 'force' stood central (Janiak, 2019). Especially the Newtonian 'force of gravity' was revolutionary. This Newtonian approach was mostly quantitative in which nature was explained using mathematical laws governing motion and force (Janiak, 2008, p. 82). Descartes used a more qualitative approach, in which he drew concepts from mathematics and geometry to describe nature. For instance, he used 'extension' from the field of geometry as the essence of a 'body'. However, he does not really apply mathematics and geometry for the sake of providing a quantitative account of particular phenomena. In the work of Newton, there is not much of discussion about which concepts you should be using, but there is a lot of mathematics itself as a way of representing quantitative relations. So, the Cartesian account could be described as a more conceptual theory and the Newtonian as a more practical theory, in which his main goal was to obtain the mathematical laws that were in line with experiments.

Descartes barely used the concept of ‘force’ in his work. In his conceptual approach, he thought carefully about what concepts to use and ‘force’ can be quite ambiguous. Descartes tended to reduce ‘force’ to nothing but ‘motion’ itself, in order to avoid any association between this notion of ‘force’ and the Aristotelian notions of ‘powers’ that were thought to underpin the activities that shape natural phenomena—a view that Descartes wanted to oppose. For Newton, ‘force’ stood at the center of his thinking. He really placed this concept at the forefront of natural philosophy. Newton described this concept of force as an ‘impressed force’, it exerts action on a body and as a result that body changes its state of motion (Janiak, 2019). Especially on the continent by philosophers like Huygens and Leibniz, this Newtonian concept of force was received with a lot of confusion. An important point of discussion was the ontology of forces: people had a hard time grasping what such a force would actually be. In Definition Four of the *Principia*, Newton states that: “This force consists solely in the action and does not remain in a body after the action has ceased”. Mechanist readers found this very hard to perceive as they believed that material bodies consist solely of properties such as size, shape, mobility and solidity.

A way to better understand the Newtonian concept of ‘force’ is to conceive it as a quantity. Such a force can be measured using the laws of Newton. For example, Newton’s second law states that force is proportional to mass and acceleration. Using the formula $F = ma$, we can measure force since we can also measure mass and acceleration. Forces for Newton are quantities and these quantities can be measured by using other features of nature. Newton’s main focus was to get mathematics right, not to spell out the exact details about the ontology of force and these other features of nature. Even if we do not know these ontological details, we can still measure them and use them as quantities in our calculations (Janiak, 2008, p. 82).

There are several keywords associated with ‘force’ that are strongly Newtonian. An obvious one is ‘gravitational’, Newton was the first to come up with gravitational force and he discussed it in detail in the *Principia*. Another one, as already discussed, is quantity. Newton saw force as something which we could measure. In Definition Eight in the *Principia*, he also dives deeper into these quantities and separates them in different types (Janiak, 2008, p. 15). Two important ones here are ‘accelerative forces’ and ‘absolute forces’. He also talks about ‘motive forces’ but this account of force is not strictly Newtonian as mechanists mainly spoke about forces when they related it to motion. Another keyword that is distinctly Newtonian is ‘attractive’ which also related to gravitational force. Non-Newtonian philosophers found it hard to comprehend how an attractive force could work at a distance, for example in the interaction of planets. These related keywords will guide us in the next section to identify the positions of the authors in the British corpus.

3. Model

In will start this section by elaborating on how the corpus was established. Subsequently, I will perform some exploratory analysis. When I have obtained all the necessary knowledge about the corpus, I will spell out the modelling procedure. Finally, I will also carry out two test cases to verify the procedure.

3.1 Establishing the corpus

The corpus used in this essay consists of selected works from a larger corpus built by Andrea Sangiacomo, Raluca Tanasescu, Silvia Donker, Hugo Hogenbirk, all from the University of Groningen. Their two main sources when building the corpus were existing *Dictionaries* of Dutch, British, French, and German early modern philosophers, and *Worldcat,* the world's largest aggregator of library catalogues. For the corpus of this study, I only used documents which they put in the category of 'primary works'. This choice has been made since these works are most systematic in nature. Moreover, in the review of the corpus, the authors also state that "primary works are the most certainly connected with natural philosophy and we expected that if anything major happens within the field, it should be reflected somehow in this group of texts". Therefore, I expect this corpus to be a suitable source for the analysis.

In the selection of these documents I looked at several aspects. First of all, I restrict my attention to English texts. During that period, a lot of texts were also written in Latin but for reasons of linguistic homogeneity, I will only focus on English texts. It also seems that, in the British context, Latin publications in natural philosophy were relatively more scarce. Moreover, another important aspect that I took into account is that the texts should give a general overview of their vision on natural philosophy. When a text focuses on a specific field of study such as medicine, it is very likely that it will not elaborate on their conception of force as it is used in discussing natural phenomena like the motion of the planets. As I will show in my exploration of the corpus in the next subsection, all selected texts seem to be relevant for this study. I have selected a few works that were published before the *Principia* in 1687 as well. This has been done to make a comparison between the works before and after the *Principia.* Nevertheless, the main focus of the corpus and this analysis is on texts published after the *Principia*. It is important to add to this that the latest selected text is from the year 1822. Until early 19th century, people who studied nature were still called natural philosophers (Janiak, 2019). However, in this time, a branching of natural philosophy into several subfields like physics and chemistry could be observed. For example, in 1833, Cambridge philosopher William Whewell coined the word 'scientist'. So, this also seems to be the moment to end our corpus. Intellectuals started to focus on subfields and there were less attempts to answer such broad questions as natural philosophers did.

On the basis of these criteria, I collected the following 42 texts:

Year	Title (shortened)	Author
1644	Two Treatises	Kenelme Digby
1651	Naturall Philosophie	John Amos Comenius
1663	Considerations Touching The Usefulness	Robert Boyle
1666	Origin Of Forms And Qualities	Robert Boyle
1666	Observations Upon Experimental Philosophy	Margaret Cavendish
1668	Grounds Of Natural Philosophy	Margaret Cavendish
1694	An Entire Body Of Philosophy	Antoine Le Grand
1705	General Laws Of Nature And Motion	Humphry Ditton
1717	A Course Of Mechanical And Experimental Philosophy	James Stirling
1727	The Principles Of The Philosophy Of Expansive Contractive Forces	Robert Greene
1728	View Of Newtons Philosophy	Henry Pemberton
1730	Principles Of Natural Philosophy	Benjamin Worster
1733	An Epitome Of A Course Of Lectures	John Banks
1734	A Course Of Experimental Philosophy	J.T. Desaguliers
1743	A Short And General Account	John Horsley
1743	Circle Of Sciences	James Wylde
1745	The Principles Of Natural Philosophy	J. Robertson
1748	Attempt To Demonstrate	Gowin Knight
1748	System Of Natural Philosophy	Thomas Rutherforth
1754	Principles Of Mechanics	William Emerson
1754	The Principles Of Philosophy	Benjamin Wilson
1758	Compendious System Of Natural Philosophy	John Rowning
1762	Essay On First Principles	William Jones
1772	Introduction To Newtons Philosophy	James Ferguson
1774	Four Introductory Lectures in Natural Philosophy	Hugh Hamilton
1774	Electrical Philosophers	Richard Lovett
1775	Newton’s Philosophical Discoveries	Colin Maclaurin
1776	A Description Of The Experiments	George Atwood
1777	First Lines Of Physics	William Cullen
1784	A Copmendium Of A Course Of Lectures	I. Atkinson
1784	Course Of Experimental Philosophy	John Robison
1786	The Young Man’s Book Of Knowledge	Daniel Fenning
1789	On The Elementary Principles Of Nature	E. Peart
1794	Lectures On Natural And Experimental Philosophy	George Adams
1794	Newtonian System Of Philosophy	Tom Telescope
1795	Analysis Of A Course Of Lectures	Adam Walker
1803	The Principles Of Mechanics	James Wood
1804	Elements Of Mechanical Philosophy	John Robison
1807	A Course Of LecturesOn Natural Philosophy	Thomas Young
1812	Outlines Of Natural Philosophy	John Playfair
1822	A System Of Mechanical Philosophy	John Robison

I want to make two further remarks on the selected corpus. The first is that for some authors, there are two or three works in the corpus. This choice has been made since these authors were quite influential and published multiple works that are very relevant for this study. Secondly, the well-informed reader might notice that some of the above works were actually published in several volumes. In this corpus, I combined these volumes to one document.

3.2 Exploration of the corpus

The aim of this subsection is to get further insights into the content of the corpus which can guide us in the modelling procedure. First of all, it is a good idea to check the most used words. When checking the most common words, you will usually observe many stop words like ‘the’, ‘a’, and ‘of’. I have removed all these stop words as they are irrelevant here. The most used words that remain can be found in the word cloud in Figure 1.

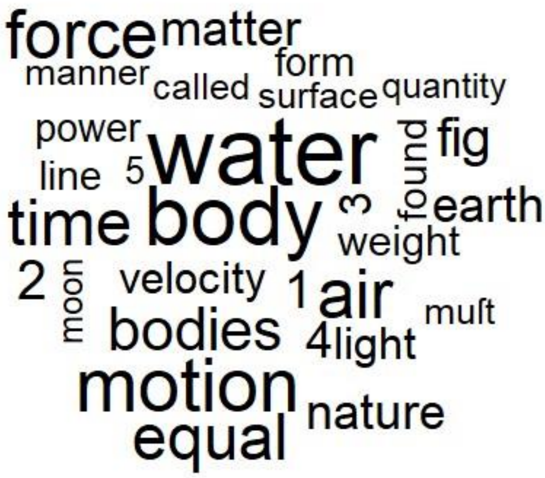

Figure 1: Word cloud of the most common words in the corpus

Here, I observe that the word ‘force’ is used extensively in the corpus since it appears relatively large in the word cloud. Moreover, the other words are also according to our expectation of a work in natural philosophy. Words like ‘body’, ‘water’, ‘motion’, and ‘time’ should be rather common here.

Moreover, it is important to check if all individual works are relevant for our analysis. One criteria for all texts should be for example that they contain the words ‘force’ and ‘gravity’. In case there would be any texts that do not contain these words, it seems rather pointless to include them as these words are the focal points of this study. I have examined this and it turns out that the word ‘force’ can be found in all works. For ‘gravity’, this is not the case, but it can be found in all works after the publishing of the *Principia* in 1687. It makes sense that the word ‘gravity’ is not found in all works before 1687. This is because, in medieval natural philosophy, the Latin word ‘gravitas’ was used to translate the Aristotelian ‘heaviness’ and it was not the focus of most works. In his work *De Caelo,* Aristotle described this concept as:

“Let us then apply the term ‘heavy’ (βάρος) to that which naturally moves towards the centre, and ‘light’ to that which moves naturally away from the centre.” (Aristotle, 1922)

The essential change of concept that Newton made was characterizing gravity as a ‘force’, whereas it first denoted a ‘quality’.

Thus, I do know that I can find the words ‘force’ and ‘gravity’ in (almost) all works. It is also relevant for this study to examine the frequency in which they were used and then especially how these frequencies developed over time. I would expect to find an upward trend over time, at least when I would compare the times before and after 1687. The use of ‘force’ can be found in Figure 2.

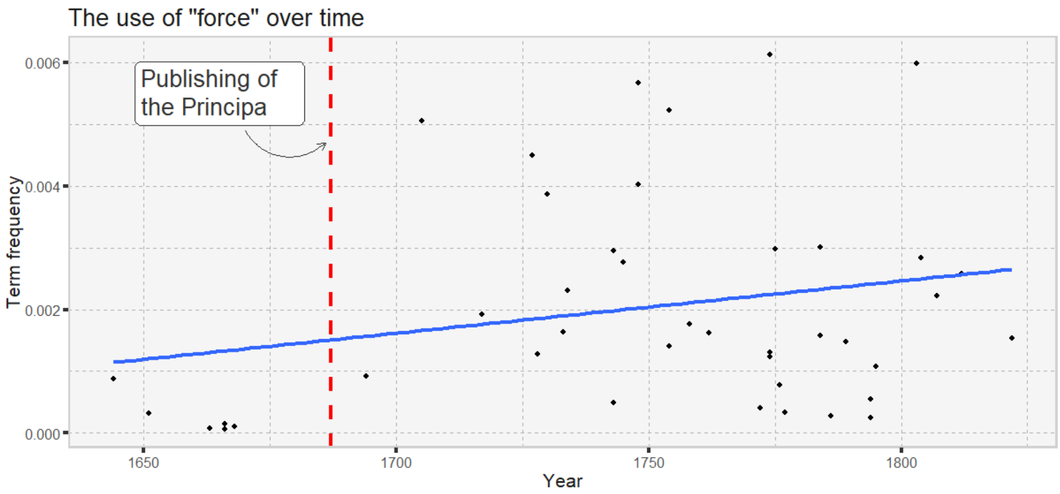

Figure 2: Frequency of ‘force’ over time

For the word ‘gravity’, I observe a similar trend in Figure 3.

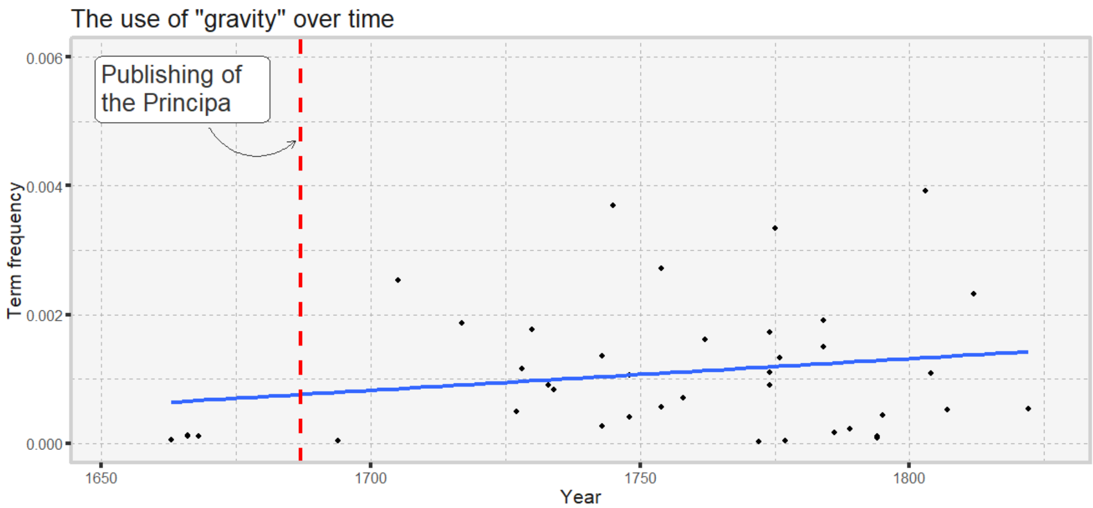

Figure 3: Frequency of ‘gravity’ over time

We could also split up the works before 1687 and after 1687 into two groups. These groups can then be seen as two separate ‘samples’. I already see in the plot that the term ‘force’ is used much more after 1687 but this could also be due to random chance. A quantitative measure that could help us to determine how likely it is that this is due to random chance is the Welch Two Sample t-test. With this test, I consider if there is any significant difference between the means of the term frequencies. Applying this test gives us a p-value of $7.2 * 10^{-8}$. This tells us that it is extremely unlikely that the difference between the term frequencies is due to random chance. Therefore, I can conclude that it is evident in the corpus that due to Newton 'force' became one of the central terms in natural philosophy. However, this does not tell us whether all authors after Newton embraced the same concept of 'force'. They could be talking about force in entirely different ways. To inspect this, I will need to look at the context. I will do this in the model which will be spelled out in the next subsection.

3.3 Modelling procedure

To get a proper understanding of how the concept of 'force' was used in the 17th and 18th century, I will use a model that examines the context in which it is used. In that context, I am going to search for keywords that are specifically 'Newtonian' or specifically 'Non-Newtonian'. As already discussed in Section 2, some words can clearly be placed in a Newtonian framework. For example, when a philosopher speaks about 'gravitational force', it provides strong evidence that this philosopher thinks about force in a Newtonian way. To get an idea of the most common associated words with force in the corpus, I created a network graph which can be found in Figure 4. In this graph, the opacity of the arrows indicates how 'strong' the association is.

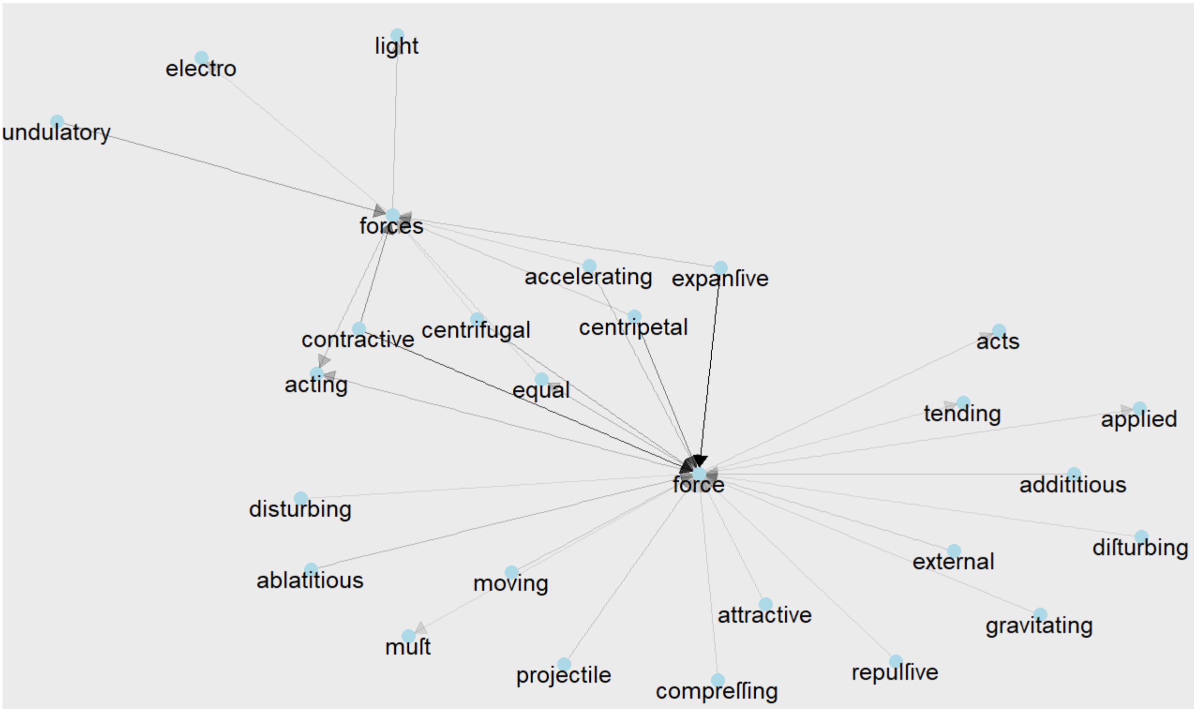

Figure 4: Network graph containing the most associated words with 'force' and "forces" in the corpus

In Figure 4, I especially observe that `expansive` (note the use of the long s, (ſ), in Figure 4 which was still common in that time), `contractive` and `centripetal` have strong connections with `force` and `forces`. Since these words are so popular in the corpus, it is essential to do some close reading to get a better understanding of how they were used. When considering 'expansive' and 'contractive', I am naturally drawn to the text by Greene in 1727 as it is called "*The Principles Of The Philosophy Of Expansive Contractive Forces*". In his work, several references to Newton can be found and also the concept of gravity is also used extensively. For example, in this sentence: "*Gravity is owing to it's Principle of Contraction towvards the Earth, which is ſomething: Diminiſi'd by that of it's Expanſion from it*" (quoted in the original OCR quality from the corpus). Here, it can clearly be observed that 'contraction' is related to gravity. Gravity is seen as an contracting force. So, in that sense, I would say that 'contractive force' is definitely Newtonian. However, I also read about an expansive force, which diminishes the expansive force. In another sentence in Greene's work, I find the following: "*which has an Expanſive Force, as the Sun, by which it Repells all Bodies ſrom it*". So, this expansive force is a repelling force, which is a notion which is not present in Newton's work. It is then the question if Greene should be classified as Newtonian or non-Newtonian, or perhaps as neutral. When reading his work, you see that he generally agrees with Newton but that he also wants to add a repelling force to the framework. Therefore, I will not model 'expansive force' as definitely non-Newtonian as it might overshadow the actual agreement with Newton in several works. Nevertheless, this assumption is debatable and it will be further investigated in the model validation.

Another important keyword which can be found in Figure 4 is 'centripetal' which is also related to 'centrifugal' which can also be seen in the figure. Although Newton elaborated on centrifugal force, Huygens already coined the term in his work '*De Vi Centrifuga*' in 1659 (Erlichson, 1994). However, it was Newton who first used the term of 'centripetal force' in the manuscript '*De motu corporum in gyrum*' which he sent to Edmond Halley in 1684 (Cohen & Whitman, 1999). Newton describes this centripetal force as a force that attracts a body towards the center. Consequently, I will use centripetal force as a Newtonian notion of the concept of 'force'.

As already discussed in Section 2, 'accelerating force' and 'absolute force' are also particularly Newtonian so these will also be used in the model. Furthermore, I also find 'gravitating force' and 'attractive force' in Figure 4 which will, obviously, be used. Although, 'attractive force' is not that strict Newtonian as the term 'attraction' can already be found back in Aristotelian and Alchemical traditions. Thus, this might be interesting to further investigate in the model validation.

When I look for non-Newtonian terms in Figure 4, the word 'external' sticks out. You would more likely classify this as a Cartesian notion of force: a ball starts to move because it got hit by another, external, ball. Next to that, it could also fit within an Aristotelian framework. Furthermore, 'moving' is also an outstanding keyword. Before Newton, when philosophers spoke about force, it was generally related to motion. Lastly, 'disturbing' does also not entail any specifically Newtonian view.

Thus, in my model, I will be looking in what context the concept of 'force' is used. I will use the following words to classify a Newtonian context:

- Contractive

- Centripetal
- Accelerating
- Absolute
- Gravitating
- Attractive.

Moreover, the following words will be used to classify a non-Newtonian context:

- External
- Moving
- Disturbing.

The model will then generate the proportion in which these keywords associated with force were used compared to the total use of force in a text. Thus, for instance, if an author will use the word 'force' one hundred times in a text, but only one time in connection with a Newtonian keyword, then the proportion will be 1%. However, if the author, for example also uses 'force' three times in connection with a non-Newtonian term, the proportion will be -2%. By also adding non-Newtonian terms to the model, I can distinguish authors who only use 'force' in a neutral sense from authors who use 'force' in a strict non-Newtonian context. Before implementing this model, a test case will be executed to examine its performance.

3.4 Test cases

In a test case, you would like to consider a comparable situation of which you already know the outcome. Therefore, I might want to look at a less controversial issue in the 17th and 18th century and see what kind of results I obverse in this case. One such issue is given by experimental philosophy. As discussed in Section 2, Newton was an empiricist and this feature is present in all of his works. However, Newton was not the first in Britain to promote experimental philosophy. This was a movement that was already dominating in British natural philosophy and was initiated by Francis Bacon at the beginning of the 17th century. Since this was such a prominent methodology in Britain around Newton's time, I can investigate the occurrence in our corpus. Although Newton did have some influence on the experimental methodology in the sense that he approached it in a more mathematical way than was usual (Anstey & Vanzo, 2016), he did not have a radical impact on it. Therefore, I do not expect to see a large shift in our corpus after the publishing of the *Principia.* I can then interpret this development of experimental philosophy as a kind of baseline. It can then be investigated if I observe a deviation from this norm when I change the focus back to 'force'.

To investigate the popularity of experimental philosophy, I will use two test cases. The first of these will only look at the term frequency of one word and is in that sense not entirely comparable with the modelling procedure spelled out in Subsection 3.3. However, it gives us a general idea of the appropriateness of looking at term frequencies. In this first case, I will use 'experiments' as the main keyword. The term frequency can be found in Figure 5.

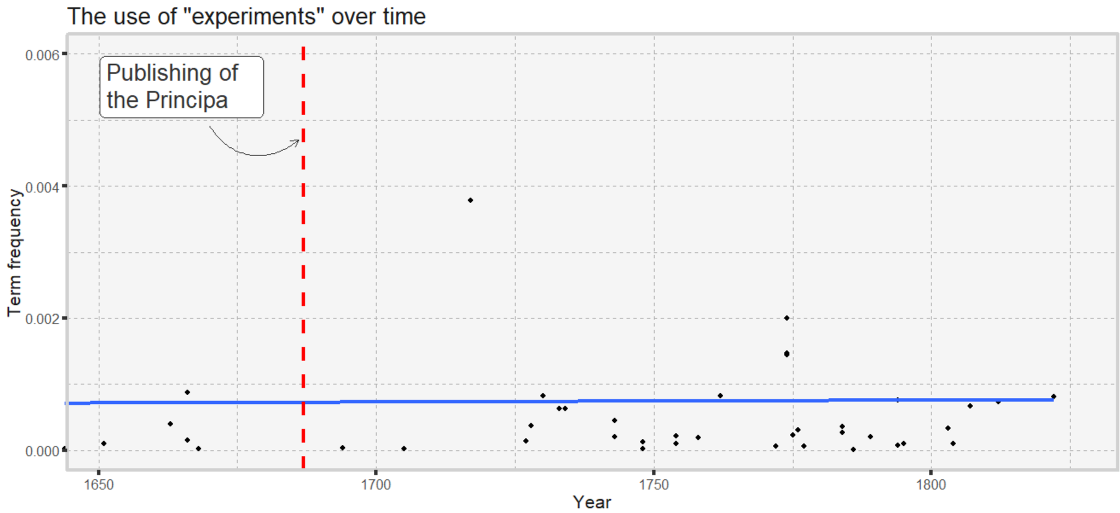

Figure 5: The popularity of experimental philosophy over time

In this figure, I observe a very constant trend over time. The blue line in the figure indicates the linear regression of term frequencies against time. The slope of this line is slightly positive but the p-value attached to this is 0.961. This indicates that there is indeed no significant effect over time and thus that the popularity of the experimental method remained constant. As was expected, the use of experiments was already quite common before the work of Newton. Moreover, I also do not observe a significant shift after the publishing of the *Principia*. This shows evidence that an approach which considers term frequencies is valid.

In the second test case, I will again investigate experimental philosophy. The difference with the first test case is that I will now do this based on associated keywords just as the modelling procedure in Subsection 3.3. In this test case, I will examine a keyword which all readers of this essay will probably like: ‘philosophy’. It will be investigated if this word is used in the same context as ‘experimental’. Of course, I do not expect that this frequency will be that high as there are numerous contexts in which ‘philosophy’ can be used. In this corpus, the use of ‘natural philosophy’ is especially highly relevant. Nevertheless, I am mainly interested in the development over time. I would expect, just as in Figure 5, that the proportion in which philosophy is used in connection with ‘experimental’, is relatively constant over time. Although this is relatively simple model, it provides a straightforward way to test the modelling procedure laid out in Subsection 3.3. The results of the model can be found in Figure 6.

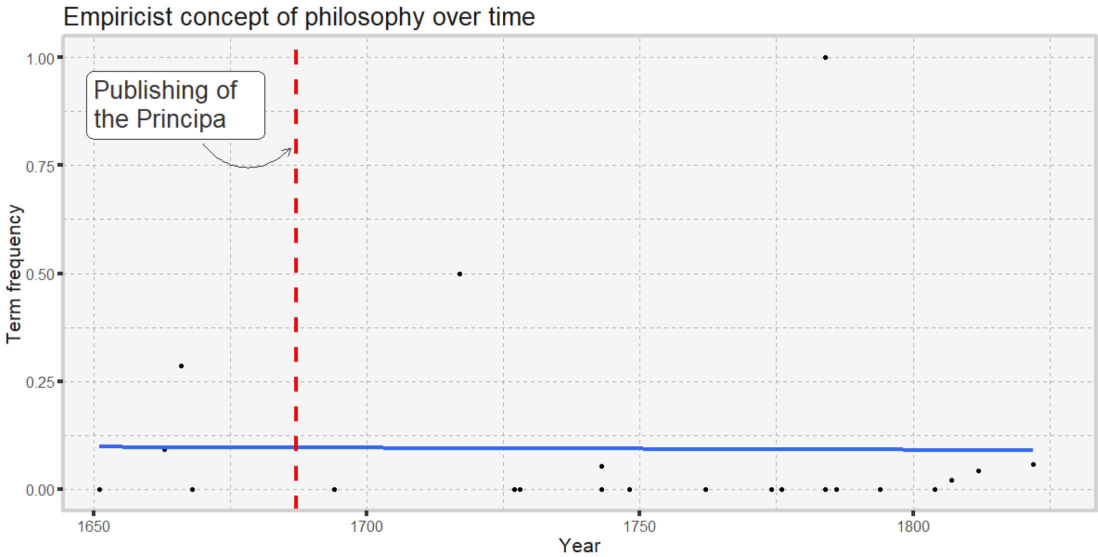

Figure 6: The proportion of 'experimental' in connection with "philosophy" over time.

In this figure, the constant trend over time can again be found. Although there are also several authors that do not use 'philosophy' in connection with 'experimental', this does not mean that they don't possess an empiricist view. This model is highly simplistic and is only meant to test the performance of the general modelling procedure. But, in that sense, it definitely succeeded as it produces reasonable results. Because of that, I can be fairly certain that the model will give accurate results when I will apply it to the concept of 'force'. This will be done in the next section.

4. Results

In this section, I will first carefully examine and interpret the results of the model. Afterwards, I will play around with the more controversial assumptions which I made in determining what a Newtonian context is and what a non-Newtonian context is.

4.1 Results obtained

I will now present the results of the model focused on the concept of force. In Figure 7, the result of this model can be found. Note that I am considering two combined proportions here: the Newtonian context in connection with the total use of force and the non-Newtonian context in connection with the total use of force. Here, the total use of force means the amount of times the term 'force' was used in the text. I then get to the numbers in Figure 7 by subtracting the non-Newtonian proportion from the Newtonian proportion:

$$\frac{\#\, force\ is\ used\ in\ Newtonian\ context}{\#\, force\ is\ used} - \frac{\#\, force\ is\ used\ in\ NonNewtonian\ context}{\#\, force\ is\ used}$$

Here, the '#' can be read as 'number of times'. In this way, the two proportions can offset each other. Also notice that these proportions therefore range between 1 and -1.

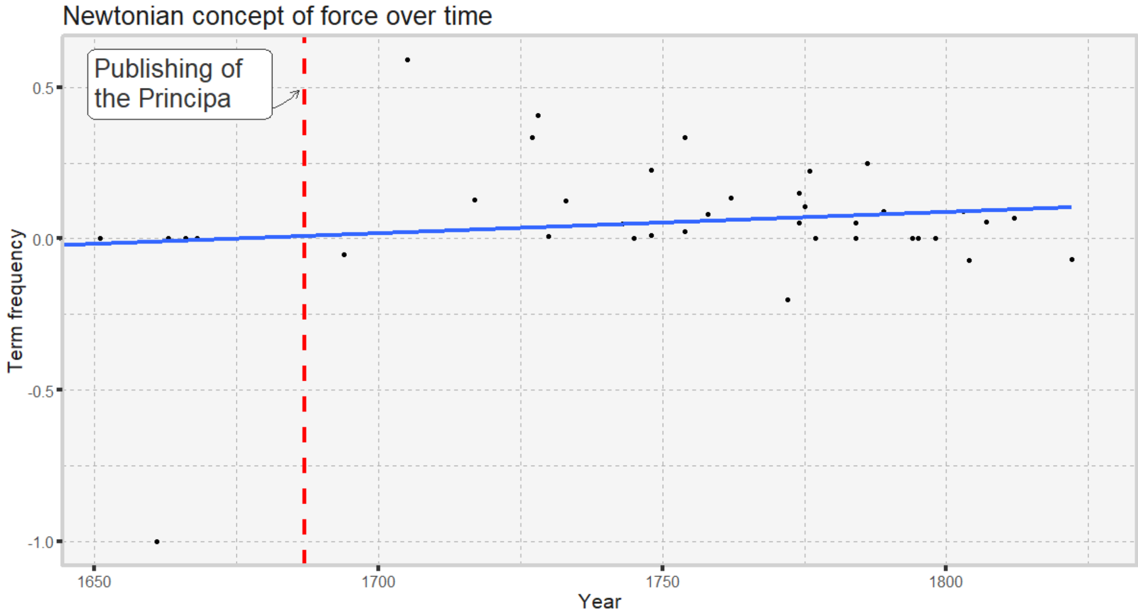

Figure 7: Proportion of Newtonian (positive) or non-Newtonian (negative) concept of force over time

In Figure 7, I observe a positive trend. Over time, there seems to be an increase in the use of the Newtonian concept of force. Furthermore, after the publishing of the *Principia,* most authors seem to be using force more in a Newtonian context. Although, I also see that some authors put force in a non-Newtonian context. In Figure 7, I am mainly interested in how Newtonian or non-Newtonian authors are and the trend over time, whereas the exact moments are not that relevant. In such case, a bar chart might be a more appropriate way to visualize the data. This bar chart can be found in Figure 8.

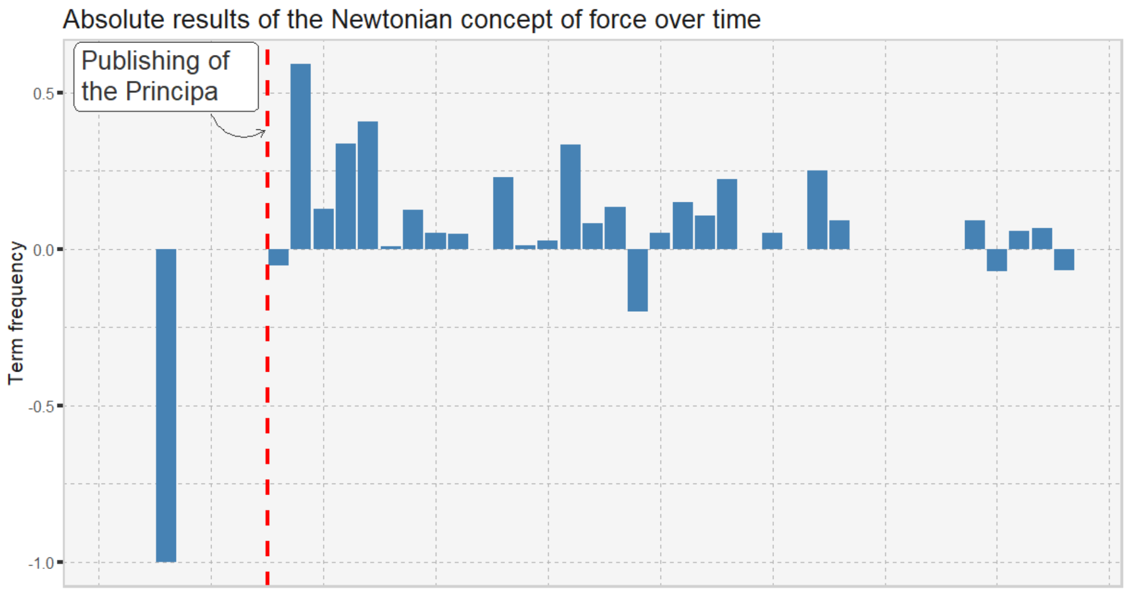

Figure 8: Bar chart of the Newtonian or non-Newtonian concept over time

In this figure, it is easier to spot the outliers. I observe for example that there is one text that uses force only in a non-Newtonian context. This is the work of Robert Boyle from 1663. Such a bar chart as Figure 8 also offers a way to quantify the impact of Newton's work. When adding all results from before the *Principia*, I obviously obtain -1. This would suggest that before 1687, the concept of force was mainly non-Newtonian. Although this result is in line with what I would expect, I cannot say too much about this. This is because the sample does not seem to be representative. It is too small as it only contains seven texts and the non-Newtonian conclusion is only based on one text. Nevertheless, it does provide more evidence for the originality of Newton's work. This is because, if Newton's notion was anticipated before Newton (i.e. what I take to be Newtonian was not that original after all, like in the case of 'experimental'), I should be able to find perhaps some trace of it before, even if the corpus there is small. But this was not found, hence chances are that Newton did in fact introduce a new of speaking / dealing with force.

Nevertheless, the focus of this essay is on the impact of Newton's work. And to study this, I use the texts from after 1687 which seems a more appropriate sample to draw inferences from. When adding all frequencies of Newtonian force from all authors after 1687, I obtain the number 3.255. This confirms our expectations that the Newtonian framework would be more popular than a non-Newtonian one. To get a better intuition behind this 3.255, it could be divided by the total number of texts after 1687. This yields that on average, having offset it against non-Newtonian frameworks, 'force' is used about 9% of the time in a Newtonian context.

Moreover, among these authors after 1687, there also seems to be a small diminishing effect. To examine this, I performed a linear regression on the Newtonian force frequency against the years for all authors after 1687. This result is also visualized in Figure 9.

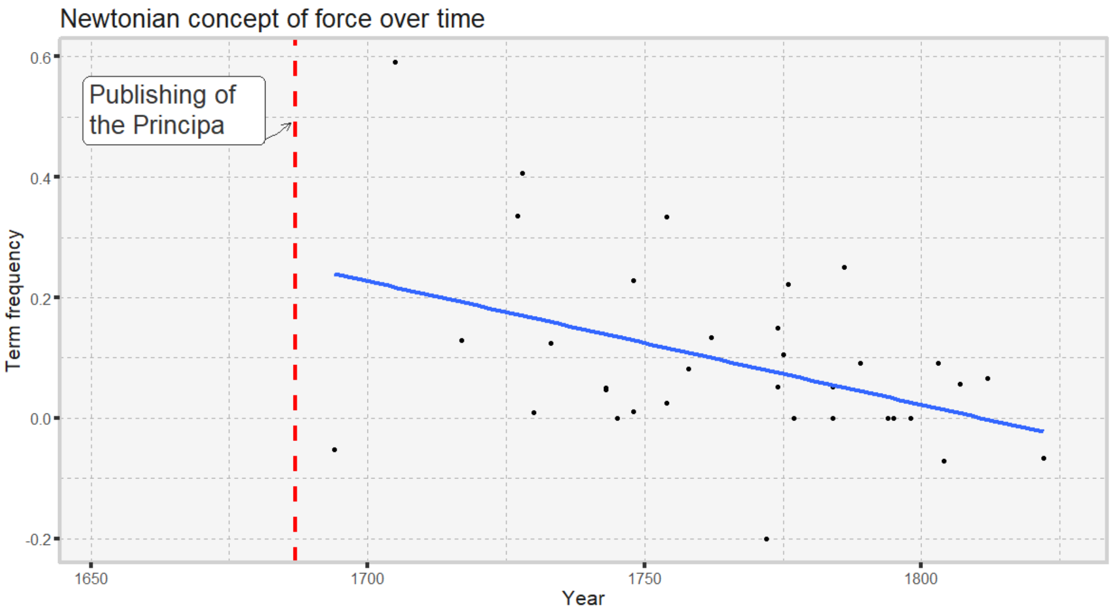

Figure 9: Linear regression for the authors after 1687.

Here, I indeed observe evidence that the prominence of the Newtonian concept of force started to diminish again after its publication. The p-value of the slope of this is given by 0.008 which indicates that this diminishing effect indeed seems to be statistically significant.

At last, it can be interesting to get more insights into the distribution of authors after 1687 per philosophical conception. However, I did not make a definite choice yet on how to classify an author under a specific conception. For the sake of simplicity, I will classify all authors with a positive Newtonian frequency in the above figures, as 'Newtonian' philosopher. I classify them as negative as the proportion is negative and neutral when it is zero. The pie chart that corresponds to this distribution can be found in Figure 10.

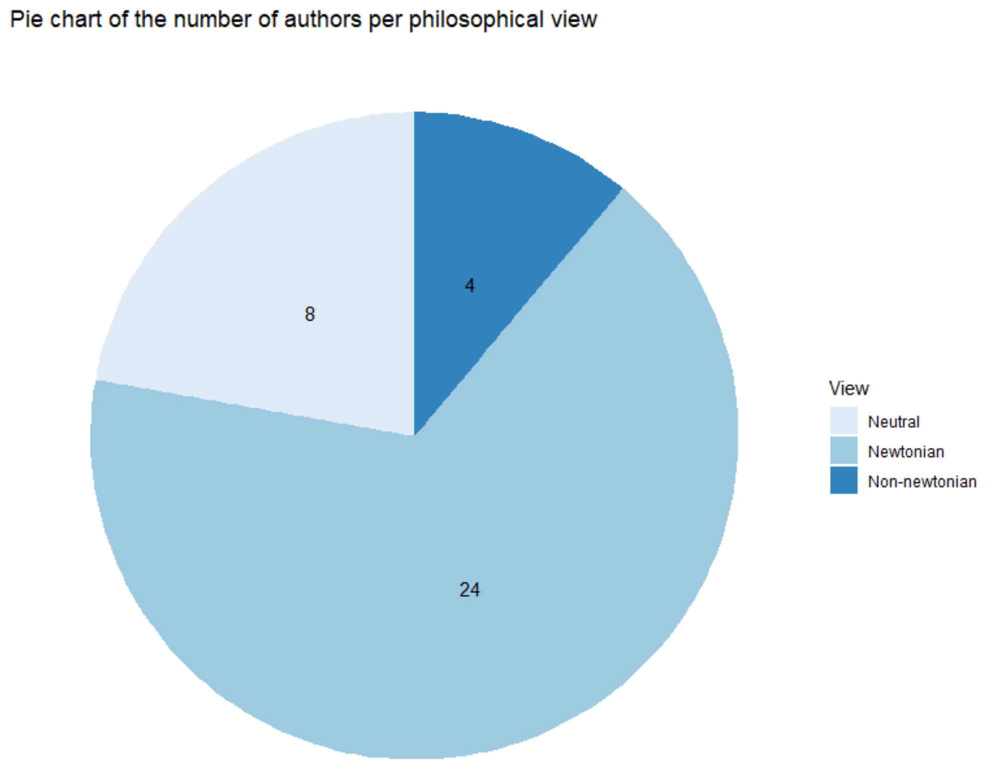

Figure 10: Pie chart of the authors after 1687

From this figure, I know that about two out of three authors followed the Newtonian conception. This is quite a substantial group so this again shows evidence that many philosophers in Britain started to share Newton's views after the publishing of the *Principia*.

4.2 Model validation

In this subsection, I will examine the performance of the model under slightly modified assumptions. The fact that I am able to write such a subsection on model validation already shows an advantage of the 'model approach'. In this approach, I need to explicitly specify my assumptions to even get a result. Since I know these assumptions, I can also play around with them to see how the results change. This offers some further insights into the robustness of the model. In qualitative approaches, you often do not know the assumptions. There may be several ways to find them some of them by asking yourself questions.

However, it remains a difficult process to identify all unconscious assumptions in such an approach.

Fortunately, the assumptions in the model of this essay are more explicit. As some of these assumptions are debatable, I will consider how the results of this model change when I slightly adapt these assumptions. One important class of assumptions that I made is regarding the Newtonian and non-Newtonian keywords. In some of these cases, you might argue that such a keyword does not strictly belong to a particular class. For example, 'attractive force' seems a Newtonian concept of force. However, the concept of 'attraction' can already be found back in Aristotelian and Alchemical traditions. Therefore, it seems a good idea to also run the model without this keyword. Besides this, the keyword 'moving' is also not strictly non-Newtonian. As can also be read in Janiak (2008, p. 15), Newton also speaks himself in the *Principia* about 'motive forces'. Therefore, the keyword 'moving' can be put in both categories in some sense. Because of this ambiguity, I will leave it out these two words in the model in this validation. In Figure 11, the results of the model without these two dubious keywords can be found.

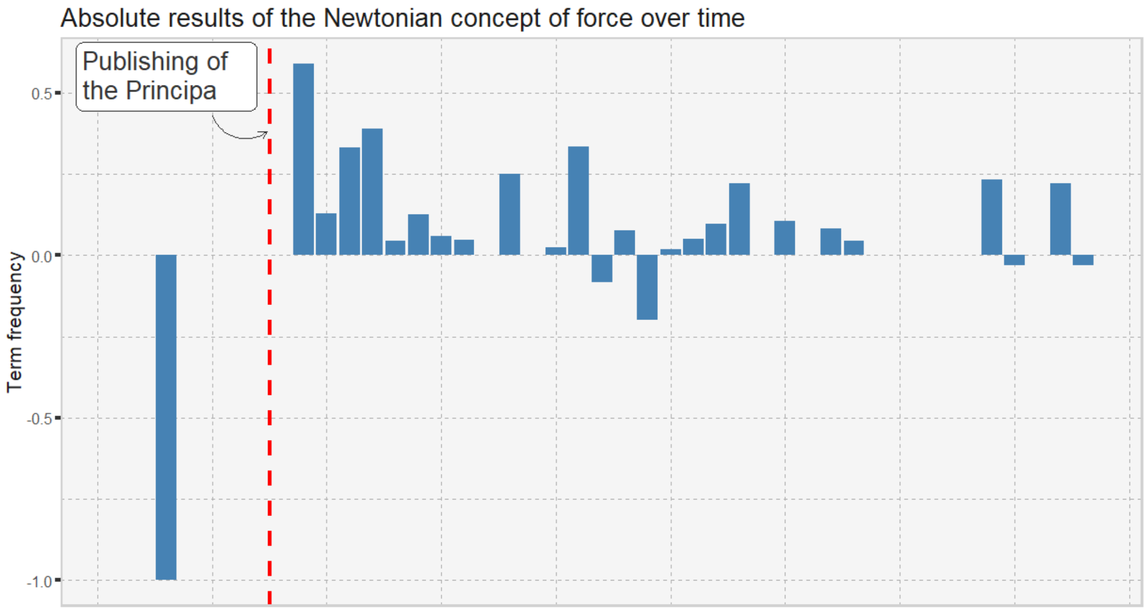

Figure 11: Results of the model without "attraction" and "moving"

When you compare these results with the results of Figure 8, you indeed see that there is a significant difference. However, it is not the case that the pattern changes drastically. Most philosophers still write in a Newtonian way and there is again a downward trend after the *Principia*. So, this shows that these keywords do have an effect on the model, but it does not change my conclusions. I also went through a process (not shown to the reader) in which I removed combinations of other words to see if they had any significant effect. For all keywords, the conclusion remained the same. You do notice the difference with the initial results, but the general trends did not change.

5. Discussion

In this section, I aim to provide further discussion about some surprising results of the model and then address some worries that the model approach might raise.

Shifting paradigm

One of the most surprising findings of the model is the declining trend found in Figure 9. In most of the secondary literature, it can be found that Newtonianism remained very popular and that Einstein was one of the first to provide a fundamental critique that was accepted by most scholars (Smith, 2008a). Therefore, it is worth investigating where this decline comes from and how we can interpret it. To do this, I will dive deeper into the works of the early 19th century philosophers of which the model says that they had a roughly neutral stance on Newtonianism. On the basis of these texts, a new network graph was generated which can be found in Figure 12.

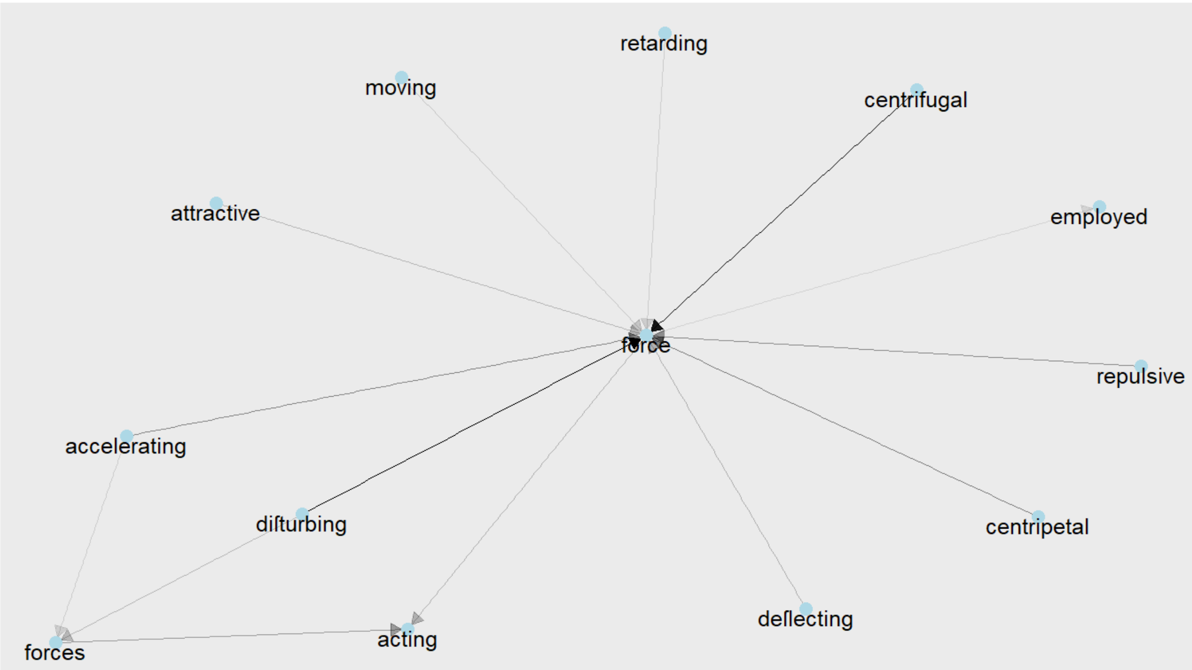

Figure 12: Network graph containing the most associated words with 'force' and "forces" for late 18th century philosophers

In this figure, I still observe Newtonian keywords such as 'accelerating' and 'centripetal'. Nevertheless, the most common associated keyword is 'diſturbing' since these arrows in the graph are the most opaque. This is a keyword which was marked as non-Newtonian in the model. Therefore, this offers an explanation why the model observes a more negative / neutral conception of the Newtonian account of force in the late 18th century. One of the most influential natural philosophers in Britain in this time period was John Robison, of which also two works were included in the corpus (years 1804 and 1822). However, John Robison is generally known as a strict Newtonian (Schaffer, 2020, p. 622). At the same time, there were several breakthroughs in France in the field of celestial mechanics by Pierre-

Simon LaPlace and Joseph-Louis LaGrange. Both of them built upon the work of Newton and their success therefore also meant a boost in the popularity of the *Principia*. LaPlace did however extend this work by adding an atheistic notion. Robison thought this was not in line with the work of Newton and wanted to revive the true Newtonian philosophy (Schaffer, 2020, p. 622). In his work, the concept of 'force' is used extensively. One important way he uses this concept is as a 'disturbing force' in the trajectories of planets. In his text from 1822, he elaborates on this in the following way: "This disturbance is proportional to the square of the distance from the disturbing planet inversely" (quoted in the original OCR quality from the corpus). Here, the inverse square law can be found back, which was also central in the Newton's explanation of conic-section trajectories of planets (Smith, 2008a). So, Robison uses a 'disturbing force' here as a force that is disturbing the trajectory of a planet in a Newtonian way. This shows evidence that a disturbing force can also perfectly be placed in a Newtonian framework. Therefore, this also leads us to a different interpretation of the results. From the debate between Robison and Laplace, it can be concluded that the question here was not about whether Newton was right. The question was more on how to extend his framework to explain other phenomena. This can be another explanation for the negative trend pointed out by the model. This does not mean that Newton's philosophy was challenged, but rather that evolutions based on his views led people to introduce new ways of speaking about force and thus drifting away from Newton's own account. What this shows is that evolution has the shape of drifting away, rather than jumping or side-tracking.

This shared consensus on the Newtonian basic framework but also the general disagreement on how to extend his work, immediately shows one of the benefits of the quantitative approach of this study. Observing this pattern could not be achieved by a method that would study individual authors, case by case. In such a manner, you spend a considerable amount of time reading each work and your conclusion remains limited to those authors. The difference with my approach is that it could easily be extended to a larger amount of authors. One example of an author who agreed upon and attempted to extend on the Newtonian framework was the Dutch professor Petrus van Musschenbroek. He contributed to the spread of Newtonianism in the Netherlands by introducing it into university teaching. His view on Newtonianism has generally been studied by the means of close reading his texts (Present, 2003; Ducheyne, 2015, 2016). There are more examples of Newtonian philosophers like Van Musschenbroek who were active in reshaping Newton's view. However, when doing case studies, we still don't know whether they were developing Newton's view in a shared and convergent direction or not. The model approach, by allowing to investigate trends in larger corpora, allows us to see this sort of aspects that can emerge only at the transindividual level, and that could not be directly observed by considering cases one by one.

One influential debate on the nature of scientific progress is based on Kuhn's idea of 'paradigm change'. Here, one single paradigm is expanded progressively by generation of scholars, until an entirely new one is introduced (Kuhn, 2012). The results of the model somehow display both these aspects. Firstly, Newton introduced a new paradigm with respect to previous discussions about force which became the central paradigm for centuries. Kuhn would describe this time period as "normal science", scientists tried to explain new phenomena guided by the Newtonian paradigm. The successes of LaPlace and

LaGrange in celestial mechanics are an example of this. Secondly, it can be seen that Newtonians also expanded this paradigm by also changing it. This will happen again, a century later, with Einstein. Kuhn would describe this as a scientific revolution.

How do you feel about it?

This discussion on the development of concepts also leads us to another critical issue of the model. This issue is about how it deals with associated keywords. Specifically, the model only looks for keywords that are associated to some concept. However, it does not consider in what kind of sentence it was used. To give an example of where this might go wrong: think about a philosopher who writes a text on Newtonian and Cartesian philosophy. He clearly supports the Newtonian concept of force and he rejects the Cartesian one. In this text, he spends about as many words to supporting Newtonianism as to dismissing Cartesianism. The model would then conclude that this philosopher is roughly neutral on the Newtonian concept of force. This is a substantial deficiency of the model. Further research could be focused on developing models that aim to analyze and understand the whole sentence or perhaps multiple sentences, and base its conclusion on those. Sentiment analysis would then become a central feature in such models[1].

How big is big enough?

Another concern for this study is the corpus that was used. Although the corpus was gathered in a process of careful inspection, there could be texts that do not adequately represent the general tendency of that time period. For example, I am using several texts from the end of the 18th century that do not discuss force in a Newtonian or non-Newtonian way according to the model. This is also what causes the gap which can be seen in Figure 11 for example, these texts are then interpreted as neutral accounts of Newtonianism. It might be the case that these texts are less appropriate for this research than was expected at first. However, it might also be that these texts are the most applicable works that are available from this time period. But then, that means that there are no texts at all that capture the notion of force from that time accurately. This could be a sign that Newtonian force was not universally accepted. It is dominant as a trend across time, but not necessarily at the level of individual authors. This is again related to the difference in perspective that the model approach offers which was already discussed. When considering texts case by case, the trend might not be observable. However, when modelling it over time, it can be visible.

` Whether or not these texts are appropriate, another issue for the corpus arises. One of the initial reasons for this study was to obtain a broader account of force by including more texts. When looking at a rich philosophical period, a few texts may simply not be enough to give a detailed picture of philosophy during that time. Although I did make some significant steps in tackling this problem, it remains an issue that is not entirely solved by adding some more texts to the corpus. You could question how many texts are enough then

[1] This is a technique which analyzes a piece of text to find out the sentiment behind it. It makes use of natural language processing and machine learning to study affective states and subjective information.

to obtain a full understanding of a concept. However, adding texts and broadening a corpus will not always expand your research. At some point or threshold, when you have a selection that is sufficiently representative, adding more texts will be either irrelevant or they will confirm the trend already noticed.

Quantitative vs. Qualitative?

To what extent can a quantitative approach help us in reaching a complete understanding of a concept, whereas the process of understanding something is in itself qualitative? The standard approach in history of philosophy to understand texts and concepts is qualitative (Sangiacomo, 2019), as is also the process of doing philosophy itself. Therefore, the methodology from this essay is quite controversial. However, it should not be seen as the counterpart of qualitative approach. Qualitative and quantitative are two methods that can work in perfect synergy. The quantitative approach is a technical toolkit which can assist a researcher in their study. As also argued by Bluhm (2016), this approach offers an objective way of looking at texts and it removes biasing effects which we create as humans. In this way, a model can serve as an objective test to verify or falsify hypotheses. If the model shows some deviations, this can be further investigated by close reading. An example from this study is the declination of the popularity of Newton. Because this deviated from what I would have expected, I had to investigate the issue. This provides you with a very different perspective than which you would have had if you would just have read the text with only your prior hypothesis in mind. This is also in line with Moretti (2016), who talks about the role of 'corroboration' in Digital Humanities research. He explains that corroboration is important to check whether a method works and to find out a different perspective to look at the materials. So, a quantitative approach can confirm ideas but it also points to new insights. Another example from this essay is that it showed that the two most common associated keywords with 'force' were 'contractive' and 'expansive' which I would not expect at first hand. Although the quantitative approach also possesses several disadvantages, as has been discussed earlier in this section, it offers an extensive toolkit to the philosophical researcher.

6. Conclusion

In this essay, I have investigated the impact of Newtonian account of 'force' on British early modern philosophy. I have done this by applying a quantitative approach, which is a controversial method in history of philosophy. I argue that Newton had a significant impact on British natural philosophy and that the quantitative approach can be very helpful in revealing it, although the method also has some drawbacks.

I started with a detailed discussion on the work of Newton and his relationship with Aristotelianism and Cartesianism. One feature that is distinct about Newtonianism is that he placed the concept of 'force' at the center of his philosophy. This Newtonian force can be understood as a quantity and can be calculated using his mathematical laws. In contrast with other natural philosophical frameworks, this force could also work at a distance such as his force of gravity. From this, it follows that a Newtonian account force can be recognized in a text using keywords such as 'gravitational'.

Subsequently, I established and explored the corpus of this study containing 42 texts from early modern British natural philosophers. Here, I showed that all works contained the term 'force' and provided further support for why this corpus is suitable for this study. Afterwards, I spelled out the modelling procedure which makes use of associated keywords to the concept of 'force'. I labeled several keywords as specifically Newtonian or specifically non-Newtonian. Then based upon the proportions in which these appeared in texts, I could tell something about how Newtonian a certain text was. Before executing this model, I demonstrated a test case in which it was shown that the model produces reasonable results for the less controversial notions of 'experiments' and 'experimental philosophy'.

In the results of the model, it was found that there is a significant difference in the use of Newtonian force before and after the *Principia*. Furthermore, a positive trend in the use of this concept was found. However, a surprising finding was that when only the works after the *Principia* were taken into account, a significant negative trend could be observed. Next to that, I examined the distribution of authors after the *Principa*, in which I found that about 2/3 of the philosophers displayed a Newtonian account of 'force'. Based on these findings, I conclude that Newton had a significant impact on British early modern natural philosophy. To confirm this conclusion, I also provided a model validation in which I removed one or two associated keywords each time. The omission of such a word is visible in the results but is does not change the general trends. This provides further foundation for the obtained results.

However, as the declining trend of the Newtonian concept of 'force' after the *Principia* was a surprising result, I also performed further investigation into the works of the early 19th century. Here, it turned out that concepts which were labeled as non-Newtonian did in fact appear in a Newtonian context. This shows the difficulty of the choosing suitable keywords in such a model as these keywords are also concepts that can develop and be interpreted in different ways. This led me to conclude that the Newtonian framework was still remarkably popular in early 19th century. However, the general question was not anymore whether Newton was right, but it was more on how to extend the Newtonian framework to explain other phenomena. There was consensus about the basics of Newtonianism but there were still several disputes on how to enhance his account.

Our ability to notice such trends among philosophers of this time shows already one of the advantages of the quantitative approach. Using this approach, I am able to analyze the work of a large number of authors. When studying these philosophers qualitatively, this would not have been possible. Especially when only studying individual philosophers, it is practically impossible to find general trends or consensus among philosophers as you remain limited to case studies.

My model does have some drawbacks such as that the corpus might not be entirely representative and it only considers associated keywords instead of the general sentiment in a sentence. Nevertheless, it is also inherent to such an approach that there are some deficiencies. This does not take away that this method is highly useful for corroboration:

both to confirm findings and to offer new insights, such as it also did in this study. All in all, I conclude that this approach provided me with several interesting insights into the impact of the Newtonian account of force.

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Code appendix

```
### In this script we define the packages to be used ######################

# List with the packages which we need
ListofPackages <- c("readr", "devtools", "ggplot2", "dplyr", "tidytext",
                   "textdata", "tidyr", "wordcloud", "stringr", "igraph",
                   "ggraph", "cowplot", "ggtext", "showtext", "patchwork")
NewPackages <- ListofPackages[!(ListofPackages %in%
                                installed.packages()[,"Package"])]

if (length(NewPackages) > 0) {
  install.packages(NewPackages)
}

lapply(ListofPackages, require, character.only = TRUE)

# No need to keep these variables
rm(ListofPackages, NewPackages)

##### In this script we define our own ggplot theme ######################

ThesisggTheme <- function() {
  theme(panel.background = element_rect(fill = "grey96"),
        axis.line = element_blank(),
        panel.border = element_rect(colour = "gray82", fill = NA,
                                    size = 1.5),
        panel.grid.major = element_line(colour = "grey70",
                                        linetype = "dashed"),
        panel.grid.minor = element_line(colour = "grey70",
                                        linetype = "dashed"),
        axis.text.x = element_text(size= 10),
        axis.text.y = element_text(size= 11),
        axis.title.x = element_text(size = 13),
        axis.title.y = element_text(size = 13),
        axis.ticks = element_line(size = 1.5),
        axis.ticks.length = unit(1.5, "mm")
  )
}

### In this script we load in the corpus as single words ##################

rm(list = ls())

setwd("C:/Users/stank/Documents/Jaar 4 uni/Thesis in philosophy")

source("Code/Packages.R")

tokenizeDocument <- function(document) {
  name = as.character(rlang::enexpr(document))
  document = document %>%
    unnest_tokens(word, text)
  document = document %>%
    mutate(author = name, year = str_sub(name, -4, -1))
  return(document)
}

Digby1644 <- tibble(text = read_file("NewCorpus/1644Digby.txt"))
Corpus <- tokenizeDocument(Digby1644)

Comenius1651 <- tibble(text = read_file("NewCorpus/1651Comenius.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Comenius1651))

Boyle1663 <- tibble(text = read_file("NewCorpus/1663Boyle.txt"))
```

```
Corpus <- bind_rows(Corpus, tokenizeDocument(Boyle1663))

Boyle1666 <- tibble(text = read_file("NewCorpus/1666Boyle.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Boyle1666))

Cavendish1666 <- tibble(text = read_file("NewCorpus/1666Cavendish.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Cavendish1666))

Cavendish1668 <- tibble(text = read_file("NewCorpus/1668Cavendish.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Cavendish1668))

LeGrand1694 <- tibble(text = read_file("NewCorpus/1694LeGrand.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(LeGrand1694))

Ditton1705 <- tibble(text = read_file("NewCorpus/1705Ditton.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Ditton1705))

Stirling1717 <- tibble(text = read_file("NewCorpus/1717Stirling.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Stirling1717))

Greene1727 <- tibble(text = read_file("NewCorpus/1727Greene.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Greene1727))

Pemberton1728 <- tibble(text = read_file("NewCorpus/1728Pemberton.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Pemberton1728))

Worster1730 <- tibble(text = read_file("NewCorpus/1730Worster.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Worster1730))

Banks1733 <- tibble(text = read_file("NewCorpus/1733Banks.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Banks1733))

Desaguliers1734 <- tibble(text = read_file("NewCorpus/1734Desaguliers.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Desaguliers1734))

Horsley1743 <- tibble(text = read_file("NewCorpus/1743Horsley.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Horsley1743))

Wlyde1743 <- tibble(text = read_file("NewCorpus/1743Wlyde.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Wlyde1743))

Robertson1745 <- tibble(text = read_file("NewCorpus/1745Robertson.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Robertson1745))

Knight1748 <- tibble(text = read_file("NewCorpus/1748Knight.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Knight1748))

Rutherforth1748 <- tibble(text = read_file("NewCorpus/1748Rutherforth.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Rutherforth1748))

Emerson1754 <- tibble(text = read_file("NewCorpus/1754Emerson.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Emerson1754))

Wilson1754 <- tibble(text = read_file("NewCorpus/1754Wilson.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Wilson1754))

Rowning1758 <- tibble(text = read_file("NewCorpus/1758Rowning.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Rowning1758))

Jones1762 <- tibble(text = read_file("NewCorpus/1762Jones.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Jones1762))

Ferguson1772 <- tibble(text = read_file("NewCorpus/1772Ferguson.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Ferguson1772))

Hamilton1774 <- tibble(text = read_file("NewCorpus/1774Hamilton.txt"))
```

```r
Corpus <- bind_rows(Corpus, tokenizeDocument(Hamilton1774))

Lovett1774 <- tibble(text = read_file("NewCorpus/1774Lovett.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Lovett1774))

Maclaurin1775 <- tibble(text = read_file("NewCorpus/1775Maclaurin.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Maclaurin1775))

Atwood1776 <- tibble(text = read_file("NewCorpus/1776Atwood.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Atwood1776))

Cullen1777 <- tibble(text = read_file("NewCorpus/1777Cullen.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Cullen1777))

Atkinson1784 <- tibble(text = read_file("NewCorpus/1784Atkinson.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Atkinson1784))

Robinson1784 <- tibble(text = read_file("NewCorpus/1784Robinson.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Robinson1784))

Fenning1786 <- tibble(text = read_file("NewCorpus/1786Fenning.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Fenning1786))

Peart1789 <- tibble(text = read_file("NewCorpus/1789Peart.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Peart1789))

Adams1794 <- tibble(text = read_file("NewCorpus/1794Adams.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Adams1794))

Telescope1794 <- tibble(text = read_file("NewCorpus/1794Telescope.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Telescope1794))

Walker1795 <- tibble(text = read_file("NewCorpus/1795Walker.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Walker1795))

Wood1803 <- tibble(text = read_file("NewCorpus/1803Wood.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Wood1803))

Robison1804 <- tibble(text = read_file("NewCorpus/1804Robison.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Robison1804))

Young1807 <- tibble(text = read_file("NewCorpus/1807Young.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Young1807))

Playfair1812 <- tibble(text = read_file("NewCorpus/1812Playfair.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Playfair1812))

Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol1.txt"))
Robison1822complete <- tokenizeDocument(Robison1822)

Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol2.txt"))
Robison1822complete <- bind_rows(Robison1822complete, tokenizeDocument(Robison1822))

Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol3.txt"))
Robison1822complete <- bind_rows(Robison1822complete, tokenizeDocument(Robison1822))

Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol4.txt"))
Robison1822complete <- bind_rows(Robison1822complete, tokenizeDocument(Robison1822))
Corpus <- bind_rows(Corpus, Robison1822complete)

### In this script we investigate the relevance of the corpus #############

setwd("C:/Users/stank/Documents/Jaar 4 uni/Thesis in philosophy")

source("Code/Packages.R")
```

```r
# Will take around 10 seconds
source("Code/CorpusPreparation.R")


FamousWords = Corpus %>%
  count(word, sort = TRUE)
FamousWords

# Now removing the stop words

NewStopWords = bind_rows(stop_words,
                         tibble(word = c("oſ", "ſame", "ſo", "theſe",
                                         "ſuch", "thoſe")))

CleanFamousWords = Corpus %>%
  anti_join(NewStopWords) %>%
  count(word, sort = TRUE)
CleanFamousWords

# The word force used a lot, excluding the stop words.

set.seed(4)
CleanFamousWords %>%
  with(wordcloud(word, n, max.words = 30, scale = c(4,.5)))


WordsCountedPerAuthor = Corpus %>%
  anti_join(NewStopWords) %>%
  count(author, word, sort = TRUE)
WordsCountedPerAuthor




# Lets consider the tf_idf
# aka the term frequency-inverse document frequency


CorpusCount = Corpus %>%
  count(author, word, sort = TRUE)

Corpustfidf = CorpusCount %>%
  bind_tf_idf(word, author, n) %>%
  arrange(desc(tf_idf))
Corpustfidf


# Lets check the idf of force
Corpustfidf %>%
  filter(word == "force")
# This indicates that all documents contain the word force

Corpustfidf %>% filter(word == "gravity")
# The same does not hold for the gravity.

CorpusAfter1687 = Corpus %>%
  filter(year > 1687)

CorpusCount = CorpusAfter1687 %>%
  count(author, word, sort = TRUE)

Corpustfidf = CorpusCount %>%
  bind_tf_idf(word, author, n) %>%
  arrange(desc(tf_idf))
Corpustfidf %>% filter(word == "gravity")
#But we do find it in all works after 1687
```

```r
### In this script we analyze the term frequency over time ################

setwd("C:/Users/stank/Documents/Jaar 4 uni/Thesis in philosophy")

source("Code/Packages.R")
source("Code/Thesisggtheme.R")

# Will take around 10 seconds
source("Code/CorpusPreparation.R")

CorpusCount = Corpus %>%
  count(author, word, sort = TRUE)

Corpustfidf = CorpusCount %>%
  bind_tf_idf(word, author, n) %>%
  arrange(desc(tf_idf))
Corpustfidf

# What word do you want to investigate?
wordtoinvestigate = "experiments"

corpustf = Corpustfidf %>%
  filter(word == wordtoinvestigate)%>%
  arrange(desc(tf))
corpustf

WordOverTime = tibble(year = rep(0, nrow(corpustf)),
                       tf = rep(1, nrow(corpustf)))

for (i in 1:nrow(corpustf)) {
  WordOverTime[i, 1] = as.integer(str_sub(corpustf[i, 1], -4, -1))
  WordOverTime[i, 2] = corpustf[i, "tf"]
}


summary(lm(tf ~ year, data = WordOverTime))

Forcetfplot = ggplot(WordOverTime, aes(x = year, y = tf)) +
  geom_point(size = 1.7) +
  geom_smooth(method = 'lm', se = FALSE, size = 1.5) +
  ThesisggTheme() +
  labs(x = 'Year', y = 'Term frequency',
       title = 'The use of "experiments" over time') +
  geom_vline(xintercept = 1687, linetype = 'dashed', color = 'red',
             size = 1.5) +
  geom_curve(aes(x = 1670, y = 0.0049, xend = 1686, yend = 0.0047),
             color = 'grey20',angle = 90,
             arrow = arrow(30, unit(0.1, "inches"))) +
  geom_textbox(aes(x = 1665, y = 0.0055), label = 'Publishing of \nthe Principa',
            color = 'grey20', size = 7) +
  theme(plot.title = element_text('sigmar', color = 'grey10', size = 20),
        axis.text.x = element_text(size = 12),
        axis.text.y = element_text(size = 12),
        axis.title.x = element_text(size = 16, color = 'grey10'),
        axis.title.y = element_text(size = 16, color = 'grey10')) +
  coord_cartesian(xlim = c(1653, 1825), ylim = c(0, 0.006), clip = 'off')

Forcetfplot


plot_grid(Forcetfplot, Gravitytfplot)



# Absolute results
```

```r
WordOverTime = WordOverTime %>%
  arrange(year)

AbsoluteResultsOverTime = tibble(absolute = 1:nrow(WordOverTime),
                                 frequentUse = WordOverTime$tf)


ggplot(AbsoluteResultsOverTime, aes(x = absolute, y = frequentUse)) +
  geom_bar(stat = "identity", fill = "steelblue") +
  ThesisggTheme() +
  labs(x = "",
       y = 'Term frequency',
       title =
         'Absolute results of the Newtonian concept of force over time') +
  geom_vline(xintercept = 7.5, linetype = 'dashed', color = 'red',
             size = 1.5) +
  theme(axis.ticks.x = element_blank(),
        axis.text.x = element_blank())


### Test of statistical difference

wordToTest = "force"

Corpusbefore1687 = Corpus %>%
  filter(year < 1687) %>%
  count(author, word, sort = TRUE) %>%
  bind_tf_idf(word, author, n) %>%
  filter(word == wordToTest)

tfBefore1687 = Corpusbefore1687$tf
tfBefore1687


Corpusafter1687 = Corpus %>%
  filter(year > 1687) %>%
  count(author, word, sort = TRUE) %>%
  bind_tf_idf(word, author, n) %>%
  filter(word == wordToTest)

tfafter1687 = Corpusafter1687$tf
tfafter1687


t.test(tfBefore1687, tfafter1687)

### In this script we load in the Corpus ngrams ###########################

setwd("C:/Users/stank/Documents/Jaar 4 uni/Thesis in philosophy")

source("Code/Packages.R")

tokenizeDocument <- function(document, ngramSize) {
  name = as.character(rlang::enexpr(document))
  document = document %>%
    unnest_tokens(ngram, text, token = "ngrams", n = ngramSize)
  document = document %>%
    mutate(author = name, year = str_sub(name, -4, -1))
  return(document)
}

Digby1644 <- tibble(text = read_file("NewCorpus/1644Digby.txt"))
Corpus <- tokenizeDocument(Digby1644, n)

Comenius1651 <- tibble(text = read_file("NewCorpus/1651Comenius.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Comenius1651, n))
```

```
Boyle1661 <- tibble(text = read_file("NewCorpus/1661Boyle.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Boyle1661, n))

Boyle1663 <- tibble(text = read_file("NewCorpus/1663Boyle.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Boyle1663, n))

Boyle1666 <- tibble(text = read_file("NewCorpus/1666Boyle.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Boyle1666, n))

Cavendish1666 <- tibble(text = read_file("NewCorpus/1666Cavendish.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Cavendish1666, n))

Cavendish1668 <- tibble(text = read_file("NewCorpus/1668Cavendish.txt"))
Corpus <- bind_rows(Corpus, tokenizeDocument(Cavendish1668, n))

LeGrand1694 <- tibble(text = read_file("NewCorpus/1694LeGrand.txt"))
Corpusngram <- bind_rows(Corpus, tokenizeDocument(LeGrand1694, n))

Ditton1705 <- tibble(text = read_file("NewCorpus/1705Ditton.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Ditton1705, n))

Stirling1717 <- tibble(text = read_file("NewCorpus/1717Stirling.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Stirling1717, n))

Greene1727 <- tibble(text = read_file("NewCorpus/1727Greene.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Greene1727, n))

Pemberton1728 <- tibble(text = read_file("NewCorpus/1728Pemberton.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Pemberton1728, n))

Worster1730 <- tibble(text = read_file("NewCorpus/1730Worster.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Worster1730, n))

Banks1733 <- tibble(text = read_file("NewCorpus/1733Banks.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Banks1733, n))

Horsley1743 <- tibble(text = read_file("NewCorpus/1743Horsley.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Horsley1743, n))

Wlyde1743 <- tibble(text = read_file("NewCorpus/1743Wlyde.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Wlyde1743, n))

Robertson1745 <- tibble(text = read_file("NewCorpus/1745Robertson.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Robertson1745, n))

Knight1748 <- tibble(text = read_file("NewCorpus/1748Knight.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Knight1748, n))

Rutherforth1748 <- tibble(text =
                            read_file("NewCorpus/1748Rutherforth.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Rutherforth1748, n))

Emerson1754 <- tibble(text = read_file("NewCorpus/1754Emerson.txt"))
Corpusngram<- bind_rows(Corpusngram, tokenizeDocument(Emerson1754, n))

Wilson1754 <- tibble(text = read_file("NewCorpus/1754Wilson.txt"))
Corpusngram<- bind_rows(Corpusngram, tokenizeDocument(Wilson1754, n))

Rowning1758 <- tibble(text = read_file("NewCorpus/1758Rowning.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Rowning1758, n))

Jones1762 <- tibble(text = read_file("NewCorpus/1762Jones.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Jones1762, n))

Ferguson1772 <- tibble(text = read_file("NewCorpus/1772Ferguson.txt"))
```

```r
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Ferguson1772, n))

Hamilton1774 <- tibble(text = read_file("NewCorpus/1774Hamilton.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Hamilton1774, n))

Lovett1774 <- tibble(text = read_file("NewCorpus/1774Lovett.txt"))
Corpusngram<- bind_rows(Corpusngram, tokenizeDocument(Lovett1774, n))

Maclaurin1775 <- tibble(text = read_file("NewCorpus/1775Maclaurin.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Maclaurin1775, n))

Atwood1776 <- tibble(text = read_file("NewCorpus/1776Atwood.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Atwood1776, n))

Cullen1777 <- tibble(text = read_file("NewCorpus/1777Cullen.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Cullen1777, n))

Atkinson1784 <- tibble(text = read_file("NewCorpus/1784Atkinson.txt"))
Corpusngram<- bind_rows(Corpusngram, tokenizeDocument(Atkinson1784, n))

Robinson1784 <- tibble(text = read_file("NewCorpus/1784Robinson.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Robinson1784, n))

Fenning1786 <- tibble(text = read_file("NewCorpus/1786Fenning.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Fenning1786, n))

Peart1789 <- tibble(text = read_file("NewCorpus/1789Peart.txt"))
Corpusngram<- bind_rows(Corpusngram, tokenizeDocument(Peart1789, n))

Adams1794 <- tibble(text = read_file("NewCorpus/1794Adams.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Adams1794, n))

Telescope1794 <- tibble(text = read_file("NewCorpus/1794Telescope.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Telescope1794, n))

Walker1795 <- tibble(text = read_file("NewCorpus/1795Walker.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Walker1795, n))

Anderson1798 <- tibble(text = read_file("NewCorpus/1798Anderson.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Anderson1798, n))

Gregory1798 <- tibble(text = read_file("NewCorpus/1798GregoryVol2.txt"))
Gregory1798complete <- tokenizeDocument(Gregory1798, n)

Gregory1798 <- tibble(text = read_file("NewCorpus/1798GregoryVol3.txt"))
Gregory1798complete <- bind_rows(Gregory1798complete, tokenizeDocument(Gregory1798, n))
Corpusngram <- bind_rows(Corpusngram, Gregory1798complete)

Wood1803 <- tibble(text = read_file("NewCorpus/1803Wood.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Wood1803, n))

Robison1804 <- tibble(text = read_file("NewCorpus/1804Robison.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Robison1804, n))

Young1807 <- tibble(text = read_file("NewCorpus/1807Young.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Young1807, n))

Playfair1812 <- tibble(text = read_file("NewCorpus/1812Playfair.txt"))
Corpusngram <- bind_rows(Corpusngram, tokenizeDocument(Playfair1812, n))

Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol1.txt"))
Robison1822complete <- tokenizeDocument(Robison1822, n)

Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol2.txt"))
Robison1822complete <- bind_rows(Robison1822complete, tokenizeDocument(Robison1822, n))
```

```
Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol3.txt"))
Robison1822complete <- bind_rows(Robison1822complete, tokenizeDocument(Robison1822, n))

Robison1822 <- tibble(text = read_file("NewCorpus/1822RobisonVol4.txt"))
Robison1822complete <- bind_rows(Robison1822complete, tokenizeDocument(Robison1822, n))
Corpusngram <- bind_rows(Corpusngram, Robison1822complete)

### In this script, we perform the ngram analysis ########################

setwd("C:/Users/stank/Documents/Jaar 4 uni/Thesis in philosophy")

rm(list = ls())

# Load in packages and theme for plotting
source("Code/Packages.R")
source("Code/Thesisggtheme.R")


# Set the size of the ngrams
n = 2

# Will take around 15 second
source("Code/ngramPreparation.R")

Countngram = Corpusngram %>%
  count(ngram, sort = TRUE)
Countngram

# These words are not interesting, we should remove the stop words

NewStopWords = bind_rows(stop_words,
                         tibble(word = c("oſ", "ſame", "ſo", "theſe",
                                         "ſuch", "thoſe")))

# Might take a few minutes
ngramSeperated = Corpusngram %>%
  separate(ngram, c("word1", "word2"), sep = " ")
ngramFilter = ngramSeperated %>%
  filter(!word1 %in% NewStopWords$word) %>%
  filter(!word2 %in% NewStopWords$word)

# Now generate the new common words, without the stop words
Countngram = ngramFilter %>%
  count(word1, word2, sort = TRUE)
Countngram


# Generating a network graph of the word force and forces

set.seed(2)
NetworkGraph = Countngram %>%
  filter(word1 == "force" |
           word2 == "force" |
           word1 == "forces" |
           word2 == "forces") %>%
  filter(n > 40) %>%
  graph_from_data_frame()

a = grid::arrow(type = "closed", length = unit(.15, "inches"))

ggraph(NetworkGraph, layout = "fr") +
  geom_edge_link(aes(edge_alpha = n), show.legend = FALSE,
                 arrow = a, end_cap = circle(.07, 'inches')) +
  geom_node_point(color = "lightblue", size = 5) +
  geom_node_text(aes(label = name), size = 6.5, vjust = 1, hjust = 0.5)
```

```r
# Lets check the development of this over time


# Before 1687
ngramSeperatedBefore1687 = Corpusngram %>%
  filter(year < 1687) %>%
  separate(ngram, c("word1", "word2"), sep = " ")

ngramFilterBefore1687 = ngramSeperatedBefore1687 %>%
  filter(!word1 %in% stop_words$word) %>%
  filter(!word2 %in% stop_words$word) %>%
  filter(word2 == "force")


TotalForceB1687 = ngramFilterBefore1687 %>%
  count(author, word2)

# Newtonian context
NewtonianForceB1687 =  ngramFilterBefore1687 %>%
  filter(word1 == "absolute" |
           word1 == "contractive" |
           word1 == "accelerating" |
           word1 == "centripetal" |
           word1 == "gravitating" |
           word1 == "attractive") %>%
  count(author, word2)


#Non Newtonian context
NonNewtonianForceB1687 =  ngramFilterBefore1687 %>%
  filter(word1 == "moving" |
           word1 == "external" |
           word1 == "disturbing" |
           word1 == "diſturbing") %>%
  count(author, word2)


NewtonianForceB1687
#No author before 1687 used these concepts

NonNewtonianForceB1687
#Boyle used Non-Newtonian concepts


# Create a data frame with only the particular years and frequencies
frequseBefore = tibble(author = TotalForceB1687$author,
                 frequse = rep(0, nrow(TotalForceB1687)))

for (i in 1:nrow(TotalForceB1687)) {
  if (frequseBefore[i, 1] %in% NonNewtonianForceB1687$author) {
    # Match the row of total use of force with the row containing the
    # non Newtonian force
    idx =
      which(NonNewtonianForceB1687$author == frequseBefore$author[i])
    # Then divide them
    frequseBefore[i, 2] =
      -(NonNewtonianForceB1687[idx, "n"] / TotalForceB1687[i, "n"])
  }
}

frequseBefore
#Seems to work
```

```r
### After 1687

ngramSeperatedAfter1687 = Corpusngram %>%
  filter(year > 1687) %>%
  separate(ngram, c("word1", "word2"), sep = " ")

ngramFilterAfter1687 = ngramSeperatedAfter1687 %>%
  filter(!word1 %in% stop_words$word) %>%
  filter(!word2 %in% stop_words$word) %>%
  filter(word2 == "force")


TotalForceA1687 = ngramFilterAfter1687 %>%
  count(author, word2, sort = TRUE)

NewtonianForceA1687 = ngramFilterAfter1687 %>%
  filter(word1 == "absolute" |
           word1 == "contractive" |
           word1 == "accelerating" |
           word1 == "centripetal" |
           word1 == "gravitating" |
           word1 == "attractive") %>%
  group_by(author) %>%
  count(word2)

##### Test case ngram

setwd("C:/Users/stank/Documents/Jaar 4 uni/Thesis in philosophy")

rm(list = ls())

source("Code/Packages.R")
source("Code/Thesisggtheme.R")


# Set the size of the ngrams
n = 2

# Will take around 15 second
source("Code/ngramPreparation.R")


# Before 1687
ngramSeperatedBefore1687 = Corpusngram %>%
  filter(year < 1687) %>%
  separate(ngram, c("word1", "word2"), sep = " ")

ngramFilterBefore1687 = ngramSeperatedBefore1687 %>%
  filter(!word1 %in% stop_words$word) %>%
  filter(!word2 %in% stop_words$word) %>%
  filter(word2 == "philosophy")


TotalForceB1687 = ngramFilterBefore1687 %>%
  count(author, word2)

NewtonianForceBefore1687 =  ngramFilterBefore1687 %>%
  filter(word1 == "experimental") %>%
  count(author, word2)


NewtonianForceBefore1687


frequseBefore = tibble(author = TotalForceB1687$author,
                 frequse = rep(0, nrow(TotalForceB1687)))
```

```r
for (i in 1:nrow(TotalForceB1687)) {
  if (frequseBefore[i, 1] %in% NewtonianForceBefore1687$author) {
    idx = which(NewtonianForceBefore1687$author == frequseBefore$author[i])
    frequseBefore[i, 2] = (NewtonianForceBefore1687[idx, "n"] /
                             TotalForceB1687[i, "n"])
  }
}




# After 1687

ngramSeperatedAfter1687 = Corpusngram %>%
  filter(year > 1687) %>%
  separate(ngram, c("word1", "word2"), sep = " ")

ngramFilterAfter1687 = ngramSeperatedAfter1687 %>%
  filter(!word1 %in% stop_words$word) %>%
  filter(!word2 %in% stop_words$word) %>%
  filter(word2 == "philosophy")


TotalForceA1687 = ngramFilterAfter1687 %>%
  count(author, word2, sort = TRUE)

NewtonianForceA1687 = ngramFilterAfter1687 %>%
  filter(word1 == "experimental") %>%
  group_by(author) %>%
  count(word2)

frequse = tibble(author = TotalForceA1687$author,
                 frequse = rep(0, nrow(TotalForceA1687)))

for (i in 1:nrow(TotalForceA1687)) {
  if (frequse[i, 1] %in% NewtonianForceA1687$author) {
    idx = which(NewtonianForceA1687$author == frequse$author[i])
    frequse[i, 2] = (NewtonianForceA1687[idx, "n"] /
                       TotalForceA1687[i, "n"])
  }
}




NewtonianForceOverTime =
  tibble(year = rep(0, nrow(TotalForceB1687) + nrow(frequse)),
         frequentUse = rep(0, nrow(TotalForceB1687) + nrow(frequse)))

for (i in 1:nrow(TotalForceB1687)) {
  NewtonianForceOverTime[i, 1] =
    as.integer(str_sub(frequseBefore[i, 1], -4, -1))
  NewtonianForceOverTime[i, 2] =
    frequseBefore[i, 2]
}

for (i in 1:nrow(frequse)) {
  NewtonianForceOverTime[i + nrow(TotalForceB1687), 1] =
    as.integer(str_sub(frequse[i, 1], -4, -1))
  NewtonianForceOverTime[i + nrow(TotalForceB1687), 2] =
    frequse[i, 2]
}


summary(lm(frequentUse ~ year, data = NewtonianForceOverTime))
```

```r
ggplot(NewtonianForceOverTime, aes(x = year, y = frequentUse)) +
  geom_point() +
  geom_smooth(method = 'lm', se = FALSE, size = 1.5) +
  ThesisggTheme() +
  labs(x = 'Year', y = 'Term frequency',
       title = 'Empiricist concept of philosophy over time') +
  geom_vline(xintercept = 1687, linetype = 'dashed', color = 'red',
             size = 1.5) +
  geom_curve(aes(x = 1670, y = 0.8, xend = 1686, yend = 0.79),
             color = 'grey20', angle = 90,
             arrow = arrow(30, unit(0.1, "inches"))) +
  geom_textbox(aes(x = 1665, y = 0.89),
               label = 'Publishing of \nthe Principa', color = 'grey20',
               size = 7) +
  theme(plot.title = element_text('sigmar', color = 'grey10', size = 20),
        axis.text.x = element_text(size = 12),
        axis.text.y = element_text(size = 12),
        axis.title.x = element_text(size = 16, color = 'grey10'),
        axis.title.y = element_text(size = 16, color = 'grey10')) +
  coord_cartesian(xlim = c(1653, 1825), clip = 'off')

NewtonianForceOverTime = NewtonianForceOverTime %>%
  arrange(year)


AbsoluteResultsOverTime = tibble(absolute = 1:nrow(NewtonianForceOverTime),
                                 frequentUse =
                                   NewtonianForceOverTime$frequentUse)

ggplot(AbsoluteResultsOverTime, aes(x = absolute, y = frequentUse)) +
  geom_bar(stat = "identity", fill = "steelblue") +
  ThesisggTheme() +
  labs(x = "", y = 'Term frequency',
       title =
         'Absolute results of the Newtonian concept of force over time') +
  geom_vline(xintercept = 7.5, linetype = 'dashed', color = 'red',
             size = 1.5) +
  theme(axis.ticks.x = element_blank(),
        axis.text.x = element_blank())
```