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Links, Letters and Lunaticks

A case study exploring the potential of Digital Historical Social Network Analysis

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Abstract

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by R.N. BOONE

The aim of this research was to explore the potential of Digital Historical Social Network Analysis (DHSNA) as a historical method. Five conditions were established on which DHSNA should be judged in order to determine if it qualifies as a promising method: added value, reliability, practicability, scope and prerequisites. In order to investigate these categories and to map the difficulties and the opportunities of applying social network analysis to bodies of historical data, a case study has been executed. This case study centered around the Lunar Society, an eighteenth-century informal scientific society in England's Midlands. The question the case study focused on was to what extent DHSNA would be able to teach us more about the social and the organizational structure of the Lunar Society.

In order to investigate the question four types of network visualizations have been constructed based on the meta-data of letters exchanged between Lunar Society members. A number of exchanged letters is not one-to-one related to the strength of a social relation. Therefore the networks mapping the collected meta-data needed to be translated to observations about the social and organizational structure. The networks mapping the collected meta-data were converted to correspondence activity networks by two techniques of reconstruction, social and organizational structure was derived from the correspondence activity networks by interpretation. Different qualitative and quantitative methods — including the calculation of metrics — have been applied in order to analyze the network visualizations.

The network visualizations and their associated metrics did bring some added value to the Lunar Society's historiography, for instance by shedding light on historical discussions by unraveling them and by uncovering underlying principles. However, many shortcomings were encountered as well, it was for instance not possible to derive from the visualizations some basic social situations described in the historical literature. The shortcomings were mainly due to the fact that the reliability of the networks fell short. Because the aim was to investigate a (relatively new) method, the discussions of the research design and the evaluations of the research process are understood as part of research results, and they served as input to judge DHSNA on practicability. Combining the observations about added value, reliability and practicability, it was concluded that DHSNA is not a suitable historical method to study *tight* historical groups (scope), that is, not until more advanced methods have been developed, the historical research infrastructure has been improved, and more easily accessible tools for historians have been created (prerequisites). At this moment, the insights the network analyses could bring are not significant enough to outweigh the amount of effort the DHSNA research process asks for.

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Chapter 1

Introducing the inquiry: an overview of the project and its motivation

1.1 Digital Humanities

Ever since the introduction of the mainframe computer during the 1950s, humanities scholars incorporated the device into their research to outsource laborious humanist tasks such as sorting, searching and counting.[1] From these efforts sprang the field of 'humanistic computation', which after the introduction of its first professional journal in the 60s, the founding of its first associations in the 70s and continuing efforts for standardization,[2] was redefined as the field of 'Digital Humanities' in the early 2000s.[3] Today this strand is known as the interdisciplinary programme to apply all kinds of digital methods in humanistic reasoning, both to answer existing questions and to question existing answers, complemented with scholarly interrogation of the way the technologies are applied.[4] The original collection of methods falling under the discipline's umbrella has since expanded from the basic preparatory humanist tasks to complex data-mining, visualization and analysis techniques, with intriguing new opportunities for humanist thinking already explored or on the way, such as extraction of the psychological makeup or recognition of the emotions of a writer.[5]

In general the field is met with great enthusiasm, and contrary to the 'classic' humanities, Digital Humanities does not have to worry about funding or prestige. However, it has of course its own problems and difficulties.[6] The main one is probably the allegation that the potential of Digital Humanities is overestimated. Critics wonder if the digital analyses will ever be robust and refined enough to provide the same level of humanistic quality that conventional methods in their eyes can, and if

[1] Hockey, 'The History', pp. 3–7.

[2] Ibidem, pp. 3–13.

[3] M. Kirschenbaum, 'What Is Digital Humanities and What's It Doing in English Departments?' in Gold and Klein, *Debates*, pp. 5 and 6.

[4] It is not possible, and not desirable, to give a very precise definition for the field of Digital Humanities, since the field is not that much characterized by a series of topics or a common goal, but by a broad collection of methods and techniques.

[5] See for instance the chapter 'Psychological Text Analysis in the Digital Humanities' by R. Boyd in Hai-Jew, *Data*, pp. 161–189. Or read about tools to detect emotions in texts in the blog post 'Emotion Detection and Recognition from Text Using Deep Learning' by Microsoft, or the article 'EmoTxt: a toolkit for emotion recognition from text.' by Calefato et. al. These tools would definitely be very interesting to apply (perhaps after required adaptations for older languages) to historical sources.

[6] Possibilities, tensions and discussions that emerge in the field of Digital Humanities as it grows are discussed in Gold and Klein's (eds.) leading book *Debates in the Digital Humanities 2016* and its associated online platform at `http://dhdebates.gc.cuny.edu/` (consulted at 9 June 2018).

so, if the digital findings could truly supply a novel perspective.[7] In other words: they wonder if Digital Humanities could fulfill its big promises of innovation and insight.

This question is especially pressing in the context of the large sums of money and considerable amounts of time that have been granted to digital projects over the last couple of years. Eventually we will know if these efforts were worth it, but until then it seems sensible to couple curiosity with caution and to let further large investments be preceded with thorough, decent exploratory research. A significant amount of digital humanities research has of course already been done, showing us both its successes and failures. However, the field is still relatively young and basic, foundational research exploring the possibilities, mapping the terrain, identifying the obstacles, formulating ways to overcome them, and working towards a better understanding of both the discipline's limits and opportunities is of utmost importance to assess the field's potential, to provide guidelines for upscaled research and to deliver material to contemplate the question if a digital future is in fact what we (besides the question if it is possible) want for the humanities.

1.2 Digital Historical Social Network Analysis

In this thesis a contribution to the exploration of one of the Digital Humanities' methods will be made: the one of Digital Historical Social Network Analysis (DHSNA).[8] DHSNA is a truly interdisciplinary field, with its roots in Digital Social Network Analysis (DSNA): the digital reinvention of the method of Social Network Analysis (SNA) at the intersection of the disciplines of sociology, mathematics, data science and computer science. The aim of SNA is to understand social relations through conceptualizing them as a network structure, and to analyze this structure qualitatively and/or quantitatively to learn more about the relations, people's social roles and the overall characterization of the social group. The digital reformulation facilitates the analysis of larger data sets and more complex network structures, with more advanced measures, in a faster way.

DHSNA is like DSNA, but applied in a historical context. As a metaphor to facilitate historical thought and communicate ideas, the concept of the (social) network has been present in historical research for some time. Yet only recently has this reasoning been expanded with the actual application of formal SNA methods on historical data.[9] This field of Historical Social Network Analysis (HSNA) (or, to prevent exclusion of non-social cases: Historical Network Analysis (HNA) or Historical Network Research (HNR)) is still young and in its formative phase, shown by the fact that its platforms, associations, its conferences and its workshop series are all not older than ten years, and the field only has a journal exclusively devoted to historical network research since October 2017.[10] But as young as it may be, attention for the field keeps growing: the number of events and instruction opportunities

[7] Note that the goal of Digital Humanities is, at least according to most digital scholars, never to *replace* classical methods, but to *extend* and *complement* them.

[8] Historical network analysis does not necessarily have to be *social* network analysis. One could think of other interesting historical cases in which networks feature that have nothing to do with social relations, like the trade routes of ships, flows of money or the epidemic spread of a disease.

[9] Düring, 'Historical Network'. Lemercier, 'Formal', pp. 281 and 282. A more extensive introduction to the field, its techniques and foundations is found in Chapter 4.

[10] The Journal of Historical Network Research, open access via `https://jhnr.uni.lu/index.php/jhnr` (consulted at 13 June 2018). The first articles considering historical (social) network analysis appeared in the 1990s, often in journals for social network analysis or social history.

increase, large research projects and efforts to professionalize (such as standardization) are initiated.[11]

If DHSNA proves to be successful, it offers historians a whole new methodological vantage point. However, *if* it will be successful and *how* successful it will be remains yet to be seen. The difficulties (*and* the opportunities) that come with the application of SNA on bodies of historical data are not at all clear yet and with that it is also not clear if those possible problems can be solved to such an extent as to make DHSNA a suitable historical method. In other words: the emerging field of DHSNA could, especially in the light of forthcoming investments, benefit a lot from more exploratory research on a fundamental level. And so that is exactly what this thesis sets out to do: it will explore the potential of DSNA as a historical method.

In order for DHSNA to qualify as a suitable and promising historical method, it should meet a number of conditions. First, the method needs to have **added value** in historical research: if it can not bring us any (reliable) results or insights at all, or if those results and insights do not transcend our current knowledge and only mirror what we already know, then the effort is not worth it.[12] Furthermore, the results of DHSNA should be **reliable**, or at least we should have good estimates of the extent to which they are insecure and the reasons causing the insecurity. Because the only way in which we could state that DHSNA indeed brings added value, is if the novel findings are to a satisfactorily level trustworthy. However, even *if* we conclude that DHSNA delivers new and fairly reliable results, it should be considered whether these type of findings are interesting enough to outweigh any practical difficulties that the method might encounter. Such difficulties could for instance include that the method might require a large amounts of time and effort, or technological limits such as calculation speed or something simple as screen sizes in principle never being large enough for certain visualizations. Or a research infrastructure that is not yet developed to the extent demanded by the field: issues such as standardization, discussions on publication and foundations, and digitization of sources and databases, might still need to get resolved. But in other words: we should also judge the method on its **practicability**, the third criterion. If the method scores well on these three conditions, we could safely say that it has the potential to become a useful historical method. However, an assessment of a new (historical) method would not be complete without exploring the **scope** of problems on which it might be applied, both to indicate the limits and the reach of the possible new method. At last, it should also be listed beforehand what kind of **prerequisites**, what kind of preparations (such as solutions to problems), are still needed in order to apply the method on a large scale: when it should be easy and reliable enough for application by researchers with very different backgrounds and perhaps in very different research contexts. In this thesis an application of DHSNA will be used as a case study to guide us through all the categories, sometimes explicit, sometimes implicit: a journey that will explore the potential of DHSNA as a historical method.

1.3 Case study: the Lunar Society

The case study that will help us assess the potential of DHSNA as a historical method considers the examination of the following question:

[11] For the particular case of historical learned networks, see for instance the forthcoming volume Hotson and Wallnig, *Reassembling the Republic of Letters: Systems, Standards, Scholarship*.

[12] Some communicative benefits of visualizations of current knowledge and interpretations aside.

> To what extent is digital historical social network analysis able to teach us more about the social and organizational structure of the Lunar Society; a private, informal scientific society in the second half of the eighteenth century?

In other words: if we carry out a social network analysis for the Lunar Society group, if we are able to build and analyze their social network, is it then possible to acquire new insights about the social and organizational structure of this formation that add to the existing body of literature and could perhaps not, not quickly or not easily be discovered with conventional historical methods? Let me first explain some of the reasons why this question was picked as the center of the case study.

The Lunar Society was a group of intellectuals, natural philosophers and manufacturers situated in England's Midlands that met and corresponded regularly during the second half of the eighteenth century to discuss issues regarding (experimental) science, manufacturing and their own on-going projects. As far as we know, the Lunar Society did not produce any official papers or records, which leaves historians with only the members' correspondence, papers and a some scarce references in the members' published works to gauge the characteristics of the society.[13] This contributed to the confusion among historians about the details of the social and organizational structure of the society: When did the Lunar Society rise and fall? How did it develop? Who were the central figures and what were the specific roles of Lunar Society members? Who can be characterized as such? And how should the society be interpreted as a whole? The confusion is still enduring and this makes it a specifically interesting opportunity to study it with DHSNA: could DHSNA perhaps answer some of those existing historical questions that historians could not (yet) answer before with conventional methods? The Lunar Society case could furthermore especially benefit from a DHSNA analysis because, as mentioned, besides correspondence and some papers there is not much primary source material about the Society available. This is the type of case where DHSNA could potentially really make a difference: by being, as will be explained later, based on the *meta-data* of the Lunar Society members' letters, DHSNA is able to make most out of the small number of historical sources available — what will this new perspective yield? What will DHSNA be able to add to the Lunar Society historiography?

The possible new insights about the Lunar Society would of course be valuable research results, but the main aim is of course, as indicated, to investigate the method of DHSNA, and the Lunar Society case is particularly suitable for that aim — because it is difficult. Since we know that the Lunar group met regularly, we know that all members probably must have met each other at least once in real life, and if not, that they at least knew who the other members were, and by the virtue of being members of the same group, felt free to contact each other directly if necessary. In other words: we know that everyone knew each other and could reach each other. We know thus from the start that the Lunar social network is completely connected, but we will try to detect and describe the relief, the details, of the social landscape. This transcends other historical social network analyses up to know, since they mostly tend to focus on who knows who and via which connections people could come into contact with each other, complemented with analyses of the overall structure of this network. The Lunar Society offers itself therefore as a perfect case to not only study the potential of DHSNA in general, but also to investigate more specifically if the tight historical group (the completely connected historical group) might

[13] Schofield, 'Orientation', p. 409. In Chapter 2 an overview of the Lunar Society's preserved materials is given.

be within the scope of DHSNA. An important question, since the number of tight groups in history is inexhaustible: think for instance of courts, leading elite families, or a church community. These kinds of groups will often be encountered as cliques in larger historical network structures and it would be a real benefit if HSNA could, on top of identifying these type of clusters, also zoom in and investigate its internal relations in more detail. The Lunar Society case is in this sense thus exemplary for social network analyses of tight historical groups.

If the method of DHSNA turns out to be successful in this case, it would be a promising result for the whole (social) historical study of science from the mid-seventeenth until the mid-nineteenth century. During this period, science (or as it was sometimes called back then: 'natural philosophy') was to a large extent defined by the activities of scientific societies and by their correspondence networks.[14] So the history of science depends much upon the histories of these epistolary active scientific societies. There have been more than a hundred scientific societies in this period, spread over more than a dozen countries — some were large, some small, some national, some provincial, some formal, some informal, some representing specific sciences and some having a broader outlook.[15] There has been quite some research done to these societies, however, some investigations do little more than to underline the need for increased attention, they 'do not do the hard work'.[16] Perhaps this is because of the scant amount of material preserved for some of these societies. DHSNA could, if it works and if it works effectively, make more out of these sources by offering quick surveys of the social and organizational structure of many of those societies. In that way it provides a means to map, compare and analyze the scientific societies landscape in an easy and structured way. Perhaps we could then, without having to find and go into *all* the materials of the more than hundred societies, already give a first draft of an overall, integrated history of all those scientific societies.[17] The Lunar Society is particularly appropriate as the subject of a good first exploration of the possibility to study scientific societies with DHSNA, since its informality and therefore its lack of official sources assures us that we do not deal with a too easy case that will make us oversimplify the others, but at the meantime, its importance and its fame *does* make sure that it would not be too difficult to locate that small number of historical sources that is available.

1.4 Approach

The case study distinguishes itself from other historical research, since setting up the research design is not just a preliminary action, but an integral part of the research itself. Precisely because of the fact that the case study sets out to investigate a new historical method, the exact way the method should be applied is not self-evident. The novelty also entails that there are not many DHSNA studies available to serve as examples, and the ones that are available are not necessarily applicable to or useful for the current case. The first step is thus to develop an execution scheme of the DHSNA method, and by constantly evaluating and adapting the initial design — the order of steps, the analyses executed, the databases built, the tools applied, the interpretations delivered — to make it as reliable as possible. If the set-up proves successful, the design could serve as an example or prescription for other research

[14] Schofield, 'Histories', p. 70.
[15] McClellan, *Science*, pp. xiii and 261–291.
[16] Schofield, 'Histories', p. 70.
[17] More details about eighteenth-century scientific societies will be discussed in Chapter 2.

and it is in this sense that the research process is just as much a part of the research results as the eventual verdict about DHSNA. In other words, in the research question we find enclosed another question: 'how is DHSNA possible in a responsible way?'.

A responsible way entails in my opinion a research process that is as sophisticated and advanced as possible. It should strive to explore options for bringing in quantitativity by means of incorporating techniques from sociology, computer science and data science. The goal should be that the level of these techniques is on par with the state of the art in those fields, but that desire should include the realization that in an interdisciplinary field such as DHSNA, it takes time to let all disciplines flourish at their highest level, and it should include the thought that it might in fact not always be the case that that highest level is of any value to the interdisciplinary field. Embracing the quantitative in DHSNA should however not mean losing the qualitative view out of sight, and it should definitely not mean viewing the numbers as the answers to the historical questions. This precept by the way applies in general for all social network analysis results: a picture is never the answer, but it is always the reflection of a process. A reflection with which you can keep interacting by applying different parameters and techniques; which you can keep adjusting to answer different questions. One needs to make choices about parameters, the datasets to include, attributes, thresholds, lay-outs, etcetera. These choices are made in constant dialogue with research questions, analysis methods, reflections on the possibilities and limits of the method, and the visualizations that appear. It is a dynamic tool to interrogate both your sources and your own thoughts. And reading, or interpreting, a figure produced by this tool is only done sensibly when one keeps in mind the historical context, the details of the data set being visualized, philosophical and foundational reflections on the (social) network concepts and methods, the decisions that were made when the networks were built and the biases that might have guided those decisions: networks should guide your thinking, but your thinking should also guide networks. Understanding the limits of your method and interpretations, is the only way not to feel limited claiming reliability for your findings. Yet, even these findings, these network-based conclusions that you might claim some reliability for, can then still only give answers to historical questions in dialogue with close-read primary sources and earlier historical research: your other dynamical historical tools.

The considerations above were kept in mind during the study of the case. The details of the research process, with all its considerations, decisions and solutions to problems, are found in the remainder of the thesis. For now the general outline of the research, the approach for answering the case study's leading question, will be sketched. The basic idea is to construct different networks by means of the meta-data of letters (date, sender, receiver) members of the Lunar Society wrote to each other.[18] In those networks, an edge between two Lunar members, between two nodes, stands for a letter sent and/or received.[19] The edge *weight* indicates how many letters have been exchanged. Analyzing these networks gives you some insights into the current situation of the available source material, or the correspondence network of the Lunar members, depending on which network is studied and the way the network

[18]The question which correspondence and whose correspondence to include is a difficult one, since collections of correspondence tend to be quite large and because there is no consensus among historians about who can be regarded as members of the Lunar Society. This will be discussed in further detail in Chapter 2 and Chapter 3.

[19]If it is 'and' or 'or' depends on the type of network constructed, this will be explained in Chapter 4.

is interpreted. For observations about the social and organizational structure of the Lunar Society, the 'correspondence structure' needs to be translated to the 'social structure' by interpretation. As will become clear later on, the different ways to understand the networks all present their own types of findings. After comparing the observations about the Lunar Society with the existing literature and evaluating the research process, we are able to give an assessment of the usefulness of DHSNA as a historical method.

In practice, this meant that the first step was to locate the letters in (digital) archives and publications, and to collect their meta-data in a database. Secondary literature proved to be very helpful in finding the desired collections of correspondence. Gathering the meta-data came down to investing many (wo)manhours of hard work, but help was warmly received during a small crowdsourcing project designed for this research. Next, after cleaning and preparing the data, studying the method of network analysis, reflecting on network design in the context of problems of network analysis, and after becoming familiar with software and learning new skills, the meta-data could be translated into multiple network visualizations.[20] All visualizations are dynamic (with a step size of five years); some are directed, some undirected; in some the edge weights represent absolute counts, in some the numbers are relative; some are corrected for missing data in the dataset, some are not.[21] After that, the networks were analyzed with different methods. Those include for instance qualitative indication of regions of interest or calculation of different quantitative measures for nodes, edges or the overall network structure.[22] Then the final part of the research process was carried out: translating the measures and visualizations to observations about the social and organizational structure of the LS, and eventually comparing these with existing historical literature. As becomes clear from the description above, the interdisciplinary nature of the research, and also the practical one of a part of it, resulted in far more distinct research phases that were quite different from each other and, connected thereto, asked for a wide spectrum of research skills, and as was found out in practice, a varied pallet of different kinds of research output. These observations will be discussed later on in more detail as part of the evaluation of the research process.

1.5 Outline

This thesis is structured around the different research phases mentioned above: it will report on them, explain them, evaluate them and draw conclusions from them. Logically then, the outline of the thesis will follow the order of the research steps. First, however, all historical and historiographical backgrounds necessary to understand the remainder of the thesis are discussed in the second chapter. It features a description of the Lunar Society and the historical contexts (including scientific, institutional, geographical, social and cultural contexts) in which it should be understood, and from an elaboration on the historiographical debates about the specifics and interpretation of the society we learn that there are many disagreements among historians about the topic. Next we will focus on how the data was collected, from locating collections till cleaning and preparing the data. Evaluation of the process especially addresses the problem of a historical research infrastructure that fails short:

[20] The details of these translations, including the details about some actions I took to make the networks more reliable and insightful are discussed in Chapter 4.

[21] More details about these types of network visualizations and their differences will be discussed in Chapter 4.

[22] The analysis methods will be discussed in greater detail in Chapter 4.

causing this phase to take up much more time than should strictly be necessary. A chapter dedicated to the data analysis thereafter shows and explains the networks built, and how that was done precisely. It also focuses on the different qualitative and quantitative techniques to analyze the networks, including the calculation of metrics. The analyses are carried out in the next chapter, and the results are compared with the body of Lunar Society literature. Based on these comparisons, conclusions are drawn in the last chapter, where we take stock to see how much the method of DHSNA was able to add to history writing about the Lunar Society and, taking this observation and evaluations of the research process into account, to formulate an assessment about the potential of DHSNA as a historical method.

1.6 Conclusions

I state that although we see from recent research examples that DHSNA is a suitable historical method to study in a fairly crude way at the level of basic observations (such as who knows who, how could people reach each other and who takes up the role of a hub) social structures that are relatively large and not too tight, at the moment, DHSNA is less suitable to study smaller, closer (completely connected) social structures that ask for more refined ways of inquiry. This is, as I postulate, partly because of the reason that the looser a group of people is, the better the structure of their correspondence activity network resembles the structure of their social relations network: implicating more difficulties to translate a correspondence activity network structure to claims about the overall social situation for the tighter groups. The other part being that the current research methods are not sophisticated enough yet to deal with such a more difficult translation situation, to deliver the refinement necessary for the analysis of tight group social structure and to overcome difficulties imposed by the historical context in which they are applied.

However, there is definitely hope for DHSNA in the context of tight communities, as it proved in the case study to be able to point towards some new historical hypotheses, and to provide a clarity useful to illustrate historical situations and to structure source material. However, the case study also uncovered some problems for DHSNA that need to be solved first in order to tap into the full potential of DHSNA, the most important one probably being that at this moment, the efforts and time to carry out the analysis are not outweighed by the noteworthiness of the results. In order to solve the problems, we need to invest in a better historical research infrastructure and develop sophisticated easy-applicable analysis methods and tools, and we need to do that from an international and an interdisciplinary perspective. There are so many interesting technologies in the fields of computer science and data science, there is so much useful experience in sociology and there are so many creative ideas on the side of the historian, if we decide we want to pursue DHSNA, if we deem it both a potentially fruitful *and* a desirable strand, the only way to do that successfully is by wisely connecting the knowledge of all these fields.

1.7 Data Management

The databases, the network visualizations, the metrics and the Python code that were created during this project, are digitally available via this link: `goo.gl/Py6rBq`. Both the unpublished sources and the published sources that were consulted to mine the meta-data used to produce these outputs, are listed in the Bibliography. Usage of the data and the analyses for further research is encouraged.

Chapter 2

Setting the stage: the Lunar Society and its historical habitat

In this chapter the Lunar Society and its historical contexts are introduced. These introductions will later on prove to be important for interpreting the constructed networks and to identify interesting historical questions to investigate with network analyses. First we delve into the many facets of eighteenth-century science and we meet a new kind of person engaging with it: the *savant-fabricant*. Then we study the phenomenon of scientific societies and we encounter the Lunar men for the first time. We explore their English surroundings thereafter and we try to understand the letter writing culture in which they were immersed. Afterwards the Lunar materials that stood the test of time are mapped and an overview of the researchers of this material — the historians — is given, together with their interpretations of the Lunar Society. As we will find out, their interpretations are quite divergent and so are their answers to some historical questions. Before attempting to contribute in clearing those issues up with DHSNA, I will elaborate on the matter of Lunar membership, explain why the constitution of the group had to be defined in advance instead of derived from the analyses, and introduce the people that made it into the Lunar selection.

2.1 Eighteenth-century science and the savant-fabricants

'Popular', 'polite' and 'hard science'

Globes were spinning and electrodes were sparking, the lecturers' voices echoed and books got devoured. During the eighteenth century, science in Europe escaped from the grip of the academy and nested in the daily lives of people of all classes: 'From the King and the Royal Society to country clergymen and cotton-spinners.'[1] People translated their enthusiasm in different scientific activities, and so we find in the same period duchesses collecting shells and young boys making fire-balloons.[2] This wide-spread attention for science and the occupation with scientific activities among all, this 'popular science', should be recognized as one of the most important aspects of European eighteenth-century culture.[3] Lunar Society member James Keir recognized this as well when he wrote in 1789 that 'the diffusion of general knowledge, and of a taste for science, over all classes of men, in every nation of Europe, or

[1] Uglow, *Lunar Men*, p. xvi. One should wonder to what extent science was in fact of any interest to poor, subordinated or marginalized people. Have there been any offerings on the 'popular science products market' for them as well?

[2] Uglow, *Lunar Men*, p. xvi.

[3] According to historian Uglow, people often forget this aspect when they talk about eighteenth-century culture. (Uglow, *Lunar Men*, p. xvi.)

of European origin, seems to be the characteristic feature of the present age.'[4] The market for 'popular science products' was vast and varied, with a supply ranging from public lectures to museum visits,[5] and from theatrical shows to scientific instruments for some experimentation at home (Figure 2.1 and Figure 2.2). Some of these products were targeted at specific groups. A tradition of science literature for children started for instance in the 1760s with *The Newtonian System of Philosophy* (1761) by John Newberry, which combined both scientific instruction and educational ideals.[6] The female audience was already addressed from the first decades of the eighteenth century, for example with Francesco Algarotti's famous *Newtonianism for Ladies* (1737).[7] The vogue for science in England was spurred by the founding of the Royal Society in 1660, because of its aim to make new discoveries public and its emphasis on experiments.[8] In subsequent years the attention for science spread: by the 1720s, public scientific lectures attracted curious crowds in London and the phenomenon soon found its way to the provinces as well.[9] In the 1740s educated people could read *The Gentlemen's Magazine* just as much for news about discoveries as for parliamentary reports or music reviews.[10]

The enthusiasm for science was especially flourishing in polite culture. Wonder, intellect and playfulness melted together in a 'cultivation' of science that was an important aspect of polite culture. Science was fashionable because it was deemed 'gentlemanly'.[11] Not every aspect of science was regarded as suitable for the polite gentleman or gentlewoman though: when doctor (and Lunar Society member) Erasmus Darwin requested information about the steam engine from the engine's improver (and Lunar Society member) James Watt to include in a didactic poem,[12] he explicitly asked for 'such facts, or things, as may be rather *agreeable*; I mean gentleman-like facts not abstruse calculations, only fit for philosophers'.[13] Believing in the intelligibility of nature, understanding fascinating ideas, performing (literally) shocking 'scientific tricks'[14] and conversing about it all were acts of politeness ('polite science'), but the 'hard work' — the theorizing and the calculations — was better

[4] Keir, *First Part*, p. iii, as cited in Jones, *Industrial*, p. 1.

[5] About early natural history museums and early science museums: Bedini, 'Evolution'.

[6] Other examples of scientific children's books are *Evenings at Home* (1796) by Anna Barbauld and her brother John Aikin, and *Harry and Lucy* (1805) by Maria Edgeworth. The books were part of the eighteenth-century literary 'instructive and amusing' genre. This genre set out to convey especially moral, and to a certain extent factual, lessons in an amusing way. The emergence of the juvenile literature could be traced back both to the mentioned spread of interest in science and to the commercialization of childhood (and commercialization in general) in the eighteenth century. (Fyfe, 'Reading'. Fyfe, 'Young'. Plumb, 'Commercialization'.)

[7] Up to this point, I have not been able to locate popular science works specifically targeted at non-Western audiences. It would be interesting to investigate if these type of popular works existed and what contemporaries thought of them. It is not a complete coincidence that both mentioned popular science books refer to Newton in their titles. His theoretical discoveries in the last decades of the seventeenth century, especially his *Principia* in 1687, the long-lasting hype of *newtonianism* not just represented the popularization of Newton's work, but interest in science and scientific principles in general.

[8] Uglow, *Lunar Men*, p. 8.

[9] Ibidem.

[10] For news about discoveries in *The Gentlemen's Magazine*: Uglow, *Lunar Men*, p. 10.

[11] Jones, *Industrial*, p. 8. Uglow, *Lunar Men*, pp. xvi and 8.

[12] Jones, *Industrial*, p. 8.

[13] Darwin to Watt, 20 November, 1789, as printed in King-Hele, *Letters*, p. 196.

[14] Doherty, 'Intellectual Friendship', p. 232.

to be left to the natural philosophers ('hard science').[15]

There was great activity in the eighteenth-century world of 'hard science'. The heavens, for example, were attracting much attention and were explored both theoretically and observationally: Laplace was applying mathematics to astronomical problems, Herschel was staring through his telescopes.[16] In the meantime, Galvani and Volta were laying foundations for the study of electricity while Count Rumford was doing the same for social economy.[17] Countries were geologized and the natural world catalogued, the last endeavor being enriched by natural novelties that adventurers like Captain James Cook brought home.[18] In chemistry there were heated discussions on theoretical foundations and accompanying nomenclature, with the debate about the origins and explanation of combustion at the center. Eighteenth-century science, in short, bustled in diverse areas.[19]

FIGURE 2.1: *The Kentish Hop Merchant and a Lecture on Optics*, a satirical engraving from the beginning of the nineteenth century that caricatures both the touring scientific lectures and the ignorance of provincials (one of them mistook the topic for 'Hop sticks').

[15]Jones, *Industrial*, pp. 8 and 19. Notice that the term 'hard science' does not imply that the practice was just a business for the natural philosopher, lost in his thought and occupied with deep contemplations. We should not forget the scientist's cooperations with more practically-oriented men (and women!) like instrument-makers, cataloguers or artists.

[16]Bolton, *Scientific*, p. 208.

[17]Ibidem.

[18]Ibidem.

[19]One of the scientific fields that deserves particular interest in the context of eighteenth-century social and political affairs, is anatomy. Under many eighteenth-century sociological, societal and political debates lay the question what the natural state of things (men, women, children, society) was, and if, and in what way, this natural state should be followed or mimicked in the social domain. Believers in such a 'natural order of things' turned to anatomy for inspiration what the natural conditions could be, usually seeking proof of the rightness of social convictions they already had. Anatomists (and biologists) themselves were not immune to social convictions, and sometimes projected their ideas and biases on the material they were studying. (See for instance: Cohen, 'Women', and Schiebinger, 'Skeletons'.)

FIGURE 2.2: *An Experiment with a Bird in an Air Pump*, by Joseph Wright, 1768. Wright was a close associate of the Lunar Society and painted several local industrial and scientific sceneries, as well as portraits of the Lunar men. The moon we see through the window is likely to be a reference to the Lunar Society.[20]

Savant-fabricants and 'industrial science'

The rise of 'popular' and 'polite science',[21] was part of a more general European development towards an information-rich society, a fact that contemporary educated Europeans were conscious of as well. Underlying this society was an interconnected knowledge economy,[22] in which ideas were a common currency thanks to an increasingly tight scientific networks. The growth of correspondence networks was facilitated by improved infrastructure (this will be discussed in further detail in Section 2.3). One should imagine Europe's highways as teemed with carriages of the well-to-do on their way to visit each other, mixed with horsemen carrying their letters and industrial traffic for carrying out their business. These leisured elites, of which most natural philosophers were a part as well, shared both their roads and their networks with workingmen, journeymen and craftsmen. The elites would only encounter lower classes on the road, while the men were trudging from town to town in bands in search of employment. But others, especially the artisans and the

[20] Fara, 'Lunar philosophers', p. 4.

[21] Terms like 'popular science', 'polite science' and 'hard science' should not be interpreted as rigid categories among which all science-like activities could be divided. Even less so should they be understood as an exhaustive list to encapsulate all practices. I do not want to apply strict definitions for the terms, but rather interpret them as fluid concepts to highlight in what way scientific practices might have differentiated, without excluding the option that they shared characteristics with multiple categories. In fact, even the interpretations of the categories themselves are already overlapping, 'polite science' and 'popular science' are for instance closely related and often come down to the same practices, similarly for 'polite science' and 'hard science'. However, I — and as we saw above, contemporaries with me — find enough differences in scientific activities to find distinguishing among them useful and insightful.

[22] I borrow this term to describe the eighteenth-century knowledge exchange situation from historian Jones (Jones, *Industrial*, pp. 1 and 2.), since I think that it gives a good metaphorical impression of the situation. However, I would like to advice caution in applying the term of 'knowledge economy' as an explanatory model, since I think the idea is anachronistic and highly influenced by our current thought of ideas as some almost-material entities traded as nicely defined quanta of information. The term 'knowledge economy' could diffuse the chaotic reality with all its different 'exchange processes'.

craftsmen, inhabited important positions in the networks of scientific exchange.[23]

This was in particular the case in England in the second half of the eighteenth century, when interactions between well-to-do natural philosophers and skilled craftsmen were not significantly impeded by institutional and social constraints.[24] In fact, there was a large share of Englishmen for whom to speak of such a dichotomy between natural philosophers and artisans does not make any sense. It would be better to label these people as a new type of group: the one of *savant-fabricants*,[25] a group that transcends classes and unites in their activity of combining science and technology in such a natural way as it being one and the same activity.[26] This combination would not necessarily spring from an ideological pursuit, but much more from business considerations and curiosity. Living in a time of industrialization, they worked for instance on the improvement of manufacturing products and procedures, or other aspects of industrial development, like machinery, transportation and communication. They were engaged in what has been called 'industrial science'.[27] By transferring scientific insights to useful applications and by using practical know-how as input for scientific reasoning, they enriched both technology and science.[28] In this way they contributed significantly to the formation of knowledge networks and the exchange of knowledge between groups that normally would find themselves at opposite ends of the social spectrum.[29] At the same time this resolves the classic myth of the scientist who 'hands down his discoveries to the technologist who thereupon finds an application for them':[30] the savant-fabricant could suffice by shaking his own hand.

Some additional historical context

The emergence of this new group of savant-fabricants can be connected to an interesting interpretative framework, but four elements of eighteenth-century cultural, political, and economical historical context need first to be clarified.

The first important development is the extension and shift of centers of intellectual life, and the flourishing of provincial culture. Traditionally, London had been the place to be for the English intelligentsia, but it could no longer fulfill all the needs of a country in change. The new techniques of manufacturing required more space, natural resources and a labour than London could offer.[31] This made manufacturers and pursuers of applied knowledge relocate to the provinces. A considerable share of this growing group of provincial residents — especially the middle classes

[23] For this paragraph I used: Jones, *Industrial*, pp. 1–21.

[24] Jones, *Industrial*, pp. 14 and 15.

[25] The observation is from Jones (*Industrial*, pp. 17 and 18.) He does however not explicitly speak of a new type of group, but of individuals that combined the role of *savant* and *fabricant*. I think this bunch of individuals is large enough, and their differences with other types of groups significant enough, to label it a distinct group.

[26] This is not to say that every savant-fabricant was necessarily a manufacturer or industrialist himself. I understand the savant-fabricant as someone being involved in applications of science on the intersection of theoretical and practical knowledge, be this via manufacturing, advising, experimenting, theorizing, inventing or coming up with new ideas.

[27] Jones, *Industrial*, p. 19.

[28] Uglow writes for instance 'As professors and savants brought their improved mathematics and theoretical knowledge of chemistry, minerals, heat or hydraulics to bear on the ad hoc wisdom of old crafts, so the artisans developed new processes and technologies at an astonishingly accelerated rate.' (Uglow, *Lunar Men*, pp. xvi and xvii.)

[29] Jones, *Industrial*, p. 1.

[30] D. Cardwell, 'Science, technology and industry', in Rousseau and Porter, *The Ferment*, p. 480, as cited in Jones, *Industrial*, p. 10.

[31] Schofield, *Lunar Society*, p. 13.

— became, as we know from the discussion about eighteenth-century science above, increasingly interested in intellectual and scientific pursuits.[32] This resulted in the growth of small intellectual and cultural communities throughout the provinces that served as local centers of intellectual and cultural life. They maintained close links with each other and with intellectual communities in larger cities like London, Edinburgh or Glasgow. We find these type of communities for instance in Bristol, Bath, Peterborough, Spalding, Manchester, Derby, Newcastle and, of course, Birmingham.[33] Without doubt, these new communities made the Midlands one of the prime sites of applied knowledge production in the western world during the eighteenth-century. Their quest for applied knowledge was tied up with their excitement for manufacturing and industrialization. England changed from 1730 to 1800 from a mainly agricultural nation to an emerging industrial force,[34] in which inhabitants no longer automatically looked to London for intellectual and cultural guidance.[35]

Secondly, the flourishing business of manufacturing was very much intertwined with another eighteenth-century development: the rise of consumerism and, connected to that, the increasingly hedonistic approach towards material possessions.[36] Fashion and taste were increasingly measured in pan-European and even trans-Atlantic terms,[37] and consumer goods were more and more produced for the international market.[38] Knowledge of design, fashion and tastefulness were in this way important ingredients for the savant-fabricant manufacturer to add to their mixture of science and technology. Some even actively stimulated and shaped demand by interventions in the market.[39]

Thirdly, there was the phenomenon that eighteenth-century England took more and more pride in its self-proclaimed open, rational outlook.[40] Of course, such an outlook would not have been present at any time, at any place and among any group of people, but in general, people strove to apply a certain style of individual critical enquiry and people valued rationality and reason.[41] This would not only translate into a high validation of knowledge in itself, but also into a wish to improve the human condition with inventions of reason. People believed in the intelligibility and the manufacturability of both the natural and the social world, resulting in theories of human rights and the creation of an ideal society, but also in suggestions to change the windflow over England or to bring icebergs to the Equator to cool the tropics and ease the northern winters.[42] Many saw the age as an age of progress. They were optimistic and believed a peaceful millennium was on its way,[43] although there was

[32] Schofield, *Lunar Society*, p. 13.

[33] Jones, *Industrial*, p. 20. Schofield, *Lunar Society*, pp. 13 and 14.

[34] Uglow, *Lunar Men*, p. xvii.

[35] Ibidem.

[36] Jones, *Industrial*, p. 11. In fact, shopping — identifying and buying the right, most tasteful, products — became an art on itself. At the end of the century, there were even books available to teach some guidelines in order to conquer the maze of choice. (See for instance: Norcia, 'The London Shopscape'.)

[37] Jones, *Industrial*, p. 1.

[38] Especially for the higher and affluent middling classes. (Uglow, *Lunar Men*, p. xvii.)

[39] Jones, *Industrial*, p. 12. Some also played the market with tricks: fashionable steel buckles laid in with enamel were for instance 'exported in large quantities to France, from whence they were brought back to England and sold as the most recent productions of French ingenuity'. (James Watt Memorandum, 1809, as cited in Uglow, *Lunar Men*, p. 25.) The international market probably always had and always will have its bizarre excesses.

[40] Uglow, *Lunar Men*, p. xvii.

[41] Jones, *Industrial*, p. 7.

[42] Uglow, *Lunar Men*, p. xvii.

[43] Ibidem, p. xix.

some suspicion of the backlash of progress as well.[44] In general, however, England was well on its way to realize the prevailing ideals, and many contemporary continental visitors concluded that Britain of all European countries approximated most closely the intellectuals' ideal model of a tolerant, secular society.[45]

The optimists already had to adjust their view after the political and social unrest of the French Revolution, witness the intense discussions (fought out in pamphlet wars) about the situation in France, and even some escalations between the opposing camps in the discussions.[46]

Industrial Enlightenment

The rise of a savant-fabricants 'class' could be regarded as the culmination of a period in which, according to historian Jones: 'the crucial technological desiderata for self-sustaining growth came into alignment'[47] and in which 'the method of trial by experiment rather than by reference to authority or received wisdom triumphed, and access costs to indispensable propositional knowledge declined significantly'.[48] Following the example of historian Mokyr, he dubs a new analytical category for this period in the second half of the eighteenth century: 'Industrial Enlightenment'.[49] Let us explore this concept a bit further.

Roughly speaking, the term 'Enlightenment' is conventionally used to indicate the period enclosed by the Scientific Revolution of the sixteenth and seventeenth centuries,[50] and the French Revolution at the end of the eighteenth. Commonly, it refers to the above described phenomenon of the move towards an open, rational outlook which emphasized intelligibility, manufacturability, progress, improvement of living conditions and the virtue of critical thinking, and to some of the new concepts, ideas and practices this outlook led to.[51] The term has a history of re-evaluation. This started in the 1970s with a call to dissolve the unity of the term, and to shift attention from an intellectual history focusing on (mostly French) 'great scientific thinkers' and the determinism of their ideas, to a social history of ideas with a wider geographical scope centering around cultural practices.[52]

[44] Uglow, *Lunar Men*, p. xix. This age knows more fascinating contradictions. The believe in progress was for instance accompanied by a concern for retrospection, which caused some to obsess with all kind of 'origins' . The focus on reason was furthermore complemented by voices stressing the power of the passions and senses as much as the mind: it was also an age of sensibility. (Uglow, *Lunar Men*, p. xviii.)

[45] Jones, *Industrial*, p. 6.

[46] About reactions to the French Revolution in England: Deane, *French Revolution*.

[47] Here Jones paraphrases historian Mokyr, but the context makes clear that Jones shares the view. (Mokyr, *The Gifts*, as paraphrased in Jones, *Industrial*, p. 14.)

[48] Jones, *Industrial*, p. 14.

[49] In a book bearing this term as its title, Jones investigates 'how "polite" science, "hard" science and 'industrial' science were blended together in a context of confident Enlightenment consumerism' in England, especially around Birmingham and the West Midlands. (Jones, *Industrial*, p. 19.)

[50] The label 'Scientific Revolution' is still heavily debated. For the purposes of this thesis it is not necessary to tap into the details of that debate. For now let it suffice to say that we notice in the sixteenth and seventeenth century a certain rise of activities executed with the purpose of collecting or demonstrating knowledge, accompanied by ideas of what would be the right way to do this and stimulated by a certain upcoming new world view that allows for this type of inquiries. For simplicity, I will apply the conventional concept of 'Scientific Revolution'.

[51] The outlook permeated all kinds of social, political, scientific and cultural expressions, including artistic ones. In novels we encounter for instance heroes who return from their (intellectual) journeys with a well-developed capacity to make comparative observations and causal analyses. (Chandler, 'Edgeworth', p. 102.) In this way these type of skills are not presented as inherently human traits that automatically develop, but as actual nouveau Enlightenment skills that can be trained.

[52] Jones, *Industrial*, pp. 4–8.

Two cultural practices that became connected with the concept of Enlightenment were the above-described 'popular' and 'polite science'.[53] These practices provided a way to link together the Scientific Revolution and the Enlightenment in a dynamical, concrete relationship:[54] 'the legacy of the revolution was an extensive involvement of all people with science, and science became a signifier of politeness and Enlightened thought.' However, this link is not a satisfying one, since it does not include the 'hard science' and the "industrial science" of the eighteenth century that we encountered as well. Understanding 'hard science' in the context of an Enlightenment framework is not too difficult: it sits well with the focus on rationality and is traditionally included in scholars' earlier attention for 'great scientific thinkers' and their ideas. But what about 'industrial science'?

To do justice to the 'industrial science' type — to find a place for the quest for applications of science within the interpretative and analytical categories of the eighteenth century as well — historian Jacob suggests that as a first step, the Scientific Revolution should be extended into the eighteenth century 'so that it overlaps and fuses with the Enlightenment [...] because the century witnessed the infiltration of the science of Newtonian mechanics into sections of the community which could actually turn this knowledge to practical use.'[55] In other words: the period of the rise of — or the growing attention for —- 'applied science' should just as much be understood as a part of the Scientific Revolution.

According to some, the extension of the Scientific Revolution is not enough to do justice to the English' eighteenth-century focus on 'industrial science', and the second step would therefore be to give a special name — a new analytical category — to this industrially-oriented 'new, open-minded scientific culture'[56] of the savant-fabricants: 'Industrial Enlightenment', a term that both encapsulates the Enlightenment spirit and underlines the industrial outlook.[57] I agree that this is a useful term to describe the specific situation in England in the second half of the eighteenth century.

However, although we use the term 'industrial', I think we should be cautious not to over-connect the new category with the one of 'the Industrial Revolution' — a term that is used to describe the mentioned industrialization and its societal effects, and is (for England) understood as extending from somewhere in the second half of the eighteenth century to somewhere in the first half of the nineteenth. Jones writes that 'Industrial Enlightenment can [...] be said to have acted as midwife to Industrial Revolution',[58] but I think this way of considering 'Industrial Enlightenment' brings along the danger to trace back the Industrial Revolution instead of tracing forth the hodgepodge of fragmented Industrial Enlightenment events. Industrial Enlightenment, its developments and its events should be interpreted on their own terms. Sure, people were working on industrialization, but that does not mean they were

[53] Jones, *Industrial*, p. 8. Strictly speaking he only talks about 'polite science', but — as becomes clear from their descriptions above — the idealistic backgrounds of these practices were related.

[54] Jones, *Industrial*, p. 8. 'Concrete relationship' as opposed to an abstract way to conceptualize the link. Twentieth-century Enlightenment philosophers with a metaphysical emphasis on an unity of 'mind' tended for instance to think of the link in terms of a metaphorical Enlightenment 'mind' somehow schooling itself in a scientific method. (Jones, *Industrial*, p. 7.)

[55] Jacob and Stewart, *Practical Matter*, chapters 1, 2 and 3, as paraphrased in Jones, *Industrial*, p. 9.

[56] Jones, *Industrial*, p. 14.

[57] I would like to refer to Jones, *Industrial*, pp. 15 and 16, for an overview of the downsides of the Industrial Enlightenment approach. Historian Chandler makes use of a term with a similar meaning, but with a different name: 'Lunar Enlightenment'. A name whose origins presumably do not require any explanation. (Chandler, 'Edgeworth'.)

[58] Jones, *Industrial*, p. 14.

consciously and goal-orientedly working towards industrial revolution.

The described intellectual and cultural communities emerging in eighteenth-century England's provinces offer promising sources to study the role of savant-fabricants. In particular around Birmingham we find a flourishing creative community of experimental philosophers, liberal professionals, entrepreneurs, manufactures and everything in between,[59] including savant-fabricants. Some of these men bunched up: some of these men became members of the Lunar Society of Birmingham.

2.2 Scientific societies and the Lunaticks

Scientific societies

In the period spanning the mid-seventeenth century until the mid-nineteenth century, there have been more than a hundred scientific societies, spread over more than a dozen countries. Some were large, some small, some national, some provincial, some formal, some informal, some represented specific sciences and some had a broader outlook.[60] Science in this period was to a large extent defined by the activities of scientific societies,[61] and as historian McClellan argues in his book *Science Reorganized*, together with academies these societies reshaped (organized) science and scientific communications on an international level.[62] He sees these institutions as the result of an organizational revolution that accompanied the cognitive and methodological ones during the Scientific Revolution.[63] The importance of the societies for the eighteenth-century scientific landscape was recognized by contemporaries as well, or at least the societies themselves did. The first volume of the *Memoirs of the Manchester Literary and Philosophical Society* (1785), a publication of a provincial scientific society, stated for instance that:

> 'The numerous Societies, for the promotion of Literature and Philosophy, which have been formed in different parts of Europe, in the course of the last and present centuries, have been not only the means of diffusing knowledge more extensively, but have contributed to produce a greater number of important discoveries, than have been effected in any other equal space of time.'[64]

At the beginning of the eighteenth century, there were only two formal scientific societies in England: the Royal College of Physicians and the Royal Society, both situated in London.[65] The Royal College of Physicians only accepted (of course) physicians, and only the ones that had graduated at the university of Oxford or the one of Cambridge,[66] so for many intellectuals it was not of any interest. Fellowship of the Royal Society remained prestigious throughout the age, but inadequacies in its organization and its lack of interest in applied science, meant for intellectuals — especially the ones more oriented towards applied science, like the savant-fabricants — that membership was deemed unsatisfactory.[67] The lack was partly resolved by

[59] Jones, *Industrial*, p. 20.
[60] McClellan, *Science*, pp. 261–291. Schofield, 'Histories', p. 70.
[61] Schofield, 'Histories', p. 70.
[62] McClellan, *Science*, p. xiii.
[63] Ibidem, p. xx.
[64] *Memoirs of the Manchester Literary and Philosophical Society*, 1785, as cited in Robinson, 'Membership', p. 153.
[65] Schofield, *Lunar Society*, pp. 11 and 12.
[66] Ibidem, p. 11.
[67] Ibidem, p. 12.

the founding of new London-based societies, mainly targeted at specific interests, such as mineralogy, botany or entomology; with the Society for the Promotion of Arts, Manufactures, and Commerce (the Society of Arts for short, and founded in 1754) as most interesting body for the ones involved in applied science.[68] The majority of England's prominent manufacturers were found to have been either members or consultants of this society.[69] It was however not a place were they could fulfill all their scientific needs, and many were merely a member because they thought there might be an off-chance that something useful might sprang from the Society's efforts.[70] Although provincial intellectuals participated in these London societies, the disappointing experiences combined with the rigors of travel and communication,[71] and the fact that like-minded people in the provinces were diffused, created a wish for provincial scientific association.[72] Some of the new scientific societies outside the capital imitated the London model, some celebrated their independence of London.[73] There was for instance the Derby Philosophical Society, and the Society of Gentlemen at Spalding, or the Literary and Philosophical Society of Newcastle-upon-Tyne. These are the type of societies that, contrary to the Royal Society and the Society of Arts, should be regarded as the true catalysts of the eighteenth-century flourishing of applied science, technology and industrialism.

England's provincial scientific societies consisted of groups of like-minded people (often circles of friends, often savant-fabricants) that met and corresponded to discuss their shared interests of science, technology and other intellectual endeavors. The extent to which these activities and exchanges were put on a firm formal footing differed from society to society, and although they were still important and influential, some of England's provincial scientific societies were rather informal.[74] Their get-togethers were somewhat equivalent to the gatherings of scientists and men of learning in London, who met for instance in coffee houses from time to time for informal discussions, news and laughs. Meetings like this — centered around a specific interest — were wide-spread in the eighteenth century: clubs of like-minded people were everywhere. There were reading societies, essay societies, photography societies; and clubs for singing, for drinking, for pudding-making, even for farting and there were also just 'societies of friends'.[75] The fact that the provincial societies were often informal and that they fit this tradition of meeting clubs, does however not mean that they were not taken seriously. Some important and well-known scientists, manufacturers, learned men and other bigwigs were members of the societies, like Newton, who was a member of the society in Spalding.[76] Furthermore, they were able to transform individuals working on their own, to groups inspired by the

[68] Schofield, *Lunar Society*, p. 12.

[69] Ibidem, p. 13.

[70] Schofield, 'Orientation', p. 409.

[71] Which, however, impeded them, but not withheld them from London. Many people traveled to London regularly and the contact between the provinces and London was quite close. (Robinson, 'Membership', p. 161.)

[72] Schofield, *Lunar Society*, p. 13.

[73] Ibidem.

[74] This type of informality has something peculiarly English about it according to historian Robinson. (Robinson, 'Membership', p. 153.)

[75] Some of these societies I encountered during explorations of the Library of Birmingham archives (reading, essay, photography and friends), the others are from: Uglow, *Lunar Men*, p. xiii.

[76] Uglow, *Lunar Men*, p. 5. Even some informal societies had some rules. As historian Uglow tells us, the rules of the Spalding society stated that 'the Chairman of the day should have the seat by the fire, and that ther shoucld be plenty of coffee, a pot of Bohea Tea, '12 clean pipes and an Ounce of Best Tobacco', a Latin Dictionary and Greek Lexicon, and a chamber pot.' (Uglow, *Lunar Men*, p. 5.)

feeling that they shared a common ground.[77] On top of that, they were capable of connecting these kind of groups not only with each other, but with intellectuals all over Europe. These provincial scientific gatherings do therefore not only provide us with one of the best examples of the development of English provincial culture,[78] they also 'open a window onto the traffic of ideas, objects and practices that all of Europe shared in, or wished to share in.'[79]

The Lunar Society

Within the creative community surrounding Birmingham we find such an informal scientific society: the Lunar Society of Birmingham.[80] The group existed roughly speaking during the second half of the eighteenth century,[81] and consisted of natural philosophers, manufacturers, doctors and other learned men. They were brought together by friendship and shared interests, such as (experimental) science, experiments, manufacturing, industrial development, other intellectual endeavors and their own on-going projects. They tried to meet regularly for dinner and discussion at the home of one of the members. Their meetings were scheduled on Mondays, and later Sundays, when the roads were safest: closest to full-moon — hence their name.[82] Alongside their meetings, the members corresponded with one another and visited each other, some members living close to each other were even in daily contact. Their interactions served sociability, business interests and scientific exchange. Over the years the prospect to share in these interactions drew many (foreign) visitors to their meetings, and many correspondents.[83] Some used the Society for instance as a channel to announce their discoveries (or those of other scientists) to fellow learned men, with the hope that they might communicate them further.[84] These kind of opportunities that the Society offered, together with its prominent members' fame, influential work and the vast array of social contacts of some of its members, made that the Society was well-known all over the West.

The group of Lunar men was widely varied. First, the strength of the club resided in the different expertises of its members, which created a broad knowledge base out of which ideas and solutions were drawn.[85] However, the backgrounds of the members were quite diverse as well. Only a few had much formal education,[86] others were for instance trained as craftsmen and learned most from experience. They came from different classes, from different parts in England and surrounding countries, and walked different paths in life before they met. Several were nonconformists and freethinkers, which proved to be a real benefit, because it meant that they were free from many traditions, hierarchies and institutional constraints.[87] This created the

[77] Uglow, *Lunar Men*, p. 70.

[78] Chandler, 'Edgeworth', 89. Robinson, 'Membership', p. 153.

[79] Jones, *Industrial*, p. 20. He made this statement in the context of the Lunar Society, but I think it is safe to assume that it could be generalized for all provincial scientific societies.

[80] The question of how the Lunar Society should be interpreted — as exactly what kind of organization the Lunar Society should be depicted, what it in fact *was* — will be discussed later on in this chapter and in Chapter 5.

[81] The question when exactly the Society came into being and when it ceased to exist will be discussed later on in this chapter and in Chapter 5.

[82] *The* Lunar Society is in fact *a* lunar society. More eighteenth-century clubs named themselves after the light needed to ride home by, and the name was thus quite common. (Uglow, 'Birmingham'.)

[83] These visitors and correspondents did not always came from far, the Society maintained close and supportive links with local science experimenters and promoters as well. (Jones, *Industrial*, p. 82.)

[84] Bolton, *Scientific*, p. 200.

[85] Uglow, 'Birmingham'

[86] Ibidem.

[87] Ibidem.

opportunity to build their own networks freely, including for instance links with the new dissenting academies that adopted a progressive curriculum in the sciences.[88] Sometimes the men encountered differences in their political, social or religious outlook as well, but these were not considered insurmountable: they always turned back to the things they shared.[89] And they shared a lot. Although their upbringings were thus quite varied, most of them grew up with the wonders spread by popular science, and some became familiar with the culture of clubs and association from a young age.[90]

Ultimately, it was this enthusiasm for experiments and conversation, and their interest in the intersection of technical skills and theoretical science, that brought them together: most of them, if not all of them, can be considered as true savant-fabricants[91] — fully immersed in the questions of applied science, and knowledgeable in both branches. Contemporaries recognized this characteristic of the group: visitors to Birmingham admired the great deal of 'pure' scientific knowledge and an uncommon level of technical skill combined within single members of the Society,[92] and Lunar men described each other for instance as 'He is I believe the first - or most complete manufacturer in England, in metal. He is very ingenious, Philosophical, Agreable.'[93] or 'He has the principles of Nature in his Palm, & moulds them as He pleases.'[94] This last statement was made in the context of a magnetism experiment and that is very illustrative for the members of the Society: they know the laws of nature — they know science—, they know how to apply them, and they will apply them whenever it brings them any benefits (Figure 2.3).
Furthermore, some of the more technically-inclined members got offered fellowships to the Royal Society as well,[95] and both their products and their scientific commandments were famous, wide-spread and consumed.[96] Today historians of the Lunar Society still recognize the trait: they describe members as 'embodiment of the Industrial Enlightenment'[97] and write that '[i]n their unfussy conviviality, their lack of dogmatism, their sponge-like capacity to absorb new ideas and new techniques and their commercial vision, they exemplified much that was typical of the way in which the Enlightenment manifested itself in Britain'[98] (this manifestation being 'Industrial

[88]Uglow, 'Birmingham'.

[89]As Priestley wrote: 'We had nothing to do with the *religious* or political principles of each other, we were united by a common love of *Science*, which we thought sufficient to bring together persons of all distinctions, Christians, Jews, Mahometans and Heathens, Monarchist and Republicans.' (Priestley as cited in Bolton, *Scientific*, p. 195.)

[90]Darwin's father was for instance a member of the Spalding Society, although he was according to Darwin 'a man of more sense than learning'. (Uglow, *Lunar Men*, p. 5.)

[91]Please keep in mind my earlier remark that according to my definition, a savant-fabricant is not necessarily someone that is a manufacturer himself.

[92]Jones, *Industrial*, p. 10.

[93]Lunar Society member Josiah Wedgwood about fellow member Matthew Boulton in a letter to his business partner Thomas Bentley, 23 May, 1767, as cited in Jones, *Industrial*, p. 19.

[94]Darwin about his (soon-to-be) fellow Lunar member Richard Lovell Edgeworth, in a letter to fellow Lunarian Matthew Boulton, Summer, 1766, as printed in King-Hele, *Letters*, p. 40.

[95]Uglow, 'Birmingham'.

[96]Lunar member William Withering's advice that 'Great care should be taken in reading not to mistake hypotheses for facts' (Withering as cited in a letter by Lady Catherine Wright of Teighnmouth, 1784, as cited in Hale-White, 'Withering', p. 1089.) was for instance deemed important enough by others to remember and repeat, and Lunar member Joseph Priestley advised a correspondent (and presumably others as well) that 'everything should be brought tot the test of fair and repeated experiment' (Priestley to Reverend Joseph Bretland, 26 June, 1791, as cited in Jones, *Industrial*, p. 15).

[97]Mokyr about Lunarian Josiah Wedgwood. (Mokyr, *The Gifts*, p. 52, as cited in Jones, *Industrial*, p. 17.)

[98]Jones, *Industrial*, p. 19.

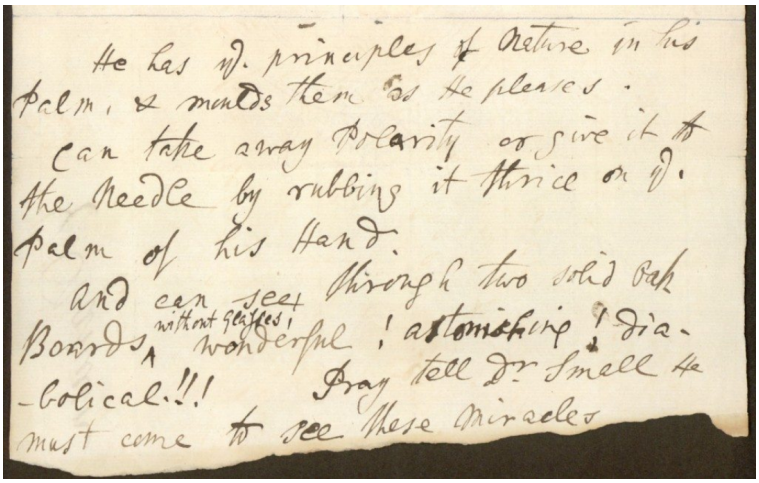


FIGURE 2.3: *'He has the principles of Nature in his Palm, & moulds them as He pleases'*: part of Darwin's letter introducing fellow Lunarian Matthew Boulton to soon-to-be member Richard Lovell Edgeworth. Including a reference to Lunar member William Small.

Enlightenment'). Many historians regarded the group as one of the best, if not the best, representative of a society combining various currents of eighteenth-century Enlightenment thought and of the described class-cutting eighteenth-century network of (informal) scientific exchange connecting craft and calculation.[99]

The Lunar men worked on different topics at the intersection of their interests. Typical Lunar subjects were for instance: electricity, transportation and infrastructure, steam-engines and engineering, metallurgy, the discussion on heat, geology, chemistry and 'material philosophy', physics and mechanics, medicine, agriculture, education (which was — following the ideas of Rousseau — understood as an experimental science), and industrial investigations to ceramic manufacturing, annealing processes and dyeing.[100] They worked on projects in these fields in many different ways. Sometimes they embarked on close cooperations, for instance in a partnership to produce steam-engines or in a joint venture to lobby for the construction of a canal or a road.[101] On other occasions, they carried out some experiments together (or they hired someone to do some long-term experiments for them).[102] Mostly, the mutual support expressed itself in a lively exchange of ideas and materials. Potter and Lunar Society member Josiah Wedgwood, for instance, sent some ceramics to fellow member Joseph Priestley after reading his book ('The Doctor seems much at a loss of a mortar, not metal for pounding in. Make him a deep one of two'),[103] while another member — James Keir — provided the group with the necessary glassware.[104] Another nice example we find in the Lunars' geological work. Wedgwood received samples of stone and clay for his ceramic experiments from the geologist in the society, John Whitehurst, who in his place, received specimens and descriptions of canal diggings from Wedgwood.[105] Furthermore, Whitehurst supplied Wedgwood with

[99] For instance: Schofield, 'Bicentenary', p. 160. Uglow, 'Birmingham'.
[100] Schofield, 'Orientation', pp. 411–414.
[101] Jones, *Industrial*, p. 25.
[102] Robinson, 'Membership', p. 157.
[103] A note by Wedgwood while reading Priestley's *Experiments and Observations on Different Kind of Airs* (1777), as cited in Burns, 'Midlands', p. 404.
[104] Burns, 'Midlands', p. 403.
[105] Schofield, 'Orientation', p. 413.

a material much needed for the potter's famous 'jasper-ware'.[106] This substance was barium carbonate, or 'witherite', named after the person that was first to analyze it thoroughly: William Withering, another Lunar member.[107] Their interest was shared by a third member, manufacturer Matthew Boulton, who had established an assay office to research the properties of ores at the site were he manufactured steam-engines together with his partner James Watt.[108] Not all members were equally involved in experimenting and theorizing, and they were more inclined to make use of the work of others than to contribute with their own studies.[109] However, they made up for this with financial support, hosting meetings, contributions to the Lunars' shared library and good social contacts.[110] The projects were often ambitious, rapidly expanding and intersecting.[111] The Lunar men were optimistic and idealistic, they truly believed their discoveries and inventions would make the world a better place.[112] Sometimes this outlook let to political action or attention for social matters as well, they all supported for instance political campaigner and Lunar member Thomas Day's anti-slavery cause.[113] We should, however, also not underestimate the personal benefits the men got out of their membership. Besides the pleasures of emerging oneself in interesting topics, the new products and innovations brought financial gain, and they were for instance not shy to send interesting business opportunities to each other ('I sent one Smith to see your Electricity of which he knows nothing, nor is like to know, but it seems he is a retail dealer in your way of Business.')[114]

An 'ordinary' Lunar meeting would start around two 'o clock and would at least go on till eight.[115] The members — together with the guests they brought — met at each other's houses, most often at Soho House in Birmingham, where Boulton lived (Figure 2.4).[116] The host and chairmen of the evening would take care of hospitality and dinner. Boulton (or, perhaps we should suspect, Mrs. Boulton) was apparently particularly well-skilled in this area.[117] It even made a correspondent express his concern to Watt that the niceties distracted Watt from intellectual pursuits:

> 'My dear philosophe I begin to think that the feeding of your belly ruins the operations of your head otherwise we should have had you vapoured in the news papers long ago - Mr. Bo[u]ltons board is ill qualified for sharping tools that are best engendered upon the hard hills of desolation and forged by the hand of the hungry mother of invention...'[118]

The initial plan was that they would meet monthly, but in practice the gathered less frequently.[119] However, it is difficult to distinguish 'normal' polite dinner-table

[106] Schofield, 'Orientation', p. 413.

[107] Ibidem.

[108] Many more brilliant examples of intriguing cooperations can be found in the works of for instance Schofield, Robinson and Uglow. For a short introduction, especially Schofield, 'Orientation', is recommended.

[109] Schofield, 'Orientation', p. 415.

[110] About the library: Jones, *Industrial*, p. 92. Robinson, 'Membership', p. 160.

[111] As Uglow puts it beautifully: 'They sail[ed] on the crest of the new' (Uglow, *Lunar Men*, p. xiii.)

[112] Uglow, 'Birmingham'.

[113] Ibidem.

[114] Darwin to Boulton, no date (176-), as cited in Robinson, 'Membership', p. 155. The Lunar men were also not shy to make use of their enthusiasm for science to charm other business men. (Robinson, 'Membership', p. 155. Uglow, *Lunar Men*, p. 60.)

[115] Robinson, 'Membership', p. 157.

[116] Ibidem.

[117] Ibidem.

[118] James Hutton to Watt, 1774, as cited in Robinson, 'Membership', p. 157.

[119] Jones, *Industrial*, p. 90.

meetings including Lunar men, from 'official' Lunar events.[120] The host would not send out formal invitations, but would just mention the upcoming intellectual party in the course of a letter.[121] These type of letters provide us with a useful opportunity to get an impression of the programme of a meeting, because they sometimes included a little preview as encouragement to come. The invitation to the Lunar meeting of 6 January 1781, for instance, reads that 'there is a new book to cut up, and it is to be determined whether or not heat is a compound of phlogiston and empyreal air, and whether a mirror can reflect the heat of the fire.'[122] The meetings were appreciated a lot by most members and were considered important, which becomes clear from the sometimes even sentimental letters of those who were not able to attend, for instance because they were traveling or because they moved away. [123]

FIGURE 2.4: *Dining room at Boulton's Soho House*: many Lunar meetings have taken place in this room.[124]

The goal of the Lunars' meetings was to communicate the results of their own investigations, to report on their projects, to discuss new scientific works, to share news from without the circle and, mainly, to enjoy experiments and 'a little philosophical laughing'.[125] For these experiments they brought tools and apparatuses, or

[120]Jones, *Industrial*, p. 88.

[121]Bolton, *Scientific*, p. 201.

[122]Watt to Darwin, 3 January, 1781, as cited in Bolton, *Scientific*, p. 201. Darwin, the receiver of this invitation and a doctor, was unfortunately not able to join the meeting, because 'this said devil has played a me a slippery trick, and, I fear, prevented me from coming to join the holy men at your house, by sending the measles with peripnenmony amongst nine beautiful children of Lord Paget's.' (Darwin to Watt, 6 January, 1781 as printed in King-Hele, *Letters*, pp. 104–106.)

[123]Especially Priestley seemed to have had a hard time being away from the Lunarians: 'philosophical friends I should in vain look for here, and as long as I live I shall look back, and with pleasure and regret to our Lunar meetings, which I always enjoyed so much, and from which I derived so much solid advantage. If I could find the same *intelligence* in any club of philosophers here, I could not find the same *frankness*, which is the charm of all society.' (Priestley to Withering, November, 1791, as cited in Bolton, *Scientific*, p. 215.)

[124]Historian Forgan noticed that in the buildings of nineteenth-century scientific societies, the way their 'functions were embodied into rooms and articulated within the building had implications for the structure of scientific discourse [and] the investigation of phenomena [...]' (Forgan, 'Context', p. 91.) In what way could the domestic surroundings of the dining room and the country house have influenced the Lunar activities?

[125]Quote: Darwin to Boulton, 11 March, 1766 as printed in King-Hele, *Letters*, pp. 38 and 39. Goal: Bolton, *Scientific*, p. 200.

they used the well-equipped laboratories of some members.[126] The main topics of the meetings were always science and experiments, but there was room for literature, art and politics as well.[127] We possess for instance an 'eye witness' description of Lunar member Samuel Galton's daughter Mary Anne Schimmelpennick about a Lunar meeting at her father's house, during which the Lunar members tried to extract all possible information about the French unrest from Boulton's son, who just came back from a visit to Paris.[128] From her descriptions we also know that her family's butler called the gathered learned men 'Lunaticks'. It is however not clear if he invented or adopted the term, since it was a popular nickname for the members.[129] Furthermore, amidst all the experimentation and the efforts to improve the human condition, there was also room for humorous interludes.[130] For instance, they drew up a satirical contract that said that Darwin had to make his invented speaking machine 'capable of pronouncing the Lord's Prayer, the Creed, and Ten Commandments in vulgar tongue', making fun of the his levity in religious matters.[131] Still, of course some of the meetings were not that satisfactory. Sometimes there was 'nothing new, except that some of my white spathos iron ore was found to contain more air than any ore Priestley had ever tried'[132] and sometimes the meeting was 'rather dull, there having been no philosophical news lately.'[133] Some reports of meetings might even strike the current scholar as quite familiar: '[...], which made Moyes contradict Smeaton, and brought on a dispute which lost us the information we hoped for, and took away all the pleasure of the meeting, as it lasted two hours without coming half an inch nearer to the point.'[134] To give an impression of what the Lunarians precisely discussed or demonstrated during their meetings, I included a list of Lunar meeting activities — beautifully drawn up by Jones — in Appendix A.[135]

2.3 Birmingham and the correspondents

Birmingham and the region

'Many men', said the bookseller, Birmingham's first historian and contemporary observer William Hutton, 'came of foot and left in chariots'.[136] The Lunar men cannot be set apart from their surroundings:[137] their activities and the development of Birmingham and the region were very much intertwined.[138] Some important Lunar

[126] Experiments were particularly carried out when the meetings were held at Priestley's Fairhill or at Boulton's Soho, since their laboratories were best-equipped. (Jones, *Industrial*, p. 94.)

[127] Chandler, 'Edgeworth', p. 90.

[128] Bolton, *Scientific*, p. 210.

[129] Ibidem, p. 212.

[130] Ibidem, p. 209.

[131] Darwin's Commonplace Book, as cited in Bolton, *Scientific*, p. 209, and in Robinson, 'Membership', p. 162. Bolton thinks the contract is from 1787, while Robinson indicates it is from 1771. Robinson must be right, because the contract was signed by Lunar member William Small, who passed away in 1775.

[132] Boulton to Watt, 3 July, 1781, as cited in Bolton, *Scientific*, p. 207.

[133] Watt to Boulton, 20 September, 1785, as cited in Bolton, *Scientific*, p. 207.

[134] Boulton to Watt, 26 October, 1782, as cited in Bolton, *Scientific*, p. 208.

[135] Jones, *Industrial*, pp. 92 and 93.

[136] Hutton, *History of Birmingham*, as cited in Uglow, *Lunar Men*, p. 17. 'Any fool can make money in Birmingham' — in the 1970s this was still a local saying. (Uglow, *Lunar Men*, p. 17.)

[137] Not all Lunar members lived (all the time) in Birmingham or the surrounding area; however, the region was the focal point for their Lunar-related activities and correspondence.

[138] 'The region' should be understood as being England's (West) Midlands. Note however that the term 'Birmingham and the West Midlands' is anachronistic, contemporaries would probably have (at least around the end of the century) used 'Birmingham and the District'. (Jones, *Industrial*, p. 22.)

places in this area were Wedgwood's 'manufactory' Etruria (near Stoke-on-Trent), Galton's home — and beloved Lunar meeting place — Great Barr Hall, Keir's chemical works in Tipton Green, Darwin's place of residence Lichfield, and Whitehurst's city Derby (known for its clock-making trade).[139] Lunar places of notice outside the area were for instance Lunar member Richard Lovell Edgeworth's Edgeworthstown (see Figure 2.6), London (especially Mr. William Matthews' place at Green Lettuce Lane Inn where Boulton stayed sometimes),[140] and the area of Cornwall, associated with the steam-engine business (see Figure 2.5). The most important site for the Lunar Society became Boulton's famous and already mentioned Soho house and accompanying manufactory, where he lived, where many meetings were held, where he led his (Western-)world-famous business and which eventually brought the whole world to Birmingham's doorstep.

However, around 1700, Birmingham was little more than a village, although it did already had become a place defined by its metal-working, and was known for its high concentration of workshops and forges.[142] In the 1740s, the Birmingham paper *Aris's Birmingham Gazette* depicted the city as busy but attractive and pleasant, with large green fields and the gardens of the houses and workshops stretching down to the river.[143] But from the 1750s and 1760s onwards, the population doubled each generation, and Birmingham would become one of the most dominant industrial cities of England and a booming market for applied knowledge.[144] In this way, the flourishing of Birmingham is a perfect example of the rise of provincial culture as described in Section 2.1. There were close links between manufacturers within the town, and with the rest of the world.[145] Birmingham became known as a commercial and cultural center,[146] in particular famous for producing and trading small metal goods, known as 'toys' (think of buckles, hooks and buttons). For some observers the 'rise' or 'miracle'[147] of Birmingham had a romantic appeal, but in reality it was quite a dirty, chaotic and noisy place.[148] Despite the dirt, it was also a place of individualism and inventiveness, and of the ideal of freedom and the idea of fortunes waiting for every man.[149]

Historians have tried to explain the success of Birmingham and the region. They have for example put forward the favorable natural resource environment — the abundance of coal supplied the lands for instance with plenty of energy.[151] Others argued for the the freedom of rules in Birmingham as key factor in its growth.[152] But

[139]For instance: Jones, *Industrial*, p. 28. Schofield, *Lunar Society*, p. 32. Uglow, *Lunar Men*, p. 9 for Derby's clock-making trade, for more information about the other places I would like to refer to Uglow's Index.

[140]This becomes clear from the correspondence between Boulton and Watt. (Library of Birmingham, MS 3782/12/76 – MS 3782/12/78.)

[141]This map was published in Uglow, *Lunar Men*.

[142]Jones, *Industrial*, p. 23. Schofield, *Lunar Society*, p. 14.

[143]Schofield, *Lunar Society*, p. 14.

[144]Jones, *Industrial*, pp. 19 and 82. Schofield, *Lunar Society*, p. 15. Uglow, *Lunar Men*, p. 21.

[145]Uglow, *Lunar Men*, p. 24.

[146]Joseph Wright's paintings of local industrial and scientific sceneries, and of wealthy Birmingham residents (these paintings were also mentioned in the caption of Figure 2.2 above), helped to consolidate the growing reputation of Birmingham as such a commercial and cultural center. (Fara, 'Lunar philosophers', p. 1.)

[147]Geologist, vulcanologist, traveler and Birmingham observer Barthélemy Faujas de Saint-Fond, *A Journey*, volume 2, p. 346, as cited in Jones, *Industrial*, p. 24.

[148]Ibidem.

[149]Uglow, *Lunar Men*, p. 21.

[150]Photographs in David Brewster's album, as found in Smith, *Disciples*, pp. 70 and 71.

[151]Jones, *Industrial*, p. 24.

[152]Uglow, *Lunar Men*, p. 19.

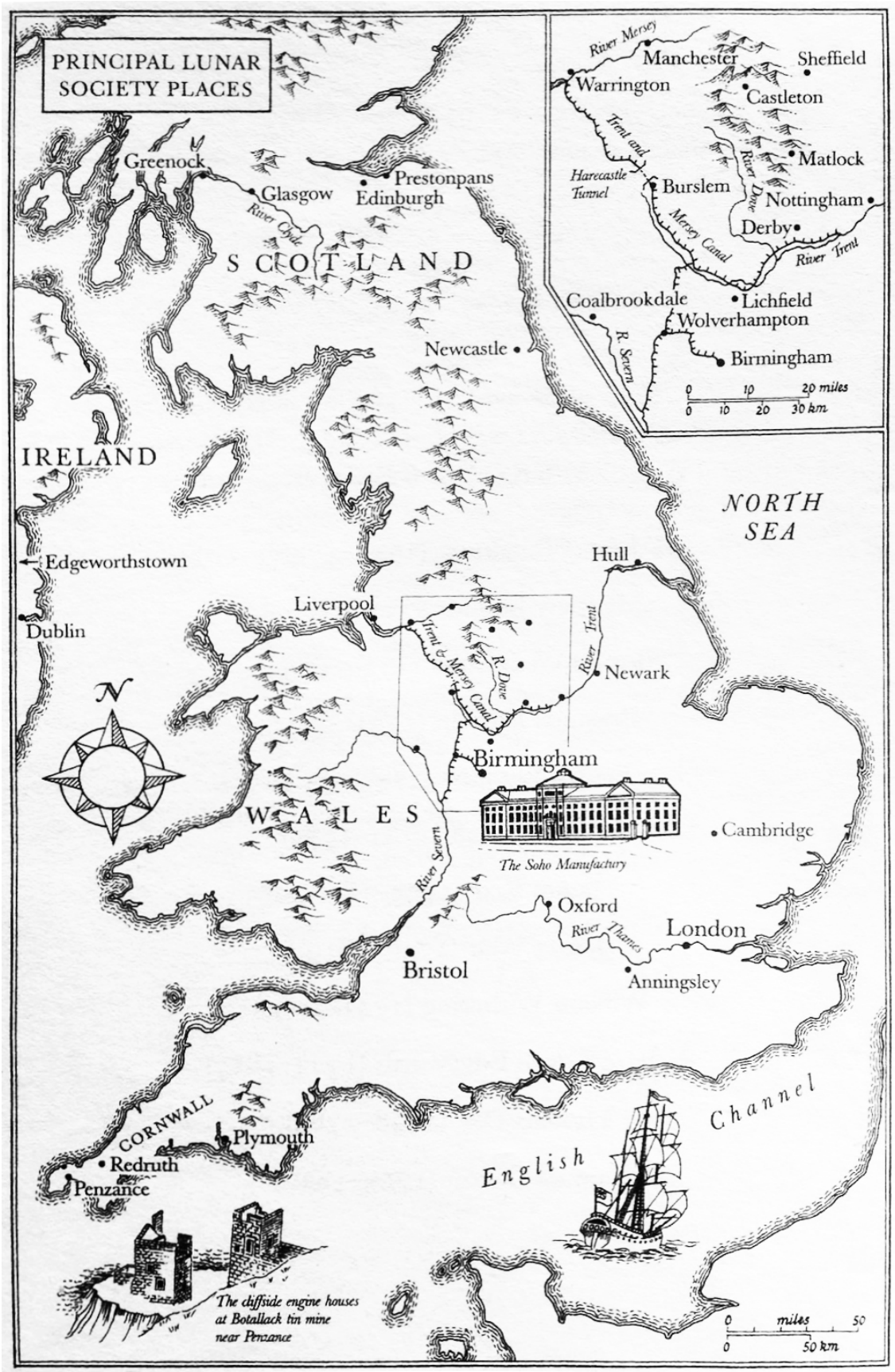


FIGURE 2.5: *Principal Lunar Society places*[141]

FIGURE 2.6: *Photographs of Edgeworthstown*: Edgeworth's house, a church and a beech tree in Edgeworthstown. Photographs taken by Edgeworth's son Michael Pakenham Edgeworth, found in David Brewster's album.[150]

there is another explanation, subscribed by many and convincing: the interlocking improvements in communication and transportation proved to be the roads to prosperity.[153] Around 1750, there was no transportation system that could handle the needs of heavy industrialism sufficiently. Boat, horse or an occasional carriage were the only means of traveling or transporting goods, the speed of the trip being heavily dependent on the weather and the quality of the road.[154] A trip from Manchester to London took for instance four and a half days in good circumstances.[155] Birmingham was not well connected at this time, with both highway and river at quite some distance.[156] This all changed in the third and fourth quarter of the eighteenth century. The turnpiking of roads and the construction of canals connected the centers of industrialization and solved to a large extent their transportation problems, which improved trade opportunities and communication.[157] Especially the canals were celebrated: canals such as the Trent and the Mersey Canal connected the Midland towns directly, thereby diminishing the importance of London that up to then often acted as intermediary.[158] Before the canals 'it was common to see a train of carriages for miles, to the great destruction of the road, and annoyance of travellers',[159] but fortunately they brought some relief by relocating some industrial traffic to the waters. As said, some of the Lunar men — especially Wedgwood and Boulton — were, together with other local manufacturers, much involved in promoting and constructing the canals: the commercial value of these new waterways was well-understood.[160]

By these type of contributions, and not to forget, especially by the efforts of all the workmen digging the canals and improving the roads, England was better connected towards the end of the century. In the 1780s it took Boulton and his business partner only six days to travel to Paris via London and Dover, a letter from Paris to Birmingham took just four days, and instead of the four and a half days, one could now travel from Manchester to London in twenty-eight hours.[161] However, we should not forget that at many places in the country the roads remained bad:

[153]Jones, *Industrial*, pp. 24–27.
[154]Schofield, *Lunar Society*, p. 7.
[155]Ibidem.
[156]Jones, *Industrial*, p. 24.
[157]Jones, *Industrial*, pp. 24–27. Schofield, *Lunar Society*, p. 8.
[158]Schofield, *Lunar Society*, p. 8. Before these innovations, London had a high betweenness centrality so to say.
[159]Hutton, *History of Birmingham*, p. 402, as cited in Jones, *Industrial*, p. 26. Apparently traffic jams are of all times.
[160]Jones, *Industrial*, pp. 25 and 26.
[161]Jones, *Industrial*, p. 27. Schofield, *Lunar Society*, p. 8.

although you did not have to leave the British isle, a journey from Birmingham to Cornwall took a minimum of eight days and a letter from Truro (a city in the Cornwall region) to Birmingham even required fifteen days.[162] With the increased traffic, we should see the roads with all their traveling business men as having become more and more a world on its own. As Uglow describes it: 'On the road, the hardwaremen might join up with Manchester manufacturers, Sheffield cutlers or Staffordshire potters, travelling together as protection against highwaymen, stopping at taverns and gradually building up a complex net of friendships, deals, shared knowledge.'[163] The roads were full of surprises, sometimes they brought you fortune, sometimes they brought you failure, and sometimes they just confronted you with your own clumsiness: 'On Monday last my Son drove me in a phaeton to meet a party of our Lunar friends but finding it cold I stood up to put on my great Coat and in that act my Son suddenly stopped the carriage which threw me over between the Horses legs...'[164]

Letters

The improvements in transportation and communication went hand in hand with developments in England's letter writing practices: letter writers demanded a good communications infrastructure, the existence of an improved communications infrastructure motivated people to write letters.[165] Letters were an increasingly important cultural and commercial aspect in eighteenth-century England.[166] In this century, we find a growing number of individuals of all ranks to participate in the letter writing culture (see Figure 2.7). This, combined with the flourishing genre of epistolary novels and letter-writing manuals both for the elite and for commoners, made some people call the age the 'golden age of letters and letter writing'.[167] When people managed to write coherent prose and if they — for instance with the help of such a letter-writing manual — were able to teach themselves the conventions, if they, as historian Whyman dubbed, acquired 'epistolary literacy', they found a way to access new commercial and social corners of society. By means of mastering the basic requirements of communication, they acquired some standing, and they were able to conduct business and construct personal relations on a higher level. This made the trait especially interesting for the middling class and those who aspired to rise into its ranks.[168] Furthermore, sensible letter writing gave people the opportunity to rise above one's own locality, exposing them to new knowledge and narratives, and it also taught them how to interact with people below or above their own rank.[169] Conventions provided a safe way to approach people that they in daily life perhaps barely would have had contact with.[170] This might have been a vital factor in the development of the networks of scientific exchange discussed earlier, that cut through classes and included practical and theoretical experts from different backgrounds. As Whyman states: '[...] letter-writing functioned as a thick, spreading 'glue' that drew elements of society together.'[171]

[162] Jones, *Industrial*, p. 27. Schofield, *Lunar Society*, p. 8.
[163] Uglow, *Lunar Men*, p. 22.
[164] Boulton to Franz Xaver Swediaur, 23 June, 1791, as cited in Robinson, 'Membership', p. 172.
[165] Whyman, *Pen*, pp. 47, 219 and 228.
[166] Ibidem, pp. 227 and 228.
[167] Pearsall, Letter Writing. Whyman, *Pen*, p. 228.
[168] Whyman, *Pen*, p. 228.
[169] Ibidem.
[170] Ibidem.
[171] Ibidem.

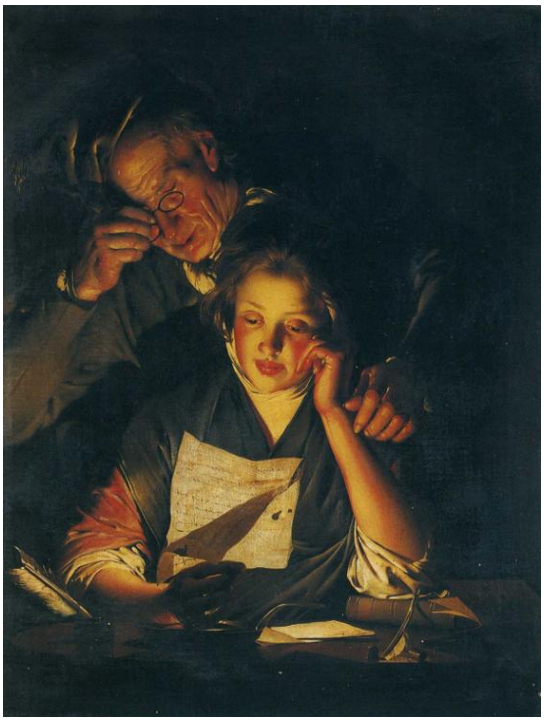


FIGURE 2.7: *A Girl reading a Letter, with an Old Man reading over her shoulder*: a painting by Joseph Wright, c. 1767 – c. 1770. During the second half of the eighteenth century, letter writing became increasingly associated with women. People in this period became preoccupied with women's (letter) reading activities. By depicting the male onlooker, the painter explicitly addresses this voyeurism.[172]

But it was not all roses. Although the roads and therefore the communications infrastructure improved during the second half of the eighteenth-century, the postal service still caused many frustrations: people complained for instance about the vagaries of the post in their letters,[173] or were concerned with the expense of postage.[174] In the 1630s a public postal system was installed in England that worked with post boys. Although some improvements in the post system had been made in the early eighteenth century in the form of expanded routes and more surveillance to detect corrupt practices, the notorious post boys remained the main means of mail delivery up to the end of the century. They carried the post from post to post, where local postmasters and postmistresses took over and took the responsibility to deliver the mail in their areas. The post boys were a source of trouble. Carrying their letters in bags on horsebacks, they had to conquer England's worst roads, they had to defeat dirt and defy rats, challenging to both the horse and the boy. On top of that, there were highwaymen and robbers that were only too willing to release them of their heavy bags. And if it were not the robbers who robbed them, then there were always some post boys that stole letters themselves. They were poorly paid, and had a bad reputation for being drunk and talented at loosing letters. Therefore many people did only pay for their services upon receival of the letter. All in all, this made

[172]The painting is in private collection. About the depiction of the girl and the man: Conway, *Private*, p. 45.

[173]Franz Xaver Swediaur to Withering, date unknown (between 1788 and 1797), as cited in Hale-White, 'Withering', p. 1090.

[174]Letter of Withering, recipient unknown, 20 October, 1792, as cited in Hale-White, 'Withering', p. 1088.

the letters travel quite slow: a post boy moved just 3 miles per hour, an express delivery 4 miles per hour.[175] Some correspondents tried to respond to the problem by packaging their letters in parcel so that they could be sent along other packages that traveled by coach. In 1784, John Palmer rolled out a plan for coach-based post delivery on a large scale. By moving mail around the country by coach, the postal system would be more reliable, since the coaches would be guarded by armed men, and it would be faster, since the coaches could reach 8 miles per hour. Unfortunately for the contemporaries, it also made the postal service more expensive: from one penny for a one-post distance to two pennies for the same distance.[176]

The Lunar men made good use of the postal system. They wrote many letters to each other, but their network extended beyond the small group and they had contacts and friends across the world. These people came from all different backgrounds and included a considerable share of savants, fabricants and savant-fabricants. As a group of savant-fabricants, the Lunar Society is an interesting node in this larger network and could offer a vantage point to study via DHSNA the eighteenth-century interface between 'pure' and 'applied science'; between the learned men and the craftsmen. Especially Boulton had a huge social network, and since many of his letters have been preserved,[177] his network could provide a useful starting point. The interface is not yet well-understood and an initial goal of my project was to study it by analyzing the complete correspondence of all Lunar members, complemented with the correspondence of people that turned out to be interesting in the first network visualizations of the meta-data (to add edges between non-Lunar nodes as well). This proved to be too ambitious for a Master's thesis, because collecting all these data would be too time-consuming. It could however be an interesting angle for further research. This does, however, not mean that there is with this project nothing to learn about the interface. Although the members of the Lunar Society were known for being savant *and* fabricant, some of the men were of course still more theoretically-inclined, while others were more technically-inclined. This makes the Society on itself an example of a fruitful cooperation between 'pure' and 'applied' scientists, so all we learn about it, teaches us something about the interface as well. Furthermore, in Chapter 5 an analysis of the Lunar network will be made to study the interface within the Lunar Society in further detail.

In the letters that the Lunarians wrote to each other, we observe that letter-writing conventions were a bit more relaxed, as was usually the case in closer friendly relationships. As I will come back to in Chapter 4: the lay-out of the letters gives us a strong hint that we are dealing with a tight network with well-established relationships. Presumably after some first more formal introductions, the Lunar men felt free to use different sizes of paper, to make full use of the paper (not leaving any space for scribbles in the margin by the recipient), to refer to their mutual friends in postscripts ('Pray when and where does Mr Keir intend in your horizon?'),[178] to waive salutations in greeting or subscript, to leave corrections and scrawls in the letter (Figure 2.8), and to include little sketches for clarity. All these actions would be

[175]Such an express delivery was for instance alluded to by Darwin as option to save Boulton an unnecessary trip in case he would be absent: ''[...] I will send an Express to prevent you if I am absent.' (Darwin to Boulton, 29 July, 1767, as cited in Schofield, *Lunar Society*, p. 101.)

[176]This introduction to the eighteenth-century postal system was based on two blog posts: Starmans, 'Royal Mail History' and Vic, 'The Postal Service'. For a comparable — but more academic — introduction, see for instance: Whyman, *Pen*, pp. 46–71.

[177]Matthew Boulton and Family Papers, Library of Birmingham, MS 3782.

[178]Darwin to Boulton, 21 April, 1778, as printed in King-Hele, *Letters*, pp. 85 and 86.

considered impolite according to letter writing manuals if the correspondents would not have been on friendly terms.[179]

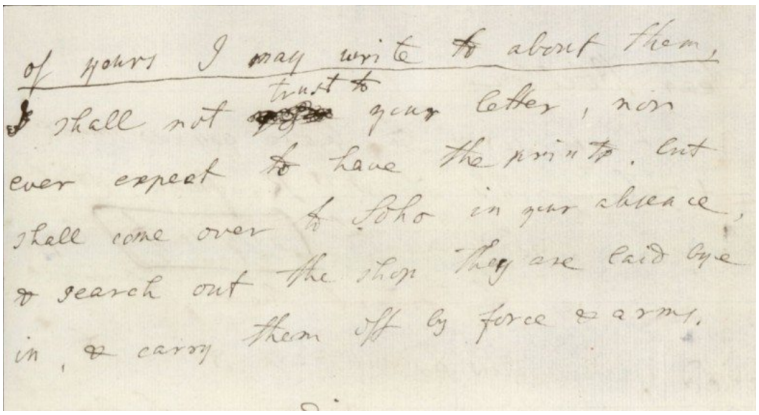


FIGURE 2.8: *A letter with a scrawl*: Darwin made a correction in his letter to Boulton, but since they were on friendly terms, this was not considered impolite.[180]

In the contents of Lunar letters we find a mixture of personal affairs (especially family matters), elaborations of ideas (sometimes including quite detailed drawings, see Figure 2.9), practical messages about visits or business, social greetings and recommendations, and many requests. These requests were for instance for information, to pass something through, for a business order, or just for 'a Chest of white Florence Wine, if He [Mr. Baumgartner] imports any this Year'.[181] It is interesting how closely personal and business affairs were intertwined, making it often impossible to distinguish clearly a business letter from a personal one. Sometimes, Lunar members found it themselves difficult as well to untangle their business and their personal affairs. Edgeworth wrote for instance to Boulton: 'One circumstance, & only one in our connection is disagreeable to me: I am restrained from having things of Etrurian manufacture because I am not treated in two different capacities, as a stranger & a friend. Let me address this letter to the firm W[att] & B[oulton] to ask whether I can [...]'[182] Here we see an example of intermingled relations both in Edgeworth's complaint (the way he was treated at Wedgwood's Etruria manufactory) and in the message of the letter (Edgeworth writes to Boulton 'personally' that he 'businessly' addresses the firm Watt & Boulton).

For the letters, the eighteenth-century writer, so presumably the Lunars as well, used paper made of cellulose fibers (from disintegrated rags mixed with warm water) and ink made by darkening linseed oil with vegetable dyes and pigments, or —- in the latter years of the eighteenth century — by extracting it from the ink sacs of cuttlefish.[184] They wrote with a quill, the common writing tool before the introduction of the steel pen. Funnily, this pen was fashioned for the first time in 1780

[179]Sairio, 'Social dimensions'. It would be interesting to investigate the lay-out of letters digitally and let a tool recognize certain visual aspects (margin size, neatness, etcetera) in order to make predictions about which type of social relationship extisted between sender and recipient.

[180]Darwin to Boulton, 9 June, 1769, as printed in King-Hele, *Letters*, pp. 57–59.

[181]Ibidem.

[182] Edgeworth to Boulton, 10 May, 1780, as printed in Farrer, *Correspondence*, volume 2, pp. 459 and 460.

[183]Darwin to Boulton, 1764(?), as published at History West Midlands, *Revolutionary Players*.

[184]Paper: Blake, 'Learning'. Ink: Rendell, 'Inkling'.

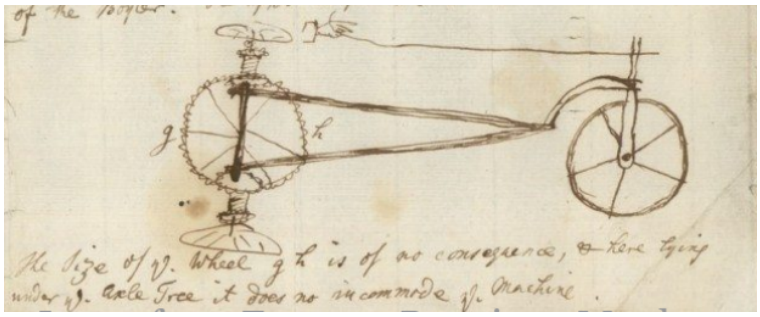


FIGURE 2.9: *Sketch for a mechanically-propelled car*: In a letter, Darwin explains his idea for a mechanically-propelled car to Boulton.[183]

by Birmingham manufacturer Samuel Harrison for Joseph Priestley, one of our Lunaticks.[185] This was not the only time that the Lunar Society members were close to the hotbed of letter-writing innovations. In 1780 — a fruitful year for letter-writing, apparently — Watt patented a reliable means of copying letters after a period of much experimentation in which Keir was involved as well.[186]

2.4 Surviving sources and the historians

Surviving sources

Some of the Lunar correspondence has been preserved,[187] and it has eventually been mainly this collection of letters on which the many historical narratives have been based. The letters are namely almost the only source material available to study the Lunar Society. The group had no membership lists, formal records, minutes, journals, constitutions or set of rules,[188] or at least: they, or references to them, have not been discovered. Furthermore, there were — quite surprisingly considering the current amount of historical attention — very few public references to the Society. The members did for instance not mention the Lunar Society in the biographical sketches they wrote about their Lunar friends, neither was the Society given any specific notice by a newspaper like the *Birmingham Gazette*, although it did publish regularly about club meetings.[189]

Still, some material to complement the correspondence is available. What has been discovered, besides the letters, were some witness accounts of (foreign) visitors,[190] a couple of minor comments in members' biographies written by their children,[191] the more extensive eye witness reports by Mary Anne Schimmelpennick,[192]

[185]Daniels, 'Ingenious pen', p. 313.

[186]Schofield, 'Bicentenary', p. 151. In 1778 Watt already writes about this method to Joseph Black. (Watt to Joseph Black, 24 July, 1778, as printed in Muirhead, *Origins*, p. 109.)

[187]Schofield claims that the Lunars letters have been preserved in 'scattered profusion', but let us withhold this conclusion until we have taken a closer look into the corpus of preserved letters in Chapter 3. (Schofield, 'Bicentenary', p. 146.)

[188]Jones, *Industrial*, p. 85. Schofield, 'Bicentenary', p. 145.

[189]Schofield, 'Bicentenary', p. 145.

[190]Jones, *Industrial*, p. 85. A benefit of mapping the complete social network of the Lunar Society, as described in the previous section, would be to locate these (foreign) visitors more easily. In this way we could perform a targeted search for references to the Lunar Society in their letters, diaries and common place books, instead of waiting for some accidental findings.

[191]Jones, *Industrial*, p. 85. Schofield, 'Bicentenary', p. 146.

[192]We encountered one of her reports in Section 2.2. Some historians question the reliability of her accounts. In 1888, Bolton makes good use of Schimmel Penninck's descriptions of the members and their meetings, but Schofield calls her stories in 1966 the products of 'the faulty memory of an aged lady'

some notations in Lunar members' diaries,[193] and a few references in published work of the Lunar men. These last references are found in Edgeworth's autobiography *Memoirs*,[194] published posthumously in 1820, and in Priestley's work.[195] Priestley mentions the Lunar Society in the dedication of his 1793 essay 'Experiments on the Generation of Air from Water',[196] in a comment in his 1803 essay 'The Doctrine of Phlogiston Established and that of the Composition of Water Refuted'[197] and most elaborately in his posthumously published autobiography of 1806.[198] Other Lunarians do refer to their fellow members or their achievements in published works, but do not mention the Society explicitly.[199]

We have to keep in mind that there must have existed much more material than is currently available, including correspondence. Most of Keir's papers have for instance been destroyed in a fire in 1845,[200] and rioters clearly did not think of future historians when they invaded Priestley's house where 'his philosophical apparatus was ruthlessly destroyed, and his library and manuscripts scattered to the winds'[201] (Figure 2.10). On top of that, specific hints about the way in which material traveled from the eighteenth century until today are not at all a cause for optimism about collections' completeness:

> 'Did you know that I made a great haul of Withering's letters, etc. A man came in one day with a bag and said 'Are you interested in W.?' I said 'rather,' and he pulled out a big bundle of letters and papers and his Edinburgh diploma. I offered him £20, at which he nearly expired, as he had hoped for not more than £5.'[202]

Furthermore, of some Lunar material we know it went missing, although the reason why might have gone lost as well. It is for instance known that Galton's many-volumed commonplace book of scientific observations and experiments, his 'Book of Knowledge', is no longer among us,[203] and for some correspondence collections it

and Robinson does not trust her reports that much either (Bolton, *Scientific*, pp. 203–205. Robinson, 'Membership', 161. Schofield, 'Bicentenary', p. 146.)

[193] Jones, *Industrial*, p. 91.

[194] Bolton, *Scientific*, p. 216.

[195] Schofield, 'Orientation', p. 409.

[196] Ibidem.

[197] Bolton, *Scientific*, p. 216. Burns neglects these comments (and of course the correspondence) when he claims that the Lunar Society was 'only referred to once during the period of the society's existence'. (Burns, 'Midlands', p. 402.)

[198] 'I consider my settlement at Birmingham as the happiest event in my life, being highly favorable to every object I had in view, philosophical or theological'. (Priestley, *Memoirs of Dr. Joseph Priestley*, as cited in Bolton, *Scientific*, p. 201.)

[199] Nice examples of these type of references can be found in Darwin's famous book *The Botanic Garden* (1791). In rhyme and in explanation he lauds his fellow members and their accomplishments. 'If a civic crown was given in Rome for preserving the life of one citizen, Mr. Boulton should be covered with garlands of oak! By this machinery [for coinage] four boys, of ten or twelve years old, are capable of striking thirty thousand guineas in an hour, and the machine itself keeps an unerring account of the pieces struck.' (Darwin, *Botanic*, p. 22.)

[200] Moilliet and Smith, 'Keir', p. 146

[201] Bolton, *Scientific*, p. 211.

[202] William Osler to Dr. Pratt, date unknown, as cited in Hale-White, 'Withering', p. 1087. However, the story was not finished, Hale-White writes that someone wrote him that Osler's memory was at fault: 'he bought this collection of Withering's letters for £20 by correspondence from a well-known antiquarian bookseller [...]' (Hale-White, 'Withering', p. 1087.) Still, both events give us an impression of the way in which people have traded, dragged and treated letters.

[203] Schofield, 'Bicentenary', p. 154. One of the reason we know not that much about Galton and his work: 'preserve or parish.'

is quite easy to notice that periods are missing.[204] Also, we should take seriously the option that some material is still in existence, but just 'lost in the historical system.' Documents get scattered, some end up in a museum behind glass, some in a box on a shelf, some in a bag on an attic. And even if they are behind glass or safely put away in an archive, they could still be considered lost as long as they could not easily be located and accessed by all historians.[205]

All in all we are left with an incomplete set of letters and a handful of references in other types of material. References that furthermore rarely provide much specific information about the working the of the Society.[206] Still, these sources proved to be sufficient to spark the historical imagination and to found — in intriguing contrast to the amount of (written) attention apparently given to the society by contemporaries — a rich historical tradition of investigating and describing the Lunar Society.

FIGURE 2.10: *Rioters Burning Dr. Priestley's House at Birmingham, 14 July 1791*: a painting by Johann Eckstein, 1791. Correspondence must have gone missing.

The historians

Biographies and memorials of Lunar men by family members and associates, published some time after 1840, preluded the upcoming period of historical interest for the Lunar Society.[207] Especially the mentioned eye witness accounts of the Lunar members and their meetings by Mary Anne Schimmel Penninck in the 1858 book

[204] One might encounter a sudden a gap of a couple of years while searching through archival material, or read about a gap in the archive's documentation. For the Library of Birmingham's MS 3147 collection containing papers of the Boulton & Watt manufactory, the archive listed for instance some years for which no materials have been found.

[205] A more detailed reflection on the current 'historical infrastructure' and the ease of collecting materials will be given in Chapter 3.

[206] Schofield, 'Bicentenary', p. 153.

[207] Ibidem, p. 145.

Life of Mary Anne Schimmel Penninck, had a lasting influence on the Lunar Society historical tradition. Although, as already indicated above, their reliability has been questioned and historians accused them of containing errors. With the publication of Samuel Smiles' *Lives of Boulton and Watt* in 1865, we should consider the period of historical scrutiny and Lunar enthusiasm as officially opened.[208] Based on the papers of Boulton and Watt, Smiles rediscovered the Lunar Society and painted a picture of the group that, directly or indirectly, influenced all subsequent accounts of the Society.[209] The picture has been fiercely criticized by Schofield, who calls it 'the beginnings of what has developed into a Lunar Society legend of extraordinary proportions'[210] which contains 'too many pure speculations for comfort.'[211] During the remainder of the nineteenth century and the first half of the twentieth century, the main place to encounter accounts of the Lunar Society were works about individual Lunar figures, on which, according to historian Robinson, 'a mass of material'[212] came into existence. A notable exception in this scheme is Cabrington Bolton's reading at the founding of 'The Lunar Society of New York' in 1888, a society modeled after the example of the Lunar Society of Birmingham. In the speech, which was afterwards printed in Schofield's *A Scientific Autobiography of Joseph Priestley (1733-1804)* (1966), he describes the Lunarians and their activities, and lists all the benefits the informal character of an organization might bring.[213] The account he gives of the Lunar Society does not seem to have taken any 'legendary proportions'. Since the work was published before the influential account of Schofield (mentioned below), it is an interesting alternative, complementary secondary source for studying the Lunar Society nowadays.

In the late 50s and the 60s of the twentieth-century, historical interest for the Lunar Society enjoyed a revival, mainly embodied in the work of historians Robinson and Schofield. Both historians stressed that they turned back to the original sources to halt the perpetuating Lunar legend initiated by Smiles, and to construct a corrective alternative to the stream of references that 'as they have increased in number they have decreased in reliability',[214] since errors grew with every republication.[215] Schofield provides a 'technological interpretation' of the Lunar Society, in which he presents the Society as being tightly interwoven with the Industrial Revolution. He understands it as a research programme, or at least, a 'pilot project'[216] for industrial development and applied science. He sees them as 'harbingers'[217] of a new society.[218] This view 'hardened into an orthodoxy'[219] and it turns for instance up in the 1964 work *The Victoria History of the Counties of England*, in the book *Art and the Industrial Revolution* published in 1968 and in a Maria Edgeworth (daughter of Richard Lovell Edgeworth) biography of 1972, where author Marilyn Butler even goes as far as calling it 'a pioneer industrial research establishment'.[220] Robinson's

[208] Schofield, 'Bicentenary', pp. 145 and 146.
[209] Schofield, 'Orientation', p. 409.
[210] Ibidem.
[211] Ibidem, p. 409.
[212] Robinson, 'Membership', p. 153.
[213] He especially underscores the 'freest interchange of opinions and the formation of those personal friendships which a social organization like the Lunar Society' could bring, if unhampered by parliamentary forms and obligations. (Bolton, *Scientific*, p. 218.)
[214] Robinson, 'Membership', p. 153.
[215] Robinson, 'Membership', p. 153. Schofield, 'Orientation', pp. 409 and 410.
[216] Schofield, *Lunar Society*, p. 439.
[217] Ibidem, p. 3.
[218] Jones, *Industrial*, p. 83.
[219] Ibidem.
[220] Ibidem

account is somewhat similar to the one of Schofield, although more inclusive and more flexible. For instance by attenuating its programmatic industrial outlook and by being — especially because of the Society's informal character — less dogmatic about aspects like membership lists and specific meeting places.[221] Robinson points out that Schofield agrees with some of Robinson's observations about the original sources, but that the differences of opinion between the two still remain extensive.[222] Whereas Smiles needed a legend in times when intellectual activity got organized, and whereas Bolton needed an example in times that asked for informality to contrast professionalization, we notice that Schofield and Robinson as well act according to the mantra that historical accounts teach us just as much about the past as about the needs and interests of the time in which they were created. Living in the twentieth-century rise of Big Science and technological research institutions, in one's quest to trace back the origins of this applied science, the Lunar Society proved to be an excellent opportunity to see the present reflected in the past. Both further increasing the historical enthusiasm and being initiated by the increased interest in the first place, was the extensive celebration of the Lunar Society's 'Bicentenary', culminating in the Bicentenary Exhibition in Birmingham in October and November 1966, attracting some 90,000 visitors.[223]

The interpretation of the Lunar Society as an industrial enterprise foreshadowing later developments continues until today.[224] However, since the 1980s alternative interpretations came into being as well. As part of the re-evaluation of the history of science in more cultural and social terms, historians started to interpret the Lunar Society in the Enlightenment tradition (as opposed to an Industrial Revolution context).[225] Historian Porter for instance loosened the Lunar interpretation from industrial settings, and linked it instead with the general rise of provincial culture and with the wish of provincials to bring Enlightenment politeness to their own environments: he depicted it much more like a civil 'conversation group' than a goal-oriented industrial project.[226] Another way in which the Lunar Society appeared in the historiography of the 80s was as an example of the phase of 'predisciplinarity' in science:[227] whereas the society had earlier served as an example of (informal) organization of intellectual efforts, now it was, contrarily, presented as a group that lacked (formal) organization — as phenomenon of the world of enthusiastic amateurs prior to disciplinary boundaries and organization. The group, as historian Langford wrote in 1989, 'had no sense of the need to establish the rigid lines of demarcation which were later to characterize the development of science as an academic discipline'[228] In this way it served as a contrasting picture in such historical accounts that set out to describe the institutionalization of science in the nineteenth century.

Nowadays, the tension between the mid-century industrial interpretations and the Enlightenment interpretations of the 80s is partly, but not completely, resolved

[221] Jones, *Industrial*, p. 84. Robinson, 'Membership', p. 155.

[222] Robinson, 'Membership', p. 153. See also Chapter 5.

[223] Moilliet and Smith, 'Keir', p. 152.

[224] For instance in a 2005 volume by Desmond King-Hele, an expert on the life and works of Darwin (Jones, *Industrial*, p. 84), and, most notably, we find the image also to a certain extent reflected in Uglow's book about the Lunar Society, published in 2002.

[225] Jones, *Industrial*, p. 84.

[226] Schofield would have probably objected to this view by stating that we should not 'confuse it [the Lunar Society] and its efforts with the general growth of intellectual and economic activities in the provinces of eighteenth-century Britain' (Schofield, 'Bicentenary', p. 146.) For the description of Porter's account: Jones, *Industrial*, p. 84.

[227] Chandler, 'Edgeworth', p. 87. This way of 'using' the Society was not tied to the 80s, for Chandler presents it in this context as well in 2011.

[228] Langford, *A Polite and Commercial People*, p. 661 as cited in Chandler, 'Edgeworth', p. 90.

by attempts to understand the Lunar Society in the above described 'Industrial Enlightenment' context. This attempt is (implicitly) made by Jones in his book *Industrial Enlightenment* (2008), although he seems to lean more towards the Enlightenment interpretation and suggests that the Lunar Society might have been somewhat like a masonic fraternity,[229] and in Chapter 5 the attempt is made as well when a new interpretation of the Society is proposed. The most influential work about the Lunar Society of our current times is Uglow's popular work *The Lunar Men* (2002). Because of its popular nature it is not explicit about its interpretation of the Lunar Society and its historiographical position. However, as mentioned above, it seems to tend more towards the industrial 'forthbringers of the modern world' interpretative tradition, as is strikingly exemplified by the subtitle of the book: 'The friends who made the future'.[230] Of course, today's interpretative pictures are shaped by our own historiographical trends as well. Mokyr presented the Lunar group for instance as an early modern example of a knowledge economy, he described the Society as akin to a mart: 'a place where knowledge was exchanged, bought and sold in exchange for patronage. The buyers were industrialists such as Matthew Boulton and Josiah Wedgwood, the sellers natural philosophers such as Erasmus Darwin and Joseph Priestley.'[231] Furthermore, 'predisciplinarity' could also be presented as 'interdisciplinarity', and so current historians like to underline the adherence of the group to our current favorite buzz word. Uglow writes for instance in an encouraging manner that 'science and art were not separated; you could be an inventor and designer, an experimenter and a poet, a dreamer and an entrepreneur all at once without anyone raising an eyebrow',[232] and while introducing the Lunar Society I was eager to notice the group's wide variety and the different expertises they brought together. Another recent historiographical trend that we see reflected in the Lunar works of the twenty-first century, is attention for material contexts: from the description of the quality of roads to an extensive account of the technologies of pottery,[233] from attention for the lay-out of letters to a phrase that says that 'the book smells of sweat and chemicals and oil, and resounds to the thud of pistons, the tick of clocks, the clinking of cash, the blasts of furnaces and the wheeze and snort of engines [...].'[234] Lastly, there is the noteworthy development that the Lunar Society pops up as an example in current thought about the idea of an early modern knowledge society and its knowledge networks, and in thought about (social) networks in general. We encounter for instance all kind of network terms in Jones' *Industrial Enlightenment*,[235] and then there is of course also the example of this thesis.[236]

Given the fact that, as mentioned above, there was not that much attention for the Lunar Society by contemporaries, all this historical excitement seems a bit off. Even more so in the light of Schofield's observation that the Lunar Society was 'neither the first nor, in the long run, the most scientifically significant of the provincial

[229] Jones, *Industrial*, p. 94.

[230] Uglow, *Lunar Men*. Notice that Uglow presumably implied the word 'made' to be interpreted quite literally: 'The friends who *manufactured* the future', a reference to the industrial character of the group.

[231] Mokyr, *The Gifts*, p. 44 note 18, as cited in Jones, *Industrial*, p. 83.

[232] Uglow, *Lunar Men*, p. xviii.

[233] Ibidem, pp. 46–56.

[234] Ibidem, p. xix.

[235] For instance 'nodes' at page 27, 'node points' at page 88, and there are more examples.

[236] It would be interesting to investigate the rise of thinking in network terms about historical 'phenomena' and to look into the history of the concept of the 'network'. When did people start to use this term? What sparked its conceptualization? How do we make translations between the abstract network idea and its real-world manifestations? What does the current attention for networks tells us about our society?

societies to be organized in eighteenth-century Britain.'[237] So why are historians so obsessed about it? A couple of aspects could perhaps explain the fuss. First, the Society sparked interest because of the quality of its membership — the members were men of eminence that on themselves already attracted historical interest.[238] Furthermore, the Lunarians' mode of meeting (at a day closest to full moon) and the name of the Society, gave it a romantic and mysterious appeal.[239] As mentioned above, there were more 'lunar societies' in the eighteenth century, but there has just been one of them that became known as '*The* Lunar Society'. The fact that the men gave themselves a name on itself perhaps already helped in stirring historical notice, since it turned them into a concrete historical entity, as opposed to many (possibly similar) assemblages that did not have given themselves a name,[240] or that carried the generic 'literary and philosophical society'.[241] The mystery was further increased precisely because primary source material was not abundant and public references were missing - because how could that be the case for such an intriguing selection of well-known men?[242] Another reason is the one that we already implicitly encountered in the previous paragraphs of this section: apparently the Lunar Society is a group of people especially well-suited to accommodate all kinds of historiographical projections and historical illustrations. Lastly, there is a very pragmatic explanation of the historians' eager to study this eighteenth-century bunch of experimenters: historical attention spurs more historical attention. There would not have been that many alternative interpretations, fierce responses or incidental references if there would not have been any historical work to interact with.

Despite the historical interest, there is surprisingly little consensus about some very important aspects of the Lunar Society. This presents us with an opportunity to explore if DHSNA might be able to contribute to the existing historical literature. As we saw above, there is a wide range of interpretations of the Lunar Society: was it a technological and industrial research programme? Was it an Enlightenment-style conversation group? Was it a group of friends that shared a love for experiments and 'a little philosophical laughing'? Was it a cooperation of commercially-minded manufacturers that 'bought' knowledge from natural philosophers? The identity and characterization of the group are however not the only topics for debate. Historians also do not agree about when exactly it came into being and when it declined, they do not agree about who could be considered as having carried out certain social roles (like 'leader', 'binder', or 'visionary' for example), in fact, they do not even agree about who specifically could be regarded as Lunar member. Exactly for that reason, the precise development of the Lunar Society, its social and organizational structure, and its constitution, have up to this point been barely described. Much of the confusion arose because of the scarce number of references in publications, combined with the fact that the largest collection of source materials we have for the Lunar Society — the members' letters — are not (all) that easily accessible, and because close-reading them is a time-consuming task. Therefore, let us make most out of the source material available, and investigate the letters' meta-data and construct

[237] Schofield, 'Bicentenary', p. 144. Robinson does not agree and calls the society 'undoubtedly the greatest of the provincial philosophical societies in eighteenth-century England.' (Robinson, 'Membership', p. 153.) Since I do not find his arguments for this claim convincing, I prefer to stick with the caution and the more nuanced voice of Schofield in this case.

[238] Schofield, 'Bicentenary', p. 144.

[239] Ibidem, pp. 144 and 145.

[240] Bolton, *Scientific*, p. 199.

[241] Schofield, 'Bicentenary', p. 144.

[242] Ibidem, p. 145.

epistolary networks first, before returning to the story of the Lunar Society. Its development, and its social and organizational structure, will then be described with reference to analyses of these networks, both in consultation with and in comparison to existing historical works.

2.5 Membership and the members

Membership

On one of the issues mentioned in the previous paragraph, my analyses will not be able to shed light: the question of who could be considered as having been members of the Lunar Society. In theory, I suspect it should be possible to construct DHSNA methods that could provide useful contributions to this debate. Such a method would come down to identifying a Lunar Society cluster within a broader eighteenth-century epistolary network, and to a description of a way in which such a network could be constructed sensibly. One could for instance use a similar method as described above to create the broader network, turned into an iterative process: first one picks a group of people that has been identified as core members of the Society by most historians (think of it as the starting value for the iteration), then one constructs an epistolary network based on the complete correspondence of all these people, after that one identifies 'peripheral figures' around the Lunar cluster that emerges in the network (these 'peripheral figures' should be understood as people that have links with multiple core members, but that had not been initially labeled as core members themselves), for these figures one would collect the complete correspondence as well and add this correspondence to the visualizations. In this way, you might discover if there were more core members the peripheral figures had contact with, or that some known relations were in fact stronger (at least in terms of the number of letters they exchanged) than you initially knew: in other words, you might discover that the figures become more closely connected to the Lunar cluster. By repeating this process a certain number of times, you get a view on the direct surroundings of a Lunar cluster within the broader eighteenth-century epistolary network. The last step is to analyze the network you constructed and identify the boundary of the Lunar cluster (perhaps using some measures and choices for cut-offs if the cluster is not clearly pointed out qualitatively). The nodes in this cluster could then be identified as possible members of the Lunar Society (with the possibility that perhaps one of the core members you started out with, is no longer around in your final selection). Of course it would be a good idea to compare this prediction with the contents of primary sources and historical literature to investigate if it makes sense. Ideally, during the execution of the algorithm one makes some smart corrections if the differences in how much of people's correspondence has been preserved are large. Furthermore, notice that this method could yield a network with multiple clusters, including clusters that might overlap with the Lunar cluster. Which would for instance be the case if a large share of Lunar men is together also associated with another social group (for example a group centering around the Boulton & Watt manufactury, or inhabitants of Birmingham) — which is not unlikely. In this case, it might prove to be helpful to use the group of people initially identified as core members as marker for the Lunar cluster.[243]

[243] A last point of attention is that one should take into account the dynamical nature of the epistolary network: a method such as this one could only be meaningfully applied as long as we construct separate networks for different time periods. This will be explained in Chapter 4.

In practice, it turned out that a method like this would not be feasible within the scope of the current project, since collecting all the required data would take up way too much time. Therefore, instead of *deriving* a possible membership list from network analyses as a research result, I *defined* it, as a research axiom, opening the path to investigate other Lunar issues. By taking the members as a given, the only correspondence to collect now was the one between priorly-defined Lunar members.

But which members should be taken as a given? As we know, the existing literature is inconclusive about the constitution of the Lunar group, so it is not given. The reason why it is so hard to determine who were members has to do with the Society's informality. In the first place because it would have made matters much more easy if the men would have kept official membership lists of course. But secondly, now that we have to — in the absence of such lists — reconstruct the constitution ourselves, it does not help that the Lunar meetings were frequently visited by guests,[244] and that there were many figures circling the Society that are not always that easily distinguished from 'real' members. Especially not since not all Lunar men attended the meetings regularly and stayed instead mainly in contact via letters.[245] On top of that, not all the scientific correspondence of members was with fellow-Lunarians, and according to Robinson there was a wide variety of people that claimed to be members.[246] Because it is hard to determine the transition from an occasional visitor to a member accurately, Robinson states that it is better not to dogmatise about it.[247] However, according to Uglow, the Lunar Society was 'rather a tight, exclusive circle'.[248] Considering some hints from primary sources, I think we have to conclude that she is right and that a case could be made for a well-defined membership of the Society. Boulton, a core figure according to all historians, used for instance the term 'Members' in this lone attempt to put the Society on a firmer footing: 'I then propose to make many Motions to the *Members* respecting new Laws [...],'[249] and we find more contemporaries using this reference. Furthermore, there is the clear example of the occasion that Watt prevented a high-positioned employee of the Boulton & Watt factory, Logan Henderson, of becoming a member: 'I send inclosed a caution to Dr. Withering what he communicates to our friend H. [Henderson] as I find the latter is worming himself into his favour and I think you should confirm what I say and prevent his becoming in any shape a member of the philosophical society [...]'[250] Lastly, the Society knew a period in which there has apparently been a membership policy, meaning that they sought actively for replacements for absenting members.[251]

Assuming that there is indeed such a thing as genuine Lunar membership, let us turn to the historians' takes on the constitution of the Lunar group. As said, they come up with quite different lists. Jones thinks ten to twelve people formed the core group of the society,[252] Schofield's estimate says fourteen people,[253] Uglow gives a list of twelve principal members in her book and states at another place that the society at least never numbered more than fourteen,[254] but then there is Bolton that names fifteen members in total, although not more than eight or ten

[244] Bolton, *Scientific*, p. 195.
[245] Jones, *Industrial*, p. 87.
[246] Robinson, 'Membership', p. 157.
[247] Ibidem.
[248] Uglow, *Lunar Men*, p. 353.
[249] Boulton to Watt, 24 February, 1776, as cited in Robinson, 'Membership', p. 164. My emphasis.
[250] Watt to Boulton, 19 January, 1782, as cited in Robinson, 'Membership', p. 166.
[251] Schofield, 'Bicentenary', p. 154.
[252] Jones, *Industrial*, p. 82.
[253] Schofield, 'Bicentenary', p. 144. Schofield, 'Orientation', p. 410.
[254] Uglow, *Lunar Men*, p. ix. Uglow, 'Birmingham'.

at any one time.[255] In historical works with the Lunar Society as primary topic, the authors seem to agree on the membership of the following gentlemen: John Whitehurst, Matthew Boulton, Erasmus Darwin, Joseph Priestley, William Small, James Keir, James Watt, William Withering, Richard Lovell Edgeworth, Thomas Day and Samuel Galton.[256] Sometimes these designations are questioned in other works, Jones doubts for instance the membership of Whitehurst (because he left the Midlands for London in 1775) and Chandler does not name Small as a member, while he is often described as one of the most important Lunaticks (in absence of a specific reason I think we should suspect this to be an involuntary omission).[257] However, in general these figures are included. More doubt exists about the possible membership of William Wedgwood, Jonathan Stokes, Augustus Johnson and some Lunar sons.[258] Uglow lists Wedgwood as one of the five principal members,[259] but Jones sees him for instance as no more than a 'distant affiliate', primarily because there is according to him no sign of Wedgwood's presence in our modest record of actual meetings.[260] Robinson takes a more moderate position: he presents Wedgwood as an example of someone in the penumbra of the society,[261] something that source material seems to back up, since we find in a letter from Watt to Wedgwood the following invitation that by the way the text was formulated suggests that Wedgwood was not seen as a full member, but not as a distant affiliate either: 'On Monday next we have a philosophical meeting at Doctor Witherings where all our society will be very happy to see you [...].'[262] Then on the other hand we have Lunar expert Schofield that lists Wedgwood without doubt among the Lunarians.[263] Similar debates center around the question whether or not to include some Lunar sons, Stokes and Johnson. Eventually, these debates mostly come down to differences in the specific criteria for membership the historians implicitly or explicitly apply. Should these criteria for instance include the presence at meetings? Residence in close proximity to Birmingham?[264] Continuous correspondence with other members? Or substantial impact on the Society's activities?[265]

The answer to the question what my own criteria for membership of the Lunar Society would be after researching the association, I postpone till Chapter 5, since my membership criteria are related to my general interpretation of the Society, and Chapter 5 is were I will discuss this interpretation. At the start of my research, in the absence of all background knowledge and (of course) research results, I decided that I would trust the membership list given by the most recent historical work primarily concerned with the Lunar Society. By picking the most recent one, I tried to take into account the option that new primary source material had come to light in the last

[255] Bolton, *Scientific*, pp. 195–197.

[256] This list is based on the works of Schofield, Uglow and Bolton. Due to Robinson's stance that we should not be dogmatic about membership, his account is more contemplative and less judgmental about who should be labeled as a member.

[257] Jones, *Industrial*, p. 87. And Chandler, 'Edgeworth', p. 89.

[258] These sons are Matthew Robinson Boulton, Gregory Watt, James Watt Jr. and perhaps Samuel Tertius Galton. (Schofield, 'Bicentenary', p. 158.)

[259] Uglow, *Lunar Men*, p. xiv.

[260] Jones, *Industrial*, p. 87.

[261] Robinson, 'Membership', p. 157

[262] Watt to Wedgwood, 23 July, 1785, as cited in Robinson, 'Membership', p. 169.

[263] Schofield, 'Bicentenary', p. 144 and Schofield, 'Orientation', p. 410.

[264] Schofield for instance applies the criterion that 'no person whose major interests lay outside the Midlands or who had never lived within easy reach of Birmingham can be accepted as a member without serious question.' (Schofield, 'Membership of the Lunar Society', as cited in Robinson, 'Membership', p. 156.)

[265] I will say more about this in Chapter 5.

years. The most recent work turned out to be Uglow's, which despite its popular nature should be taken seriously as a scholarly work, since it is well supported with evidence and the immense amount of detail testifies of Uglow's deep study. As mentioned above, this meant that in my research I took the following people to be the members of the Lunar Society: Whitehurst, Boulton, Wedgwood, Darwin, Priestley, Small, Keir, Watt, Withering, Edgeworth, Day and Galton.[266] This means that they are the people for which I collected the meta-data of their correspondence and that they were included in my network analyses.

Reflecting on this list with the knowledge and insights I have now, after the research, I am happy to have included Wedgwood. I think he has made invaluable contributions to all kinds of Lunar cooperations. Furthermore, in my opinion it was just to exclude Jonathan Stokes, for he had only be associated with the Lunar circle for a maximum of four years,[267] which is shorter than the length of the five-year steps I used to track the development of the Society, as I will explain later. Moreover, from primary sources one gets the impression that he was not seen as a *full* member by others and neither by himself. He wrote for instance in a 1783 letter that he was 'within an hour and $\frac{1}{2}$'s ride of the philosophical circle consist^{g} of D.^{rs} Priestley and Withering and Mess.^{rs} Boulton, Watt, Keir and Galton who meet once a month to converse on philosophical subjects. They have for title the lunar society and I have been regularly invited to their meetings.'[268] and in the notes of his book *Botanical Commentaries* (1830) he wrote in a distanced manner about the 'members dining in rotation at each others houses'[269] and does not mention himself as having been a member as well.[270] Keeping out the Lunar sons seems to have been a sensible decision too. By the time the sons entered the Lunar stage (around 1795),[271] the character of the original society had changed to such an extent that I wonder if this Lunar Society of the sons' generation could still be regarded as the same organization once nursing the curiousity of their fathers — and this is the society I set out to track the development for. Johnson, in hindsight, I would have liked to include him in the research. Although he was recruited quite late — in 1787, still before the addition of the sons and just some years later than Galton's accession — and is according to Jones unlikely to have attended many meetings,[272] the fact that Johnson regards himself as member when he writes that 'Our Lunar meetings I am sorry to say are not held so regularly as they used to be. Our reduced numbers make the absence of one member material and therefore we can only meet when its suits the convenience of all...'[273] and especially the fact that Priestley explicitly names Johnson as a member in his *Memoirs of Dr. Joseph Priestley*, convinces me that we should see him as such as well.[274] However, besides the addition of conclusions about Johnson's own position and relations of course, I do not expect that including Johnson would have changed the current research results significantly, because Schofield states that

[266] This is Uglow's list of *principal* members. Only later in her work does it become clear (implicitly) that she thinks there have been some non-principal members as well. How we should interpret their position and role does not become clear, since Uglow does not write much about her non-principal members, which apparently include Johnson and Stokes as well. (Uglow, *Lunar Men*, p. 353.)

[267] Jones, *Industrial*, p. 87. Uglow, *Lunar Men*, pp. 382 and 383.

[268] Stokes to Carl Linneus, June, 1783 as cited in Robinson, 'Membership', p. 168.

[269] Stokes, *Botanical*, p. cxxvi.

[270] Ibidem, pp. cxxv–cxxvi.

[271] Schofield, 'Bicentenary', p. 158.

[272] Jones, *Industrial*, p. 87.

[273] Johnson to Withering, 23 March, 1793, as cited in Robinson, 'Membership', p. 174.

[274] Priestley, *Memoirs of Dr. Joseph Priestley*, as cited in Bolton, *Scientific*, p. 201.

Johnson has not made a substantial impact on the Society's activities,[275] but it would be an interesting opportunity for further research.

The members

Before we turn to collecting meta-data and constructing networks, let me first introduce our protagonists in a bit more detail, since it is good to have an impression of who we are dealing with and because I think we should take personalities into account when interpreting the networks.[276]

John Whitehurst was a Derby clock- and instrument-maker,[277] known for his patience and discriminating judgment, and very much interested in geology.[278] He was tall and thin, kind and with a sense of humor, unpretentious in appearance.[279]

Manufacturer and inventor Matthew Boulton was an influential figure in Birmingham culture and characteristic for the upcoming class of industrialists, therefore he will be described in a bit more detail compared to the other members. Boulton is a prime example of a savant-fabricant: he had a quick mind and a philosophical spirit, but was especially well-skilled in elaborating other people's ideas and translating them to practical use.[280] He was an impulsive promoter, improver and expander of projects, and was held in high regard throughout the country.[281] 'Everything that Mr Boulton did', stated Keir, 'was done on a large scale.'[282] He took pleasure in gathering around him people with kindred interests and tastes, and was known for his warm, flamboyant character.[283] Schimmel Penninck describes Boulton as 'the Father of Birmingham', who

> 'was tall and of a noble appearance; his temperament was sanguine, with that slight mixture of phlegmatic which gives calmness and dignity; his manners were eminently open and cordial: he took the lead in conversations, and with a social heart had a *grandiose* manner like that arising from position, wealth, and habitual command. He went among his people like a monarch bestowing largess. His forehead was magnificent: the organs of comparison, constructiveness, and individuality were immense'[284]

We should however remember that the jubilant descriptions of Boulton above are largely based on accounts by friends or fellow (semi-)elitists. Different groups and classes of people would have perceived Boulton, powerful employer with commercial interests, differently. What is perceived by some as the generosity of a 'monarch', is in the eyes of others 'careless intolerance of a proud merchant prince.'[285] This

[275] Schofield, 'Bicentenary', p. 155.

[276] More about this in Chapter 4 and 5.

[277] Schofield, *Lunar Society*, p. 21. Uglow, *Lunar*, p. xiv.

[278] He 'works with minutes but dreams of millennia.' (Uglow, *Lunar*, p. xiv.)

[279] Schofield, *Lunar Society*, p. 22.

[280] Jones, *Industrial*, p. 19. Schofield, *Lunar Society*, p. 18. Uglow, *Lunar Men*, pp. 15, 24, 57, and 58.

[281] A contemporary asked for instance for his endorsement when aspiring to become the secretary of the Society of Arts. (Jones, *Industrial*, p. 18.)

[282] Keir memorandum, as cited in Uglow, 'Birmingham'.

[283] Bolton, *Scientific*, p. 198. Uglow, *Lunar Men*, p. xiv.

[284] Schimmel Penninck in Hankin, *Life* as cited in Bolton, *Scientific*, p. 203. In the terms 'sanguine' (warm, open, extroverted) and 'phlegmatic' (calm, caring, easy-going) we recognize a classic way to describe personalities. Well-developed 'organs of comparison, constructiveness, and individuality' were valued Enlightenment traits (see for instance the the story of the personal growth of an enlightened hero in Maria Edgeworth's *The Absentee* (1812) as described by Chandler, 'Edgeworth', p. 102.

[285] Uglow, *Lunar Men*, p.66.

attitude was for instance expressed when he wrote the following response to the accusation that he had robbed the poor of their rights by claiming common land:

> 'I speak form experience; for I founded my manufactory upon one of the most barren commons in England, where there existed but a few miserable huts filled with idle beggarly people, who by the help of the common land and a little thieving made shift to live without working. The scene is now entirely changed. I have employed a thousand of men, women and children, in my aforesaid manufactory, for nearly thirty years past.[286]

Which historical crumbs describing Boulton would these 'idle beggarly people' have left behind, had they been able to? Similar reasonings hold for the descriptions of the characters of the other Lunar men.

Another good example of a savant-fabricant was Josiah Wedgwood, [287] who was a business man, artist, inventor, experimenter and above all a potter.[288] The Wedgwoods had been potters since the early seventeenth century and when Josiah's newly invented types of ware called after the family came in high demand, the family name became internationally well-known.[289]

Then we have Erasmus Darwin. This doctor was a skilled inventor and a poet, moreover, he was a pioneer of evolution, half a century before his grandson Charles.[290] According to Schofield he had a talent to catch intellectual movements when they arose,[291] and if there were no movements to catch he would initiate them himself. Besides enormously gifted, he was also enormously overweight (a semi-circle had to be cut in his dining table to fit his stomach).[292] His appearance was unkempt and he stammered, which contrasted with the wit and entertaining anecdotes that he apparently seasoned conversations with.[293] However, for the young Mary Anne it had been above all the dismay caused by his appearance that made a lasting impression: 'What , then, was my astonishment at beholding him, as he slowly got out of the carriage! His figure was vast and massive; his head was almost buried on his shoulders, and he wore a scratch-wig, as it is called, tied up in a little bobtail behind.'[294]

The next one is preacher, chemist, theologian, polemicist and philosopher Joseph Priestley. He was one of the most talented members of the Lunar Society, but also one of the most complex ones. People who knew him thought of him as open-minded and free from personal bias, as charming and sincere, and as dedicated to the truth. Some of the people that did not know him thought of him as a great scientist and a persistent polemicist, but others pictured him as a bigot, as violent, and as a revolution-bent atheist.[295]

As opposed to some other members, William Small did not carry any heavy philosophical baggage, had no commercial ambitions and preferred to stay anonymous — declining fellowships of societies and not producing any publications.[296]

[286] Boulton to Lord Hawkesbury, 17 April, 1790, as cited in Uglow, *Lunar Men*, p. 66.
[287] Jones, *Industrial*, p. 19.
[288] Schofield, *Lunar Society*, p. 43.
[289] Bolton, *Scientific*, p. 197. Uglow, *Lunar Men*, p. 46.
[290] Uglow, *Lunar Men*, p. xiv.
[291] Schofield, *Lunar Society*, p. 101.
[292] Uglow, *Lunar Men*, p. xiv.
[293] Bolton, *Scientific*, p. 205.
[294] Schimmel Penninck in Hankin, *Life* as cited in Bolton, *Scientific*, p. 205.
[295] Bolton, *Scientific*, p. 196. Schofield, *Lunar Society*, p. 193.
[296] Schofield, *Lunar Society*, p. 35. Uglow, *Lunar Men*, p. 84.

This physician, chemist and former professor in mathematics and natural philosophy was with his benevolence, charm, unthreatening appearance and profound sagacity beloved by many.[297] Keir described him as 'a gentleman of very uncommon merit . . . who to the most extensive, various, and accurate knowledge in the sciences, in literature, and in life, joined engaging manners, a most exact conduct, a liberality of sentiment, and an enlightened humanity.'[298] As a natural diplomat and an unassuming figure, Small had a talent to maintain friendships, to ease conflicts and to support others with advice.[299]

The following member was described by Schimmel Penninck as 'the wit, the man of the world, the finished gentleman, who gave life and animation to the party.'[300] She refers here to James Keir, or actually: Captain James Keir, since he had served in the army for some time.[301] After his military career, Keir pursued his intellectual interests and developed himself as a chemist and an author, and he became the proprietor of several chemical establishments.[302] He was painstaking and patient as an experimenter, but lacked imagination and insight.[303] Still he would have been an asset for any intellectual group, if not for his self-effacing manners and his reliability, then for his good sense of humor.[304]

Another Lunar member was James Watt, instrument-maker of origin, chemist, engineer, and famous inventor of steam engine improvements.[305] Schimmel Penninck describes this Lunatick as contemplative, deeply introverted and a patiently observant philosopher.[306] She remembers of him the picture in which '[h]is head was generally bent forward or leaning on his hand in meditation; his shoulders stooping, and his chest fallen in; his limbs lank and unmuscular, and his complexion sallow'.[307] There was however no way for Watt to drown in his intellectual activities and his contemplation, since 'everybody practically knew the infinite variety of his talents and stores of knowledge. When Mr. Watt entered a room, men of letters, men of science nay. military men, artists, ladies, even little children thronged around him.'[308]

William Withering was 'kind, but his great accuracy and caution rendered his manner less open, and it had neither the wide popularity of Mr. Boulton's, nor the attraction of Mr. Watt's true modesty.'[309] The physician, botanist and chemist appears to have had a quite austere and irritable personality, predisposing him to conflicts.[310] Even the writer of his obituary felt the need to point out his shy and reserved character.[311] Still, perhaps quite surprisingly considering these negative descriptions by contemporaries, Withering had his fair share of adventures: while

[297] Bolton, *Scientific*, p. 196. Uglow, *Lunar Men*, p. 84.
[298] Keir, *An Account*, pp. 29-30, as cited in Schofield, *Lunar Society*, p. 35.
[299] Schofield, *Lunar Society*, pp. 35 and 36. Uglow, *Lunar Men*, p. 84.
[300] Schimmel Penninck in Hankin, *Life* as cited in Bolton, *Scientific*, p. 204.
[301] Schofield, *Lunar Society*, p. 76.
[302] Bolton, *Scientific*, p. 196. Schofield, *Lunar Society*, pp. 75 and 76.
[303] Moilliet and Smith, 'Keir', p. 151.
[304] Ibidem, 'Keir', pp. 150 and 151.
[305] Uglow, *Lunar Men*, pp. xiv and 27. Bolton, *Scientific*, p. 196.
[306] Schimmel Penninck in Hankin, *Life* as cited in Bolton, *Scientific*, p. 203.
[307] Ibidem, p. 203.
[308] Ibidem, p. 204.
[309] Ibidem, p. 204.
[310] Schofield, *Lunar Society*, p. 124. Uglow, *Lunar Men*, p. xiv.
[311] Schofield, *Lunar Society*, p. 124. During his illness preceding his death, his friends created the play on words that 'the flower of physics is withering'. (Bolton, *Scientific*, p. 217.)

traveling from Portugal to England, his ship was for instance chased by frigates and privateers on four occasions.[312]

Perhaps the most capricious of the bunch was Richard Lovell Edgeworth;[313] politician, writer, philosopher, inventor, educationalist and father of twenty-two children from four marriages.[314] He was considered charming and eccentric,[315] impulsive and outgoing, and 'very sensible, acute & lively. [With] many excellent notion of education, & manners in general [...]'[316]

As eccentric as Edgeworth was Thomas Day, although in many senses they were opposites: Day was more depressive than the excitable Edgeworth, a misogynist rather than a womanizer, and he totally lacked in any social graces and polite manners.[317] He was tall and stooping, and Edgeworth described Day's appearance as not prepossessing, stating that 'He seldom combed his raven locks, though he was remarkably fond of washing in the stream.'[318] This freedom to take some distance from social standards could be related to the substantial fortune he inherited when he was young.[319] His money probably sparked some interest for this remarkable figure among Lunar men, but it were mainly the outpourings of his idealism in the form of educational work, anti-slavery campaigns and political causes that made his fellow members take him seriously.[320]

The last one on the list is Samuel Galton (Junior, to be precise). Galton was a gun manufacturer in Birmingham with a good career that was accelerated by his family, especially his father.[321] His scientific work was more of a hobby compared to the other Lunar members, but he was well-skilled in chemistry and natural history, topped with a wide variety of leaping interests.[322] He was a man of family and a man of opulence, who found a way to combine these traits with his scientific interests: walks with his daughter were brightened up with new botanical surprises, and at his beautiful estate he loved to receive a certain peculiar group of philosophical friends.

[312] Hale-White, 'Withering', p. 1088.

[313] Schofield, *Lunar Society*, p. 49.

[314] Inspired by the Rousseau-istic tradition that understood education as an experimental science, Richard Lovell and his daughter Maria experimented with the upbringing of the children, the results of these experiments and their experiences with the children proved to be a source of inspiration for the writings on education and the children's books that they published together. One of the children was born in the same year Thomas Day died. This child carried the name Thomas Day Edgeworth, apparently in honour of the late Lunarian.

[315] To go visit his friends, Edgeworth drove for instance across the country in his 'specially designed, low-slung, one-wheeled chaise, with leather sides which folded up when he went through water - like a sort of high-speed black banana.' (Uglow, *Lunar Men*, pp. 184 and 185.)

[316] Wedgwood to Thomas Bentley, 29 Augustus, 1777, as cited in Schofield, *Lunar Society*, p. 49, and in Doherty, 'Intellectual Friendship' p. 6.

[317] Uglow, *Lunar Men*, pp. 124 and 183.

[318] Edgeworth, *Memoirs*, as cited in Uglow, *Lunar Men*, p. 183.

[319] Uglow, *Lunar Men*, p. 183.

[320] At times Day liked a nice social experiment as well, especially one in which he could express his admiration for Rousseau's ideas about education. Most remarkably he adopted too young girls (eleven and twelve) when he was twenty-one, in order to raise them as the perfect wife and mother according to his own specific standards. It failed. (Uglow, *Lunar Men*, pp. 185–188.) The popular French novel *Paul et Virginie* (1787) by Jacques-Henri Bernardin de Saint-Pierre has been based on these events. (Chandler, 'Edgeworth', p. 101.)

[321] Schofield, *Lunar Society*, p. 220

[322] Bolton, *Scientific*, p. 197. Uglow, *Lunar Men*, p. 352.

Chapter 3

Delving into data: data collection and its difficulties

As explained in the Introduction, the construction of the Lunar Society networks was based on the meta-data of the letters the members of the Society wrote to each other. Keeping in mind the membership list determined in the last section of the previous chapter, this implied that the correspondence between Whitehurst, Boulton, Wedgwood, Darwin, Priestley, Small, Keir, Watt, Withering, Edgeworth, Day and Galton had to be mapped. Such an overview of Lunar correspondence was not available in the existing literature yet,[1] therefore it had to be compiled. In this chapter I explain how that was done. Because investigating how a DHSNA research could be set up is part of the project, I will describe the data collection process step-by-step. Furthermore, I will evaluate the different stages in order to assess the practicability and reliability of DHSNA.

3.1 On the hunt for correspondence

Locating the letters
The goal of this stage was to create a database that listed promising places to look for Lunar correspondence, and to indicate if there were indeed Lunar letters present there.[2] These promising places to explore were for instance collections in archives that included correspondence of Lunar men, biographies of Lunarians, and books, websites and articles that published (a part of) the correspondence of members. For the promising collections in archives I listed in the database: the name of the collection or the name of the Lunar figure it was connected to, the name of the archive the collection was in, the archival code if they had any, the URL that directed to the collection, an assessment of its accessibility, notes, and an estimate of the number of Lunar letters present, if any. For the other type of promising places I listed: the title of the work, its author (or editor), the Lunar member(s) the publication was about, the year the work was published, how I got track of the source, how I could access the source, notes, and an estimate of the number of Lunar letters present, if any. Including the mentioned estimates of the accessibility of the source and the number of letters present in the database is highly recommended, because this information is important to plan the stage of the data entering.

However, before I was able to write down all these details, the first step was to locate the promising places. I looked for archival collections by exploring the archives

[1] Notice that the term 'Lunar correspondence' is understood as 'the collection of letters that were both sent and received by a Lunar member', and not as 'the collection of the complete correspondences of all members'.

[2] A 'Lunar letter' being a letter that was both sent and received by a Lunar member.

that Uglow and Schofield listed as the ones they consulted. Furthermore, I applied search engines designed to inspect multiple archives, like the one of The National Archives, ArchiveGrid, and the one of SNAC (Social Networks and Archival Context).[3] The hunt was brought to a close with a general Google and Worldcat search for collections consisting of Lunar correspondence. The list of promising published correspondences and biographies was made by investigating the bibliographies of secondary sources, by looking up references to books in archives, and again by general searches in Google, Worldcat and the library catalogue of Utrecht University. In all cases I used the Lunarians' names and the name of their society as keywords (taking into account spelling variants of writing the names). If necessary, I chose the period 1700-1830 to narrow down the results. By using all these different ways of looking for promising places, and by being tolerant in what counts as 'promising', I tried to make the list as inclusive as possible, in order to detect as much Lunar correspondence locations as possible. The efforts resulted in a database of promising places that includes around a hundred collections in almost forty archives, and around twenty-five other type of interesting sources. After checking for Lunar correspondence, it turned out that twenty-seven collections and sixteen other sources together contained roughly-estimated around three thousand Lunar letters. Of course, this number most certainly included an unknown number of duplicates, since there were on the list both archival collections and sources that published items from these collections.

There are some things that I did not do, but which could perhaps have increased this number. First, for some promising places it was not possible to determine if they did or did not include Lunar correspondence, since they were not (easily) accessible or available, and because an extensive description of the contents was missing. To solve this, it would have been for instance an option to contact archives, authors or to go at great lengths to acquire a specific book. Another way to look for more material would have been to investigate all footnotes in secondary literature about the Lunar Society. The reason that I did not take these actions, is that they did not seem promising enough compared to the amount of time they would require.[4] This made them within the scope of this project not feasible. They would however be valuable to add in a larger project.

Evaluation

Reflecting on the process, what stands out is that locating the letters is far more difficult — and therefore time-consuming — than should strictly be necessary. In this area, the historical research infrastructure is not — at least not according the experiences during this project — ready for large-scale data-collecting practices.

What is lacking, is a central place that provides a reliable overview of locations of archival collections, preferably worldwide. The National Archives, Archive Grid and SNAC make efforts towards this goal. However, all three were disappointing in the number of search results they delivered, omitting many of the locations that I discovered elsewhere. The National Archives search engine delivered the best results, but it is just focusing on England (probably the reason why it delivered the best results in the context of this research). SNAC is most promising in the context of DHSNA, since it both localizes collections and offers options to visualize networks at the website, however, for now the search results were — at least for this project

[3] The National Archives, `http://discovery.nationalarchives.gov.uk/` (consulted at 28 July 2018). ArchiveGrid, `https://beta.worldcat.org/archivegrid/` (consulted at 28 July 2018). SNAC, `http://snaccooperative.org/` (consulted at 28 July 2018).

[4] Exactly how promising they were was estimated based on contexts and descriptions.

— not of any use. All three initiatives do have a lot of potential, and since Archive Grid and SNAC seem to be just in their early stages of development, I expect that the situation will improve as time passes.

Another aspect of the historical research infrastructure that could be improved to ease the process of locating collections, is the quality of the websites of some — of course, not all — archives. Pages were outdated, contained errors or looped you around before you found the hidden collection. Furthermore, since it is in many cases and for many historians not possible to visit all the archives, much improvement of the situation could be achieved by offering more elaborate descriptions of the collections on the web pages. If we want to do more digital history, the websites of archives should get prepared for the future.

3.2 Gathering the loot

Entering the meta-data
The next phase was to collect the core meta-data of the located letters. Under these meta-data should be understood: the name of the sender, the name of the recipient, the date the letter was sent (day, month, year), the location of the sender and the location of the recipient. In order to do this, I made for each location of Lunar correspondence a collection form in which the details of the letters could be entered. This form included columns for the mentioned meta-data, a column for the number a letter had in the archive / the page number of the page where the letter was found, a column for the number of the entry in the collection form, and a column for notes. This last column will of course not directly be taken into account while constructing the networks, still, the notes column is very important. In the first place because the striking aspects you noticed about a letter could be useful for interpreting interesting findings in the networks. Furthermore, notes help you to keep track of all kinds of typos, unclarities or questions. The notes bring you ideas and material for further research, and they come in handy when the data-set is reused. Most importantly for the current research, they can be used to remove duplicates, as will be explained later on. The forms were constructed in such a way that they could later be easily combined into a single database. A column to keep track of the place the letter was found and a column for the number of the entry in the original collection form were added to the database. In this way it was easy to retrieve the letter that belongs to the meta-data, which proved to be convenient on many occasions.

'Entering the meta-data' might sound easy, but there are all kinds of decisions to be made about when to or when not to include a letter, and about in which way this should be done. It is important to keep track of these kind of considerations, in order to be as consistent as possible. Here I will list the criteria that I used, and the choices that I made in the case of aberrant letters and deviant data.

- The basic requirement for a letter to get included was that three pieces of information were available: the name of the sender, the name of the recipient and the year the letter was sent. If one of them was unknown, the letter was neglected. This is because the name of the sender, the name of the recipient and the year, were the basic ingredients for constructing the networks. Without these data, the letters could not have been included in the analyses anyway,

so in order to ease the collection task a bit, it was best to leave them out completely.[5] Although not obligatory for inclusion, if available, the day and the month were recorded as well, since they would serve as markers to remove duplicates, as will be explained later. The locations of the sender and the recipient were also not obligatory, but were entered when available to facilitate the option to construct geographical networks. In the end, I have not made these networks, but the data are ready for further research.

- Any mail sent to a company, or signed in the name of a company, was not included. This implies that letters to or from the companies 'Boulton & Forthergill' or 'Boulton & Watt' were for instance excluded. The primary reason for this decision, is that the goal was to investigate the relations between persons, and not the relations between persons and institutions. Although for example the persons Boulton and Watt could not just be easily separated from their manufactury, the company could be considered as being a historical agent on its own. The idea that the firm on itself was something distinct from just the combination of two people, became for instance clear from the quote by Edgeworth we encountered in Section 2.3: different messages were addressed to Boulton, Watt and 'Boulton & Watt'. Furthermore, the decision to include business letters would have brought along all kinds of trouble. It would have meant exploring all the extensive archival collections of companies run by Lunar men, and in case a business letter is interpreted as two links that connect each partner with the sender/recipient of the letter, the edge weights of the partners' links would have grown disproportionately with regard to the rest of the network — which would have made it harder to analyze the networks appropriately. However, as we know from Section 2.3 as well, business and personal affairs were often intermingled in letters, implying that there must have been 'messages for the company' within letters addressed to a single person (and just as well: personal messages within letters addressed to companies). Also, some contemporaries addressed company mail to just one partner, meaning that these letters would get mistakenly included in the database according to the rule. Within the scope of this research, it would not have been possible to study the contents of all these letters in order to make distinctions. My expectation is that by excluding the letters that are explicitly addressed to or signed by a company, most cases are obviated.[6] For further research, especially in the context of the savant/fabricant-interface, it might be interesting to do include companies as separate nodes, and for instance to investigate how personal correspondence (edges of a partner) and business correspondence (edges of the

[5] In the context of a larger project I would recommend to include them in the database, because it does make the overview of Lunar correspondence more complete, which could be useful for further research. However, one must realize that the database would then probably consist of many more duplicates, since there is in the absence of a date no way to remove those duplicates, except for checking the contents of individual letters, which is time-consuming and contents are not always (easily) available. In short: one creates an overview of archive numbers and pages where correspondence could be found, and probably not a trustworthy overview of the correspondence itself. Still, such an overview of archive numbers and pages is an useful research tool in itself.

[6] The most important example of business letters that were excluded in this research, are however not addressed to or signed by a company name. These are the letters Boulton and Watt sent to each other in the guise of partners (Library of Birmingham, MS 3147/3). Including them would have made the networks almost unreadable, since their edges would have been even thicker than what they now already are based on their other correspondence. We do not need to include these letters in order to be eventually able to establish that they wrote a lot to each other because they were in a partnership.

company) relate to each other, or which function the company might have had in connecting savants and fabricants.

- Letters that were marked as 'draft', 'transcript' or 'copy' (perhaps made by Watt's copying machine, see Section 2.3) were included. There is a (small) chance that a draft might have never been actually sent. However, even for the small number of cases for which this is true, the action of writing the draft is still some sort of indication for social contact between people (which is in the end what counts). In the case that the letter has been sent, there was a chance that both the draft and the actual letter would got added to the database. The same applies to transcripts. This was not a problem though, since most of these cases were going to get accounted for while removing duplicates. The benefit of gathering more meta-data by including drafts, transcripts or copies of otherwise lost actual letters outweighs this worry about some duplicates.

- Everything else that was not a letter, such as bills or memoranda, were excluded.[7]

- If the day, the month or the year was inferred, they would nevertheless appear in the database in the same way as non-inferred data, with or without a note added about the inference. It was done like this because there is no room for uncertain years during network construction; because too much meta-data would otherwise be excluded; because the date and the month would only be used to remove duplicates and I expected that in most cases historians would make the same inferences for the same letter (or that the inference in a published source was for example copied from the one in an archive); because the uncertainty of an inference is in most cases less than five years, which is the step size in the analyses, as will be explained in Chapter 4[8]; and because I trust the estimates of the archivists and editors, especially when the inferences are for instance based on the location of a letter in a letter book.

- If the year is only available as a range (1776-1780 for instance), I always entered the lowest year. Assuming that in most cases the same range would have been given for the same letters (because similar estimates would be made or because the range in a publication was copied from an archived item), hopefully the same year was picked and therefore hopefully the most duplicates would get removed (if the day and the month did were clear). Adding a note that the year was given as a range is even more useful to remove duplicates, since it serves as an identifier for the letter.

- If a letter was written by an assistant or an employee in the name of a Lunar men, this Lunarian that dictated or commissioned the letter was understood as being the sender.

- Letters marked as 'unsent' were included, for similar reasons as described above about why possibly unsent drafts were included.

- If a letter had multiple Lunar senders or recipients, then the letter was given several distinct entries (which will translate in edges between each sender and

[7] These were for instance included into Boulton's letter books, which he used for drafts and transcripts of the letters he sent. (Boulton's letter books, Library of Birmingham, MS 3782/12/1–MS 3782/12/9.)

[8] Take into account that the letter could however nevertheless end up in the wrong five-year period, but in general an uncertainty smaller than the probe length is a good rule of thumb.

each recipient). To keep track of these 'splittings', the same entry number is used for the letter, but a letter (a, b, ..) was added. This did not apply for letters that contained a message to another Lunar member in the content of the letter, for instance in the form of a subscript. It did however apply to letters that had attached another letter to pass on to someone.

- Public, published letters ('To the inhabitants of Birmingham')[9] were excluded.
- Except from adding some notes, nothing extra was done in the database with letters of introduction. It would however be interesting for further research to highlight these type of letters in (dynamic) networks, since they mark the start of connections, and provide an interesting and particularly clearly-defined way to study triadic closure within historical networks.[10]
- If there were no item-level descriptions available in an archival collection, only the letters that could with certainty be deduced from more general descriptions of the collection were included.
- If the location of the sender mentioned in the letter deviated from the location where we would expected the writer to have been based on other correspondence or secondary literature, the letter 'wins'. It is more likely that secondary literature or other correspondents made a mistake, than that the writer did not know where he was. Of course, there are some exceptions imaginable, for instance that an assistant posted an earlier-written letter in the absence of the indicated sender, or that the writer interrupted his writing and continued the letter on a different location, but such cases are most likely not that common.

Keeping these criteria in mind, I explored archive collections, published correspondence, secondary sources and websites, and entered the meta-data of the letters I found in the appropriate collection forms. This all had to be done by hand, since there were for instance no options to download the data from the websites of archives. However, sometimes it was possible to ease the task if the archive presented item-level descriptions in a fairly consistent way. This was for instance the case for a part of the large collection of correspondence by Boulton.[11] To mine the meta-data of the letters in this collection, I used the free online tool RegExr to extract the meta-data of a copied archive web page with the help of regular expressions,[12] and manipulated the copied text in such a way that it could be entered into the collection forms.[13] Unfortunately, by the way the archive's web page was designed, this could only be done for a part of the letters, the rest still needed to be entered manually. Fortunately, I did not had to do all the work by myself, because I was lucky to receive some help during a crowdsourcing project.

[9] Priestley, *Familiar Letters*. Strictly speaking, Priestley addressed his Birmingham-bound Lunar friends with these letters as well of course, but since these letters are nothing like personal correspondence, they should be kept outside the analyses.

[10] Triadic closure is the property that if a node has strong relationships (strong ties) with two other nodes, then there is or there will form (at least) a weaker relationship (a weak tie) between these other two nodes. (Granovetter, 'Strength'.)

[11] Boulton correspondence, Library of Birmingham, MS 3782.

[12] A regular expression is a sequence of characters that defines a search pattern. In this way you can look for certain patterns in a text. After locating the patterns you could then copy, delete or replace them. By making a certain order of copying, deleting and replacing patterns (an algorithm), the data was extracted and prepared for the forms.

[13] Gskinner, 'RegExr', `https://regexr.com/` (consulted at 29 July 2018).

Crowdsourcing

'Crowdsourcing' is a portmanteau of the words 'crowd' and 'outsourcing',[14] and roughly speaking it means that work is outsourced to a crowd. Within digital humanities, crowdsourcing became the practice of asking a group of interested volunteers to execute small tasks in order to accomplish large-scale ventures, such as transcribing texts, describing objects or processing data.[15] Brabham calls this 'distributed human intelligence tasking'.[16] Usually, these tasks are done via an online platform, where people can sign-up from home and start directly. Crowdsourcing within the humanities is however not only about the benefits of receiving help with the creation of large digital datasets: more and more humanities scholars became to realize that it is just as much about public engagement. The practice provides ways to involve people in humanities research and show its importance, and it offers ways for the public to do more with digital collections of historical material than just consume the information: a long-cherished wish of historians.[17] As Owens wrote: 'At its best, crowdsourcing is not about getting someone to do work for you, it is about offering your users the opportunity to participate in public memory.'[18]

The experiences of the first humanities crowdsourcing projects have translated themselves during the last years into a growing body of literature on the topic.[19] This literature includes guidelines for setting-up crowdsourcing initiatives. One should for instance realize when designing the project that the target audience of a humanities crowdsourcing project is not the large network of laborers that you might attract with other (paid) crowdsourcing endeavors. Rather it is a group of interested volunteers that signs up, of which eventually only a small cohort of the most enthusiastic contributers will commit for the long-term and do most of the work.[20] There are a couple of things one could do to motivate the crowd and to make the outcomes of the project more reliable at the same time. I summarize this as that contributing to the project should be clear, easy and fun. Some actions to accomplish this according to the literature are for instance: making the goals of the project clear; building relationships with the project; creating a community; adding more content regularly; acknowledging and rewarding the volunteer's help; showcasing the results; making sure the contents are novel and interesting; providing tools that are reliable, quick and intuitive; giving people a choice what they want to work on; including challenges of different levels; making the tasks fun, and implementing for instance a competitive element ('gamification'); and last but definitely not least — trusting the participants.[21] Furthermore, to improve the quality of the results it is important to built in mechanisms to highlight problematic data or users.[22]

Still, there is a lot of research that needs to be done to the best ways to design, build, deliver and evaluate the projects.[23] Therefore — and to practice with crowdsourcing — a crowdsourcing adventure was added to my research project. So even

[14]The term was first coined by a magazine in 2005, in an article that described how businesses used online platforms to outsource work to large groups of individuals for a small payment. (Terras, 'Crowdsourcing', p. 421.)

[15]Terras, 'Crowdsourcing', pp. 420–423.

[16]Brabham, *Crowdsourcing*, p. 50, as cited in Terras, 'Crowdsourcing', p. 422.

[17]Terras, 'Crowdsourcing', pp. 428–430.

[18]Owens, 'Cultural heritage'.

[19]Terras, 'Crowdsourcing', p. 426.

[20]Ibidem, pp. 426 and 427.

[21]Terras, 'Crowdsourcing', p. 427. Holley, 'Libraries' as cited in Terras, 'Crowdsourcing', p. 427.

[22]Terras, 'Crowdsourcing', p. 428.

[23]Ibidem, p. 432.

more than about gathering the meta-data, the crowdsourcing project was about exploration: it might in fact better be called a crowdsourcing *experiment*. To make it feasible within the context of the research project and to listen to feedback directly, the crowdsourcing was not done by people at home at an online platform, but during two afternoon meetings for which the local community of historically-inclined students, researchers, librarians and other enthusiasts were invited. In designing the project, I tried to take into account the guidelines above from the literature on crowdsourcing. The meetings started for instance with a presentation to involve participants with the research project, to clarify the goals of the crowdsourcing meetings, and to explain the tasks, the procedures and the conventions. Participants made use of a website (Figure 3.1) that listed the sources that included meta-data to be mined, together with an estimate of how many letters one might find there (the difficulty), and if the source was a book, an article, a document or digital (to provide choice). The list included links to collection forms very similar to the ones I used myself, but contained some extra instructions for handling the specific source and an example of how the data should be entered. Furthermore, I included a field for people to write their name (both to give people a feeling of authorship, and in the context of quality control, because if it turned out that someone had been a bit sloppy, their other work was easily checked), and a field to indicate if the form was complete yet. To make the enterprise more fun, I included a competitive element: people could enter how much data they collected in a field on the website, these scores were showcased as a ranking list, and there was a small present for the one on top of the list after the second meeting. A bar on the website displayed the progress of the data collection, which was adjusted when people entered their scores. The experiences and feedback of the first afternoon were used to improve the the set-up of the second afternoon, in this way the benefit of the suggestions could directly be tested in practice.

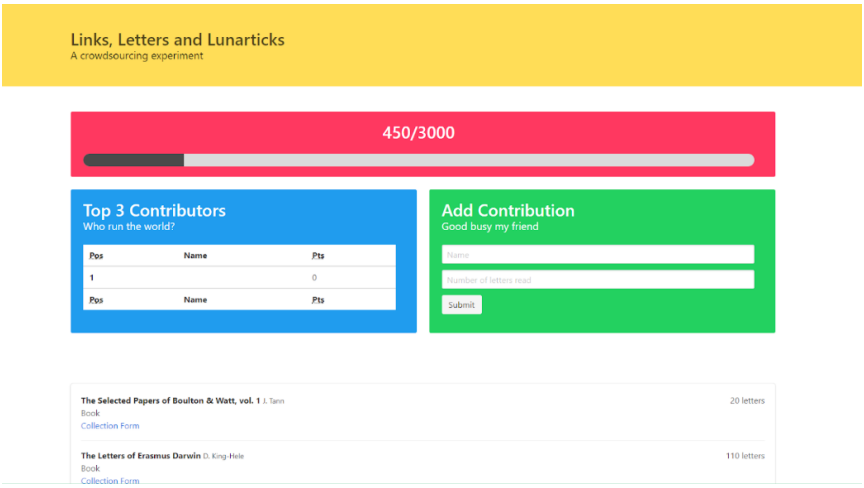


FIGURE 3.1: *The web page used for the crowdsourcing project*

Let me list some lessons drawn from the crowdsourcing project. The most important observation is that purely based on the amount of meta-data the project yielded, the output did not outweigh the amount of effort put into organizing the meetings, designing the project, correcting the participant's entries and adding forgotten data. However, as indicated above, the project was not just intended to gather data, but also to create an opportunity for people to engage with the research and to study the process of crowdsourcing. Dunn and Hedges agree that you do not always save time with crowdsourcing, but that it is useful nevertheless:

> 'it [crowdsourcing] is not simply a form of cheap labour for the creation or digitization of content; indeed in a cost-benefit sense it does not always compare well with more conventional means of digitization and processing. [...] The creativity, enthusiasm and alternative foci that communities outside that academy can bring to academic projects is a resource which is now ripe for tapping into.'[24]

Still, approximately 20% of the entries (before cleaning the data) came from crowdsourcing, which shows its potential. Especially because after the first investments of designing a project and instructing a group of volunteers, the costs are low and the benefits are high if the project is prolonged as long as the group is willing to contribute.

Another lesson is that in the current set-up, people picked up the tasks quite easily. Judging on the kind of questions participants asked about both the research and the sources, I also have the impression that they connected with the topic quickly. It worked well to use a central online place that was easily accessible for everyone. In general the forms functioned properly, although participants voiced that it was important for them to enter the date (day, month, year) in the order they were used to; they preferred this over the option to have all obligatory fields next to each other (sender, recipient, year). The notes column was of special importance, since participants appreciated the freedom to add comments, useful both for their contents and for the stage of data-cleaning. There was no significant preference to work on either a book, an article, a document or a digitized source, but there was a preference for clearly-structured and manageable sources. Some things that went wrong are the following: it turned out that not all headers were self-explanatory, there was some confusion about conventions for entering names, some spelling errors popped up, and some letters were forgotten (including one severe case in which more than half of the Lunar letters in a source that was marked 'complete' were not entered.) A last lesson is that competitive elements probably work better for large-scale projects. In this project, it seemed that people were for instance more motivated because of the contents of the material, than by the outlook to beat fellow participants and win the prize.

Evaluation

In my opinion, the process of meta-data gathering again required more effort than should strictly speaking be necessary. With some improvements in the historical research infrastructure, this step in the collection procedure could get significantly easier and less time-consuming.

The first improvement that in itself would already make quite a difference, is (again) redesigning archival web pages and — connected to that — adjusting the organization of archival collections, in order to prepare the collections for the large-scale data mining operations that digital history projects wish for. Item-level descriptions are very important for DHSNA based on the meta-data of letters, because this amount of detail is necessary in order to not only claim that people were connected (which you might conclude based on a more general description), but also to investigate details like how much they wrote to each other and in which periods. At the moment, item-level descriptions are not (easily) available for each collection, and even if these item-level descriptions are available, it is not said that all required meta-data is listed. Furthermore, the existing item-level descriptions are definitely not always stored in a convenient way, and thus one finds oneself strolling through

[24] Dunn and Hedges, 'Scoping Study', p. 40.

archaic documents drawn up at the beginnings of the twentieth century. Of course, it should already be appreciated that the archives took the effort to put these kind of documents online. Still, it would be a lot easier if the item-level descriptions were integrated into the web page itself, and, ideally, if each page offered an option to select desired items and to download their meta-data.[25] Perhaps we could even include such an option at the proposed web pages providing overviews of the locations of collections?

Connected to the first suggestion for improvement, is the one that in order to make large-scale historical data-mining within reach, it is important to agree on international conventions about how meta-data should be stored and formulated. From the data gathering process, it became clear that at this moment the meta-data is displayed in all kinds of styles. However, uniformity and consistency of data both within a single collection and between collections, is very important to process data digitally, because it opens the door to easily execute computer analyses, without first extensively cleaning the data. Ideally, one could use analysis programmes that are themselves adapted to correct for data deviating from the norms, or that automatize the process of extracting meta-data (in all kinds of different forms) from sources. Until that kind of tools are available, an 'easy' solution is well-defined conventions — something that historians already started working on.[26]

For the purposes of this research project, building the described databases with simple spreadsheet programmes met the demands. However, I suspect that for larger research projects it is recommended to explore the possibilities of free database software, and to delve into the art of database construction, which is a field of research on its own. Perhaps it would be worth examining the idea to build database software that is specifically adapted to the needs of digital historians. One could for instance think of a database programme that has integrated options to convert dates from one calender to another, to convert geographical places to their modern equivalent, to correct for different ways of spelling names, and offer ways to easily visualize the data, either within the programme itself or with an option to export the data in such a way as to import it easily within other software (conventions are here again key).

Lastly, the crowdsourcing experiment within the project showed the benefits the practice might bring. Some specific ways in which the crowdsourcing project could have been improved were already listed above. However, apart from such more detailed questions about how crowdsourcing projects should be designed, there are some more general issues that need to be investigated in the context of crowdsourcing. Two of them were already touched upon: we need to think about quality control and we need to explore ways to diminish the organization efforts at the expense of valuable research time. Furthermore, there is the (legal) issue of authorship (who owns the data that was gathered by a crowd?) and there is an ethical concern as well

[25] Although it is in my opinion not advanced enough to meet all the demands of digital history, for now archives might want to explore the Calm archive collections management system that is used by some archives in the United Kingdom (Axiell, 'Calm', `https://alm.axiell.com/collections-management-solutions/technology/calm-archive/`, consulted at 30 July 2018). In my experience, the archive collections displayed within the CalmView environment, were well-structured and the item-level descriptions were, if available, easily accessible. Furthermore, I expect that it should not be too hard for digital historians to build a simple programme to extract the data from these web pages, in order to bridge the period in which offering downloading options is not yet within reach for an archive. There are some collections for which an option to download (meta-)data is already available, I did however not encounter them during gathering the Lunar meta-data. Perhaps such options are (for now) reserved for the most popular (or important) archives and collections.

[26] See for instance the previously mentioned Hotson and Wallnig, *Reassembling the Republic of Letters: Systems, Standards, Scholarship*.

('projects have to be careful to work with volunteers, rather than exploit them'[27]). In the context of quality control, organization efforts and to a certain extent in the one of the ethical concern, I think it might be interesting to develop a crowdsourcing platform for small-scale research projects that brings together enthusiastic volunteers and historians that themselves can post their materials and tasks on the platform for free. Large- and medium-scale projects usually have the resources to build a platform themselves, or to pay for the services of a crowdsourcing platform supporting multiple projects,[28] for small-scale projects this is however not within reach. Since the small-scale projects are usually short-term, they present an opportunity to use the free platform for experimentations with crowdsourcing project designs, making it not only a data machine, but a crowdsourcing laboratory as well.[29]

3.3 Preparing the data

Data cleaning
Combining all the collection forms with entered data resulted in a database with 3027 entries. The next challenge was to clean this data. First, I corrected typos and errors, made the notes more clear, checked some questions and uncertainties added by crowdsourcing participants, removed redundancies, and made the data overall more consistent. A step towards consistency that is worth mentioning, is the replacement of the entered locations with their modern equivalents and the substitution of the names of houses and streets with the one of a city or village. 'Soho' was for instance replaced by 'Birmingham', 'Green Lettuce Lane' (see Section 2.3) by 'London', and 'Cosgarne' by 'Cusgarne'. This served three purposes: most importantly, it is a necessary step in order to be able to find the coördinates of the places, which would be needed for a geographical network; furthermore, it prevents us from mistaking the names of houses for the names of a city; and lastly, it avoids us to think that contemporaries intended a distinction when they wrote for instance either to Boulton in 'Soho' or Boulton in 'Birmingham', which was not the case, they used locations interchangeably.[30]

The next step was to remove duplicates. If two or more entries listed the same sender and recipient, and if they were marked with the same day, month and year, I assumed that they referred to the same letter (kept or reproduced at two different places). Of course, there is a chance that two letters were sent by the same person to the same person at the same day, but I expect the chance to be very small, especially when we consider the description about the postal system given in Section 2.3. In the first place, it was noted that sending letters was expensive, however, our Lunar members were rich, so perhaps this did not bother them that much (although we did see in this section as well that Withering was in fact concerned about the expenses of postage). What however most certainly did bother them was the slowness of communication. This made it unlikely that they received a response to a letter at the same day they sent it *and* send a letter back again. Furthermore, because you could not write that often, quite a lot of effort must have been put into the letters before they were sent (illustrated by the fact that drafts were made, and that letters were

[27] Terras, 'Crowdsourcing', p. 433.

[28] The Dutch 'VeleHanden' platform is a good example of such a crowdsourcing platform. (VeleHanden, `https://velehanden.nl/`, consulted at 30 July 2018.)

[29] In this way such a platform might perhaps even be able to make a claim for research funding, a possible way to finance the platform.

[30] Description accompanying Matthew Boulton: Letter Book 1766 - 1768, Library of Birmingham, MS 3782/12/1.

transcribed or copied before they were sent).[31] Therefore, I think it is unlikely that people often had to send a second letter because they forgot to mention things or made some mistakes. With an option in the spreadsheet programme, it was easy to reduce entries with the same sender, recipient, day, month and year to just one entry.

For entries for which the day was missing, matters became more difficult. Since the Lunarians did write more than one letter to the same recipient during a month — which could be concluded from the entries for which the day was included — it was not possible to use the same trick and reduce entries that shared sender, recipient, year and month (but with a missing day) to one entry. Likewise, this was also not possible for the ones that besides the day also missed the month. In the case of multiple entries that had the same sender, recipient, month and year, I decided if we dealt with duplicates based on a comparison of the (descriptions of the) corresponding letters, the notes, the locations of the sender and the recipient, peculiarities and the sources the entries stemmed from. In the case of multiple entries that had the sender, recipient and year in common, but missed the day and also the month, I tried to do the same thing. However, for quite some cases and for different reasons, it was not possible to make a definite decision. If it was not possible to determine with certainty if entries were duplicates, I left each of them in the database, since otherwise quite large groups of entries with a missing day and month might had got (unjustly) reduced to a single entry.

Evaluation

A general observation about the process of data cleaning is that it is a step in the collection process that is easily overlooked, but nevertheless very important. It is in this stage that you make some final decisions about which data will be included, and mistakes you do not detect might cause trouble in further stages of the research. Ways to make the procedure more practical are already mentioned above, and include for instance style conventions for the display of meta-data and software that is able to clean (historical) data.

There is more to say about data cleaning in the context of the consequences decisions during this step have for the reliability of DHSNA. During the removal of duplicates, the expectation is that some entries were unjustly removed (for instance when someone in fact did write two letters to someone at the same day), while others mistakenly remained in the dataset (for instance when it was not possible to determine if entries with the same sender, recipient, year and possibly month, were in fact duplicates). I suspect that the first case almost never happens and that we do not need to worry much about the last case either. Only about seven percent of the entries before cleaning the data were entries for which the day missed. After cleaning the data, it was about ten percent of the entries. Furthermore, having in mind the size of the final dataset, a couple of double entries probably would not significantly change the results, especially not when they are somewhat equally divided among the correspondents (for which you, however, have no reason to assume that). The same applies to unjustly removed data. Also, there is no reason to feel concerned that it was just that one discovered letter between people that proved that they corresponded which got removed, because if there was just one letter exchanged between people, it would not have gotten removed in the first place. All in all, on the scale of all the other uncertainties that will be mentioned later on, these uncertainties originating from duplication removal are worth taking into account, but will not undermine the analyses completely. It is however smart always to keep a copy of

[31] Matthew Boulton's letter books, Library of Birmingham, MS 3782/12/1–MS 3782/12/9.

the original dataset, if not in order to check hypotheses about mistakes or wrongly in-/excluded data, then at least to save the notes (it would be great if a future tool bundled the notes of duplicate entries when they get reduced to one entry).

Conventions might again be key to find more reliable ways to detect duplicates. It is for instance possible to define the meta-data of letters as to include some keywords about the content as well, or for example the incipit of a letter (although both tactics run into trouble too: how to stimulate that people more or less pick the same keywords? Is it always clear what the 'first words' of a letter are? What to do when they are generic?). Such an approach would work best if archives included this data in the desired dowloadable item-level descriptions. Adding those kind of terms during the process of data gathering for a venture like this current research project would namely not be feasible. In the first place because the close-reading that it would require would cost too much time to do by yourself, and it is both too much to ask and too inconvenient to request crowdsourcing participants to do it. Secondly, only a small share of the (Lunar) letters is published or digitized, the contents of the other letters are unavailable. Since this close-reading keyword-gathering task could then only be done for a relatively small share of the letters, it still does not provide you with the solution for removing all duplicates reliably.

3.4 The result

After locating, gathering and cleaning meta-data, the result is a database of 1812 letters, ranging from 1755 (a letter from Keir to Darwin) to 1813 (a letter from Edgeworth to Watt). Before we turn to the analysis of this data, let me to conclude list some examples of the kind of uncertainties that slipped into the database due to the process of data collection:

- Not all letters might have been located. This could be due to the fact that investigating a source was outside the scope of the project because either the task of examining it or the task of getting access to it, would be too time-consuming in the absence of a good prospect for new findings. (For example: checking all the notes of a secondary source, going to great lengths to access archival collections.)
- Some letters in examined archival collections and other sources might have been overlooked during the data gathering stage.
- Letters of some Lunars were harder to find than those of others, due to the nature of search engines and the English language. Correspondence of Small and Day was for instance difficult to find, since some engines were not able to distinguish the names from the common words 'small' and 'day'.
- The uncertainties about dates specified by archival collections and other sources — such as a date being inferred, or if only a range was given — were for the purposes of executing analyses removed, or at most shifted to the notes field.
- The mistakes made by archives or other sources might have gone undiscovered during the location or gathering stage, and therefore appear uncorrected in the database.
- Archives might not have (digitally) listed all their available material, either due to mistakes, practical constraints, biases, or certain decisions. Something similar definitely applies to published correspondence: at least in most cases,

not all available correspondence material of the figure(s) could get published in the book, and so the constitution of the published set of letters is the result of certain decisions and goals of the compiler.

When building and interpreting the networks in the upcoming chapters, these uncertainties should be kept into account.

Due to the way in which the dataset was translated to network visualizations, which will be explained in the next chapter, it was difficult to process errors in the dataset once the visualizations and accompanying measures were already constructed.[32] The analyses in this project have been made with the mentioned dataset that contains 1812 letters.[33] Afterwards, however, I discovered some unremoved duplicates and six unentered letters.[34] Unfortunately it was not possible to redo the analyses, but I included an updated database in the online resources set,[35] so it can be used for further research. I do not expect that any of the research results would have been significantly different, would these duplicates not have been included in the analyses. The unentered letters were taken into account during interpreting the networks.[36]

Evaluation

Some solutions to alleviate the above mentioned uncertainties have already been proposed in other parts of this chapter. Let me however underline the difficulty to adapt visualizations and graphs when mistakes in the database get discovered. This problem arose because of the five-year periods I used to make the networks social and dynamical, because that required multiple five-year period data sets — as will be explained later — and because database, five-year period data sets, visualization software and analysis software were not integrated, meaning that you have to repeat each step of the analysis process if a mistake in the database is uncovered. The problem therefore again points out the potential value of advanced software adapted for DHSNA, integrating multiple tools. Furthermore, since creating dynamical networks is especially a feature tied to *historical* network analysis, and since discovering mistakes in a dataset will, I suspect, happen more in history due to the nature of the source material, it is in the context of DHSNA highly recommended to explore options for applying more advanced types of methods to create dynamical social networks. I will describe an idea for such a method in the next chapter.

Lastly, since this project is relatively small, data management is not really a problem: making the datasets available via a shared folder was sufficient. In larger projects however, the construction of a data management plan should get the same attention as the other stages of data collection. One should think about where the data could be stored; if there are means to keep the system supported; how the

[32] This is especially the case for the accumulating network type.

[33] In fact, in the first place they were actually made with one that contained 1818 letters, but since including these six letters would have been such a big mistake, I decided it was worth the effort to remake the network visualizations. It was not necessary to do the measures again, since these five letters either did not have an influence on the graphs, or their influence was so easy to spot that it could also be easily ignored. The annoying error was that some Lunar men were apparently able to send letters from their grave: there were some letters dated after the sender's or the recipient's death. I suspect that these errors stem from typos, perhaps from archival errors, and the mistake to confuse the name of a son for the one of his father.

[34] An example of the errors unaccessibility might cause: the paper that mentioned these letters was hidden behind a pay wall, and only after the data collection stage I decided it was worth purchasing. It is reassuring that the other eighty letters the paper mentioned were in fact already entered.

[35] See Section 1.7 for the URL.

[36] They are recognizable in the updated database with a letter instead of a number in the first column.

data could be accessed and reused; how to inform the historical community about the dataset in order to prevent double work; if there are options to make the data interesting and accessible for a wider audience; if there might be any legal issues involved in storing and spreading the information; and if you might want to consider other ways of storing the data besides the digital drawer. Up to now, many of these questions are still open in the field of digital history, but options are investigated and discussed.[37] For now, the first place to consult for data management advice and storage room is the librarian's office at an university. However, with projects becoming more and more international, alternatives are desired.

[37]See, for example, the project 'Early Modern Letters Online' (EMLO), at: `http://emlo.bodleian.ox.ac.uk/` (consulted at 21 August 2018).

Chapter 4

Producing the pictures: network visualizations and their metrics

In the previous chapter it was explained how a database of Lunar correspondence meta-data was composed. In this chapter I will show how these data were used to construct network visualizations and how their associated metrics were examined. It will become clear that the translation from data to networks is not straightforward, therefore I will concentrate on the methodological and interpretative issues that came with it. The calculation of metrics was not uncomplicated either, and I will explain the ways in which the interpretation of conventional metrics needed to be redefined in order to be appropriate for the specific design of the current case study.

4.1 Exploring the options of Historical Network Analysis

A short introduction

The basic building blocks of a network are *nodes* and *edges* (Figure 4.1). Nodes are certain objects and edges are links that connect specific pairs of these objects. These links symbolize a particular relationship. Asymmetric relationships ('A gave B a gift') are expressed by a *directed edge*, and symmetric relationships ('A and B are friends') by an *undirected edge*. Reoccurences of a specific link ('A and B went on three dates') are represented by multiple edges (a *multi-edge*) connecting two nodes. Edges can be assigned a certain *edge weight*, this is a numerical value associated with the edge that is either defined as the number of reoccurrences of a link (in which way the multi-edge can be replaced by a weighted edge) or as a specification of a certain (continuous) feature of the link ('The gift cost 20 euros').[1] If the constitution of the group of nodes and edges is allowed to change, for instance when a network is studied over time, the network is called *dynamic*, if not, the network is called *static*.[2]

In Historical Network Analysis, these building blocks are used to provide insight into complex historical data. First, a method of constructing the networks that represent the data is invented, in such a way that it suits the type of historical questions that are explored.[3] Thereafter, the patterns in these networks and their overall structure are studied in order to understand the past situations represented by the networks better.[4] One identifies for instance *clusters*, which are groups of nodes that have significantly more connections amongst each other than with other nodes in the

[1] Easley and Kleinberg, *Networks*, p. 23. McGlohon, Akoglu and Faloutsos, 'Statistical', pp. 19 and 20.

[2] For a more extensive introduction to (social) network analysis, see for instance: Easley and Kleinberg, *Networks*. Wasserman and Faust, *Social*.

[3] Lemercier, 'Formal', p. 287.

[4] Lemercier, 'Formal', p. 5. Wetherell, 'Historical', pp. 126, 129.

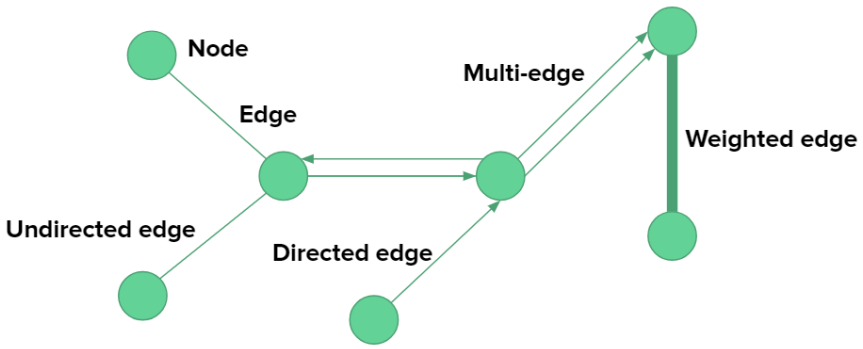


FIGURE 4.1: *The basic building blocks of a network*

network that do not belong to the cluster. If all the nodes in a cluster are connected (which is called 'completely connected'), then this cluster is called a *clique*. Furthermore, there are for example nodes that can be identified as a *hub* or as a *broker*. A hub is node that has significantly more connections with other nodes than nodes have on average in the network, and a broker is a node that links two otherwise unconnected clusters. In case they were not connected by the broker, each cluster would have been a *component* of the network. The overall structure of a network could be characterized as well, one could for instance describe a network as *dense* if many of the possible edges are actualized. Also, by studying the development of networks, researchers observed certain general 'laws' for which it could be checked if they apply to the network under scrutiny as well. In social network analysis, the principle of triadic closure is for instance often encountered, which is the idea that if a node has strong relationships (strong ties) with two other nodes, then there is or there will form (at least) a weaker relationship (a weak tie) between these other two nodes.[5] Different type of metrics, which should be understood as different type of numerical indicators calculated on the basis of different formulas, can be applied in order to ease the study of the mentioned structural elements.[6] The *betweenness* measure is for instance associated with the broker label, connecting a numerical value to the amount of 'brokerage' a node possesses. More structural elements and metrics will be discussed later on. What we can already see in these examples is that networks can be studied at the level of nodes, at the level of groups (clusters, components) and at the level of the overall structure. The value of network analysis lies to a large extent in this opportunity to navigate between different scales, to study a certain situation both at the micro- and at the macro-level.[7]

The goal of Historical Network Analysis is not to prove that a certain network existed or that networks are important in general, neither is the goal to produce a picture that maps historical reality.[8] Instead, one should take the existence of the network as a hypothesis,[9] and interrogate the data through the lenses of network structures in order to detect and understand its patterns. There is not just one pair of lenses to study the data with: you can keep adjusting parameters, choices and techniques in order to answer different historical questions. In other words: network

[5]This principle was explained earlier in footnote 10 in Chapter 3. (Granovetter, 'Strength'.)
[6]The topic of metrics will be discussed more elaborately later on in this chapter.
[7]Lemercier, 'Formal', pp. 291–293.
[8]Ibidem, pp. 287 and 291.
[9]Ibidem, p. 285.

visualizations are not answers to historical questions, but merely tools that can contribute in investigating these questions.[10] It is also good to realize that the network analyses are not necessarily tied to a specific theory. Social network analysis for instance, does assume that actors are interdependent rather than independent,[11] and it does study social structure from the perspective of relations,[12] however, it does not need to make any other theoretical commitments tied to a specific sociological theory whatsoever.[13] There has been much debate among social network analysts about what exactly the status of their field is ('is it a method, [...] a technique [...], a theory, a paradigm, an 'ontology', [...]?'[14]), and nowadays most researchers think of it as an 'approach' — as a way to view things, a tool — as well.

So, network visualizations should be interpreted as tools, and there are different tools for different historical questions. The type of tool constructed is however not only dependent on the specific parameters and techniques you apply to tweak a network, much more so is it dependent on what exactly the edges represent. The differences could be very clear: an edge could for instance represent a biological connection (kinship), a resource transfer (donor-receiver) or a shared connection (same city of residence for example), among others.[15] Other times the differences are more subtle. To study who knows whom, who writes with whom, how knowledge flows through a network or how goods transfer in a network, requires for instance all a different network with a slightly differently interpreted edges. However, as Lemercier states: 'The network vocabulary is often used in a purely metaphorical way, without reference to any more or less systematic information on precise ties between specific individuals or organizations.'[16] What she means is that all sorts of different ties get — even in the same network — mixed-up and get aggregated under 'general words such as "bound" or "relationship".'[17] To avoid these type of loose 'quasi-ritual'[18] references to network terms, Lemercier underlines the importance of formal methods and careful definition of the edges.[19] Such a definition should according to her take three dimensions into account: the difference between interaction and the potential for interaction, the awareness of the relational structure among the actors in the network, and the temporality of edges.[20] Especially this last dimension has been scarcely discussed in network analysis literature,[21] perhaps because the field of dynamical network analysis is still relatively young. Dating ties is a complicated question that brings along some difficult interpretative questions,[22] and according to Lemercier 'assigning a duration to ties has rarely been used in historical or sociological studies.'[23] I agree with Lemercier that these dimensions are very important: they point out the subtleties that need to be taken into account for historical network analysis to be able to rise above the metaphorical. In the remainder of this chapter

[10] Lemercier, 'Formal', p. 283.
[11] Wetherell, 'Historical', p. 126.
[12] Lemercier, 'Formal', p. 283.
[13] Ibidem.
[14] Ibidem.
[15] Wetherell, 'Historical', p. 127.
[16] Lemercier, 'Formal', p. 282.
[17] Ibidem, p. 287.
[18] Ibidem, p. 282.
[19] Ibidem, pp. 282 and 287.
[20] Ibidem, p. 287.
[21] Ibidem, p. 289.
[22] Lemercier, 'Formal', p. 289. Questions are for instance: When does an edge end? What happens with the node after an edge disappeared? Does it disappear as well, even if there is still potential that a new edge will form? Do edges disappear with for instance the death of a node?
[23] Lemercier, 'Formal', p. 289.

we will encounter a discussion of the first, the third and to a certain extent the second dimension in the context of the case study of the Lunar Society.

4.2 Designing the blueprints for the Lunar Society networks

Demands

Above we encountered a couple of different examples of network characteristics, let us now consider which set of characteristics is needed in order to construct Lunar Society networks that could help us investigate its social and organizational structure. In historical social network analysis, networks are mostly medium-sized and the edges represent acquaintance or friendship (who knows whom), in which case the social relations are mined by close-reading of different sources. Sometimes, the edges represent strictly speaking a different kind of connection, but they are used as a proxy for acquaintance or friendship. Examples of these different kind of connections are for instance the epistolary one (who writes with whom), in which a letter between two nodes is for instance the source for an edge,[24] or an economic one (who traded with whom), in which a contract is for instance a source for an edge. For each case one should wonder if the use of such a proxy is in fact justified. Often, these social networks know a lot of heterogeneous structure, and so their structural patterns could be quite straightforwardly investigated by identifying structural aspects like the ones mentioned above (clusters, hubs, etcetera).

However, if we try to do something similar for the Lunar Society networks, we run into trouble. If it would be mapped who are acquainted, the network would be completely connected and all informative structural aspects would be lost.[25] If it would be mapped who could have written with whom (and presumably: wrote), the network would be completely connected and all informative structural aspects would be lost. Because even if some members might have never met each other in real-life (which I deem unlikely),[26] they did know who the other was, and even if they had never in fact written each other, they *could* have done so by the virtue of being a member of the same society. Belonging to the same close group allows for a wide-range of possible interactions. In fact, if we would study a larger eighteenth-century acquaintance or epistolary network, we would encounter the Lunar Society as a clique within the larger structure. We thus need to find out how to zoom in on this completely connected cluster in order to study the structure of the tight (and tied) community itself. We take as a hypothesis that they were acquainted and look for the relief in their social landscape.[27]

Which characteristics does the Lunar Society network need then? Based on the discussion above, we first need to conclude that the edges should not represent a *potential* for interaction, since that would lead in many cases to complete connectedness in the context of a tight group. Therefore, we need edges that represent *actual*

[24] Notice that an epistolary network is not the same as a map of all exchanged correspondence. Here we encounter the difference between interaction (the map of all correspondence) and the potential for interaction (the epistolary network). Contrary to the map, the epistolary network can be unweighted, the edge representing merely 'that they wrote', not 'how much they wrote'.

[25] Of course, the network is completely connected with the exception of people that could not have known each other during their Lunar Society membership because one of them already passed away before the other entered.

[26] Again, with the exception of members already being dead before another member arrives.

[27] As mentioned in the Introduction, finding a way to study the internal relations of historical cliques could be a real benefit, since there are many historical groups that could be identified as such.

interactions. Furthermore, since we want to study the overall social and organizational structure of the group, it is best to start with *whole networks*, and only fill in the details with *egocentric networks*. Whole networks focus on the edges among all participants in a social system, while egocentric networks just map the relations of a single node.[28] Lastly, because the aim is to study the *development* of (the social and organizational structure of) the Lunar Society, the data should be captured in dynamic networks. So, what could a model satisfying these criteria look like?

Models and methods

In the network models built in the context of this project, the edges represent a type of actual interaction that is the exchange of a letter.[29] In the first type of network that was built — the others will be encountered later in this chapter — each letter was translated to an edge directing from the sender towards the recipient (Network A) . Of course, the Lunar men sent each other multiple letters, which translated in the networks to multi-edges. For convenience and analytical purposes, these multi-edges were replaced by weighted edges, with the edge weight corresponding to the multiplicity of the edge (in other words: the number of letters that was sent/received).

One of the Lunar Society network demands listed above, was that the network should be dynamic. The edges all have a third coordinate that is the year in which their associated letter was sent, so the question was how that coordinate could be put to use in such a way that it contributed in providing insight in the social and organizational structure. Let me start by listing two methods that would not have led to this intended goal. Intuitively, one might had proposed to create a dynamic network in which edges were introduced in the year the letter was sent and in which the edge weight kept track of the number of letters that was exchanged between people up to a certain year: in other words, one's first inclination might have been to build an accumulative network. In the first place, this approach would not have been effective because it is impractical: at least with the techniques I had at my disposal, it would have meant building the network by glueing together separate one-year time slices, and creating such time slices for each year would have been very time-consuming. However, more importantly, this accumulative network would not have shown us a network that could eventually be translated to the social and organizational structure we are looking for. We want to know the social situation at a certain moment, but such a situation would not have been adequately represented by all the exchanged letters up to that point. Human relationships change, and it makes no sense to let the number of letters that has been exchanged between people, say, fifty years ago, play a (large) role in assessing the social situation at a specific moment.[30] Furthermore, such an accumulative network would had implied that nodes and their edges remain in the network, even if the members associated with them left the society (we could of course have decided to remove such nodes and edges at the

[28] Wetherell, 'Historical', pp. 127 and 130.

[29] Why not just mine the social relations directly and use these as the edges? There are two ways in which one could do this: extract them from existing literature, or derive them by close-reading primary sources. The first way is not an option, because we set out to check and complement precisely this literature. The second way would be to time-consuming: we are in fact looking for a method to circumvent the process of close-reading and end up with reliable results nevertheless.

[30] This does however not mean that the letters exchanged in the past do not influence a social situation at a later moment at all. The accumulative network plays the role of an abstract epistolary network (known to an extent by the participants in the network) that in a certain way maps the strength of 'life-long friendships' and the potential for possible new interactions. For this reason, the accumulative network was in fact built, as will be mentioned again later on.

moment members left, but then we would have assumed things based on the historical literature that we in fact wanted to conclude from the networks, in order to check or complement the literature). Also, the type of network would by definition have given the impression that the society was becoming closer and closer, denser and denser, as the years went by,[31] which does not have to be true and seems counterintuitive as well. Moreover, at a certain point everyone might have had exchanged a letter with someone else, which would have meant that the network would have become at a point completely connected again, and structure could then only be found in the edge weights. All these problems have one thing in common: they stem from the fact that in an accumulative network, edges do not disappear. We need to think about the temporality of the edges.

The next inclination might then have been to build the dynamic network from time slices that depict only the letters exchanged in that specific year. In other words: the edges would just exist for one year. However, that would not have worked as well. First, it would again be very time-consuming and impractical to create and interpret a network for each year. Furthermore, looking at the number of letters entered per year in the database, this number would have been to low to make meaningful networks, there would simply not have been enough structure to interpret. Also, if one would glue all these time slices together, the resulting dynamic network does not show any development, but just some flashing edges, especially because there are many years for which there is no letter between certain pairs of members included in the database.

Instead, the method chosen to study the social situations of the Lunar Society over time, was to bundle the meta-data in periods of five years, and to make networks for each of these five-year periods. Each network is then understood as *corresponding to* an instantiation of the social situation of the last five years,[32] and by glueing this series of static networks together, one creates a dynamic network. The crux of this method, is that by bundling the data in periods, you study a measure for how much letters pairs of people on average exchanged each year during the five year period (the average 'letter-writing rate').[33] Summing the years' numbers of letters neutralizes possible outliers: years that during the five-year period have a suspiciously high or low number of exchanged letters.[34] An average letter-writing rate during a certain period is intuitively easier to translate to conclusions about social behaviour, than an absolute number of letters exchanged within a single year without taking into account the surrounding years (both conceptually and because of the mentioned outliers). What one in fact does with the method, is letting a network with specific letter-writing rates grow for five years, in order to let it develop

[31] Lemercier states something similar when she writes about social networks without temporal edges (representing social interaction): '[I]t would, for example, lead to consider that social capital only increases during any individual's life, as each interaction would create an everlasting potential for future ties.' (Lemercier, 'Formal', p. 289.)

[32] As will be explained later on, the network thus not *is* an instantiation of the social situation. Remember that the edges represent numbers of letters, not social relationships.

[33] Perhaps counterintuitively, we do not have to divide all total amounts of letters exchanged between people by five to create network visualizations that depict the letter-writing rate of the period accurately. Since all periods have the same length, the visualizations are shown in the right proportions. Dividing all the amounts of letters in the periods by five to show the average letter-writing rate, would merely result in a scaling of the thickness of all edges (which visualizes the edge weight).

[34] Of course, since we are dealing with historical networks, we should not forget to pay attention to these outliers: what was the reason causing these sudden increases or stops in letter writing? However, these couple of interesting outliers do not outweigh the benefits of being able to study large time periods, to neutralize to an extent missing data and to be able to translate exchanged letters to social conclusions in general. It is always possible to go back to the database to localize outliers.

enough structure to investigate it.[35]

To determine the length of the periods in which one wants to divide the data, one should take into account the earliest date and the latest date as given by the metadata in the database, and choose a length that is balanced between depicting certain situations relatively adequate (the period should be long enough to create enough structure, but short enough to capture different situations) and practical constraints (the shorter the period the more networks one needs to make). For the current case, the period length of five years was chosen for the following reasons. In the first place, describing changing social situations in steps of five years seems to make sociologically and historically sense. During this time period we can reasonably expect that both the nature of relationships and historical contexts (such as the quality of the postal system) are usually relatively stable, which translates in principle to a relatively stable letter-writing rate for that period. Observations from our own human experience support this: social situations are rarely stable over, for instance, ten years. However, from these human experiences, we might as well want to conclude that a period of three or two years is a better scale to gauge social relationships, however, during such a period we encounter the risk that there is not enough structure to be investigated. The data is not of such a high quality that it could specify social structure at such a fine-grained level. For a period of five year, the current data set however includes enough data as to have enough structure that could be interpreted. Furthermore, such a short period of two or three years would mean that many more networks should have had to be constructed, which is unpractical. Lastly, the length of five years proved to be useful because the historical literature described the development of the Lunar Society often in similar periods of five years, which could be useful in the process of comparing the network results and the literature.[36]

Of course, this method has its problems as well. The most important issue we might encounter, comes from the realization that social situations do not all collectively transform at pre-defined points in time five years apart from each other. Investigating the data set in periods of five years should be understood as taking a series of samples. Some developments that have taken place in a time span shorter than five years (a three-year upheaval in a friendship for instance) might go unnoticed if they fall in two different sample periods in such a way that they do not have a significant effect in either of them. To alleviate this problem, one could always combine different samples in order to investigate periods of interest (a curiosity that might be sparked by certain findings or claims in the literature). It is however important to further investigate to what extent the choice of the begin- and endpoints of the five year periods influence the resulting networks. Do we get completely different results if the steps begin at 1757 instead of 1755?

Ideally, one would build a tool that is able to determine the network for a time period of each chosen length and begin- and endpoint, summing all the data that falls within the chosen range. (Think of a slider adjustable in size that could be

[35]Compare this with the following example. To determine if a certain mysterious car is a Ferrari or a slow car, you are not interested in its top speed or stops, but in is its average speed, because that is a characteristic feature. To determine this average speed you let the car drive for a couple of hours and see where it ends up. Notice that you could not let it drive for just a couple of minutes: the distance would be too small to give a conclusive answer about the average speed. Building a network for each period of five-years is like investigating multiple mystery cars.

[36]However, take into account that when you want to check or complement existing literature, it is better not adjust the lengths of the periods you use to interrogate the data to certain periods listed in the historical literature as marking a specific development. You would like to come to conclusions about such possible developments independently, with unbiased samples of the length.

slided trough the dataset and depicts the associated networks.)[37] In this way, you can make an approximation for the social situation at each year, even for the years for which no correspondence might have been found. This is because taking the samples in the way we did, is in fact a method to approach the letter-writing rates in the year that is in the middle of the period (see Figure 4.2). To determine the letter-writing rates of this year *exactly*, one should determine the slope of the tangent to the curve mapping the total number of letters exchanged up to a point,[38] this tangent drawn at the point associated with the year in the middle of the five year period. By summing the data in a five year period surrounding the point, in other words, by determining the growth of the total number of letters exchanged during these five years, you approach the slope of this tangent (divide by five for the numerical values, in network visualizations this factor is just a matter of scaling).[39] This immediately shows why it is important not to pick a time period that is too large, because in that case the growth during the period does no longer approach the rate in a year. Notice that for years in which no correspondence was found, it is in this way possible to assign approximations for the letter-writing rates (and thus the social situation) as well.

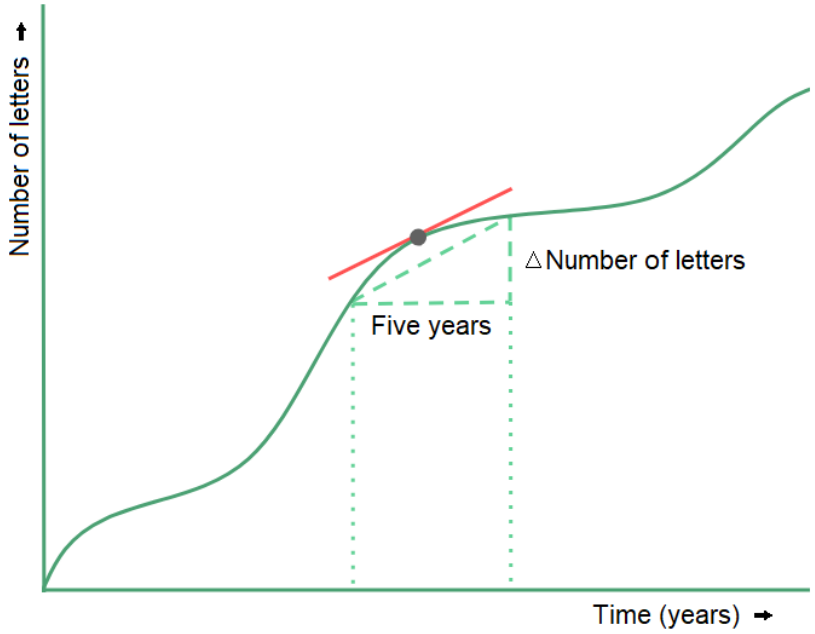


FIGURE 4.2: *A graph illustrating the relation between the five-year periods and the letter-writing rate of the year in the middle*

The type of edge that was chosen — the exchange of a letter — brings along a

[37] Gephi includes a slider that is adjustable in size and that could be slided through the dataset, however, this slider does not sum the edge weights of the edges within its range, therefore this slider would not be suitable for our current purposes.

[38] Strictly speaking, we should think of such a graph for each pair of persons, however, since the reasoning would run the same for each pair, we could for simplicity just think of one graph.

[39] It might seem counterintuitive and ahistorical to take future events into account to determine an earlier state of social relationships. It makes however perfectly sense: you need to take into account both past and future events in order to determine the 'social curvature' of a specific moment. You determine if things 'become better' or 'become worse', but this should not be seen as interpreting earlier events in the terms of later ones. The curvature is a historical observation on its own, the past and future events only provide material in order to reconstruct it.

couple of issues to consider. First, the temporality of the edges in the above described method (they are only included for a period of five years), entails that we need to think about possible temporality for the nodes as well. What happens with the nodes if they are not connected to any other node? I chose to depict all the twelve Lunar nodes in each five-year period network, even if they were not tied to others. The reason to do this, is that the absence of an edge could be just as informative as the presence of one: it shows when someone might not have been introduced to the Society yet, it shows that people might have not corresponded during a period, it shows that data might be missing, or it shows that people might have left the group. Because the context of association creates the potential to correspond, all associated nodes should be included.[40] A special case are nodes associated with members that passed away at a certain moment.[41] I did not remove those members from the networks, because for some network types created in this project their inclusion is useful, but to avoid confusion, I marked these members with a little cross. Another issue is that we should realize that, although the Lunar members would have been aware of their own letters they sent and received, they were not aware of the whole map of letters transferring between all members. In other words, the edges are 'subjective' (Lunar members knew about them and would describe them in a similar way as we do) as long as it is in the context of their own letters, but they are 'objective' if we consider the whole network.[42] Furthermore, in the context of letter-writing, the Lunar members might have been even more aware of their, and possibly others, relational structures in the described accumulative network. This network plays in a way the role of an abstract epistolary network, that provides a measure of the strength of 'life-long friendships' and indicates the potential for possible new interactions. For this reason, although it is not able to show us specific social situations, the accumulative network is in fact useful to contribute to a discussion about social and organizational structure. Especially, as we will see later on, because it provides an option to investigate some observations by network researchers about the development of empirical networks. Therefore, an accumulative network was created as well (Network D, but the design for this network as described up to this point will be labeled Network D', since the design will be adjusted later on). This was done in steps of five years too, both to make it feasible and for a reconstruction reason that will be explained later on. Lastly, we should keep an eye on the issue that the metrics conventionally used for social network analysis, are developed for networks with edges with a different interpretation ('These people know each other, this is how information could flow' or 'These people like each other, these do not'). Therefore, we should think about how the metrics could be reinterpreted in the context of the current networks.

[40] Notice that in other contexts, you might want to make another decision. If there is no specific reason (such as association), it does not necessarily seem always wise to include future correspondents already in earlier networks for instance. For these future correspondents (if there is no specific reason) there is just as much potential to correspond with as with any other figure living at that specific earlier time, and would not want to include all those other figures as well.

[41] Lemercier, 'Formal', p. 289.

[42] I borrow this use of the terms 'subjective' and 'objective' to describe edges from Lemercier, 'Formal', p. 288.

4.3 Refining the scale models by reconstruction and interpretation

Reflection
Up to now, two type of networks were introduced:

- Network A: The dynamic, directed network constructed from a series of networks associated with meta-data bundled in periods of five years, in which edge weights represent numbers of letters.
- Network D': The dynamic, directed network that portrays the accumulation of the number of letters in steps of five years, in which edge weights represent numbers of letters.

Before I explain the practical side of how the Lunar Society networks were built, let us first reflect a bit more on the meaning of the current network designs, in order to refine them.

It might have become already clear from the discussion above, but since it is a very important point, it is good to make it more explicit: the networks in the way they are currently designed, do not depict the Lunar Society's social and organizational structure itself. The edges do not represent social relationships, they represent numbers of exchanged letters, and these numbers (equivalently: these letter-writing rates) are not one-to-one related to the strength of social relationships. One could think of many other factors besides the quality of the relationship that influenced the number of letters sent or received, like how close people lived to each other, their personalities, their wealth, the quality of the postal system, or special circumstances, like disputes or sickness (both could lead to more and to less letters exchanged). Furthermore, it should be emphasized that the networks as they are currently designed do not depict knowledge flows either. The edges do not represent the paths along which knowledge traveled, they represent numbers of exchanged letters, and these numbers are not one-to-one related to how many ideas were transferred. One could think of many alternative ways besides letters in which knowledge traveled in the Lunar Society community: during the official Lunar meetings, during other gatherings, via publications, during some chit-chat in the streets of Birmingham, etcetera. Moreover, a network depicting knowledge flows usually depicts how knowledge *could* have flown. In the case of the Lunar Society such a network would again be completely connected: they could all have written each other a letter, they could all have met each other in real-life.[43] It would be very interesting to map how knowledge in fact *did* flow, but to do this, one should delve into the contents of letters and other source materials. Perhaps we could develop a tool that combines network visualization and text or figure recognition in letters, in order to track certain phrases or figures (illustrations, drawings, formulas) symbolizing ideas through the network. In this way we could map the flows of knowledge in a (correspondence) network, as if we would map the flow of a river by tracking the route of a paper boat.[44]

[43] Again, the dead members excluded.

[44] Of course an idea is in reality not a quantum of information that springs in finished form from a source node, ready to travel over the network's roads of knowledge, immune for any change while on its way. One should think of ways to map the and idea's development, spread, and the interaction between those two.

So, if it is not the social structure, might it then be the 'correspondence activity' of the Lunar Society that the networks depict?[45] Do we create an accurate map of all the letter-writing rates that were present between members over the years? Unfortunately, we do not. The networks do not provide a reliable picture, because we have to conclude that meta-data — and thus edges — are missing. In the first place, an evaluation of the data collection process must already point us in this direction. Have a look at the list of uncertainties in Section 3.4, many of these would result in missing data, because in those cases the data were not available, not found, not entered, or entered erroneously. Moreover, a quick analysis of the resulting dataset shows us quite clearly that data must be missing. Between 1775 and 1780, Keir sent Boulton for instance fifty-one letters according to the dataset, while it lists just one letter sent from Boulton to Keir, and this is not the only striking discrepancy in the dataset.[46] Of course one could just conclude that there are large disparities to be found in the dataset, and that we should interpret an observation like the one above as an instance of a desperate letter-writer, stalking the famous Boulton, but never receiving a letter back. However, that is very unlikely in the current context of the Lunar Society. These people were part of the same association and they corresponded — as we saw for instance in Section 2.3 — as equals. In such a case one might expect reciprocity. The contents of the letters support this explanation as well. If we study the references to other letters within the letters that were found, we have to conclude that there must have been more letters in existence once than the ones that were entered in the database. Take for instance the case of Keir and Boulton again. At the first of March, 1777, Boulton wrote to Keir: 'Dear Sir, I sent you about a fortnight ago some gilt scraps and some plated scraps [...]'[47] Then, at the twenty-ninth of October, 1778, Keir wrote to Boulton: 'Dear Sir, I have just now received yours [your letter] of the 23d.'[48] Comparing these two quotes, we come to the conclusion that there must have been more than one letter sent by Boulton to Keir. Also, already from the topics and tone of the letters one gets the impression that they are part of a more extensive correspondence (see Appendix B): data must be missing. Has the collection process then be executed that badly? Or have archives and sources with publicized correspondences then made that many mistakes? No, the Lunar correspondence data set is incomplete in principle: even if the meta-data of all currently-existing Lunar letters had been rightly entered, we should have had to draw the conclusion that data was missing. As described in Section 2.4, and taking into account the description of the postal system of Section 2.3 as well: there are just way too many occasions on which letters must have gone lost.

There is just one option left: all we would see in the networks is a visualization of the (dated) Lunar correspondence available at the moment for us historians to investigate — or at least, of the part of the material that was located and entered during this project. This is useful information. We can spot promising places where we have a good chance at finding undiscovered primary material in the blink of an eye, and we get an idea of the source material on which existing historical literature has been based. In this way, we acquired a tool to detect biases and prejudices in

[45] Remember that a 'correspondence activity network' is not equivalent to a correspondence network. The first one maps actual interactions, while the second one maps who interacts with whom. They relate to each other in the same way as phone records and contact lists.

[46] Another noteworthy observation, is that there has been no correspondence found from before the year 1755, while one should expect that based on (undisputed) information from secondary literature, like friendships that started already before the beginnings of the Lunar Society (which according to some literature started around this time).

[47] Boulton to Keir, 1 March, 1777, as cited in Moilliet, *Sketch*, p. 56.

[48] Keir to Boulton, 29 October, 1778, as cited in Tann, *Selected*, p. 174.

interpretation the constitution of the preserved material might have caused, which otherwise perhaps had gone unnoticed. However, although useful, the information will not answer any questions about the social and organizational structure. Yet, that does not mean that the research should be thrown away. First, it is important to realize that an incomplete data set is in itself neither problematic for history, nor for historical social network analysis. History is always written based on an incomplete data set. No historian ever has a perfect overview of the set of all the existing material, which in turn would very rarely be complete itself. Researchers of historical networks and other historians have the same historical shards at their disposal. Furthermore, the worry that the fragmentary nature of historical sources might not suit the data requirements of network analysis,[49] is just based on the misconception that the aim of HSNA would be to construct and study 'complete networks'.[50] This is however, as described above in Section 4.1, not the case. Networks are tools to investigate highlighted patterns, they are not meant to be complete depictions of the past, and fragmentary patterns are still informative patterns. On top of that, even sociologists, the ones that developed the method, hardly ever have 'complete information' at their disposal.[51] Dealing with missing data is inherent to (empirical) network analysis. This leads us to the second reason not to discard the project: there are indeed ways to deal with the missing data, and it is possible to translate observations about our 'maps of source material' to conclusions about social and organizational structure. Let me explain how.

Reconstruction and interpretation

The translation of the depiction of the available primary source material to observations about the social and organizational structure consists of two steps (see Figure 4.3). First, we should try to infer or approach the correspondence activity network based on our maps of available source material. To do this, we can apply methods of reconstruction. We ask ourselves: based on what we have found, what do we think the actual correspondence activity network would have looked like? Remember that reconstruction in itself should never be the goal of HSNA — the aim of the research is not to produce complete pictures of the correspondence activity networks — but it is a useful step to ease the derivation of conclusions about social structure from the source material maps. Secondly, to convert the resulting correspondence activity networks to insights into the social and the organizational structure, we need to interpret and to apply our historical skills. As I will explain later on in more detail, we have to combine the visualizations of the group's letter writing behaviour with historical contexts, biographical details, methodological considerations and an understanding of the data set we work with, in order to study social roles and organizational positions.

The missing data prevent the maps of primary source material to accurately reflect the complete correspondence activity in two ways: there might be no edges at all depicted between members that did in fact correspond, and visualized edge weights might not accurately represent the actual numbers of exchanged letters — which would cause mistakes during interpreting the networks because of unreliable relative proportions of the edges. In this project two reconstruction methods have been applied: converting edges representing absolute numbers of letters to ones that represent relative numbers, and complementing the network by edge symmetrization. Both were only capable of alleviating the second way in which the missing data

[49] Wetherell mentions the worry in 'Historical', p. 125. Lemercier in 'Formal', pp. 2, 6 and 7.

[50] Lemercier, 'Formal', p. 6.

[51] Ibidem, p. 7.

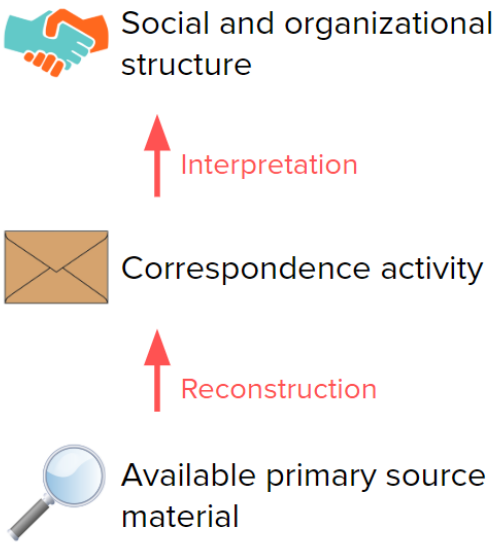


FIGURE 4.3: *Translating a map of available primary source material to observations about social and organizational structure*

distorted the networks. In other words: both methods provided a way in which biases created by preservation and by data collection were reduced, but they could not infer more connections on top of those given by the dataset.

As announced, the first method of reconstruction that was applied, was to convert the edges representing absolute numbers of letters to edges that represent relative numbers. These relative numbers were defined as the absolute number of letters associated with the edge divided by the total number of letters sent during the five year period by the sender of the letters associated with the edge.[52] By doing this, the edges became to represent the percentage of a Lunar member's complete (sent) correspondence within the five year period, as sent to a certain correspondent. By analyzing and comparing these percentages instead of absolute numbers, one alleviates the biases created by preservation and by data collection. We might not have found much correspondence of a certain member, but at least we know which part of the found (sent) correspondence was taken up by whom — which could be interpreted as a measure of social contact. The method should be thought of as understanding a member's found letters as an accurate sample of their total correspondence, the sample therefore reflecting the actual proportions of how much was written to each of his correspondents.[53] This however immediately points out a weakness of the approach: the found sample, especially a small one, will almost never be an accurate reflection of the total correspondence. If correspondence is missing, it is more likely that a certain topic, year, or correspondent is missing, than that the number of letters disappeared equally over the whole range. Still, although such specific gaps in the data might distort the proportions, they probably do not obscure them completely. Another weakness of the method is that because we work with percentages, increasing correspondence activity in one place might cause the false impression of decreasing activity in another. Even if two members started to write each other more

[52] In other words: the edge weight of the directed edge divided by the weighted degree of the tail node in one five-year period network slice.

[53] It is in this way that it is a method of reconstruction: it reconstructs the constitution of the the total (sent) correspondences of members, and by those reconstructions it reconstructs a network of correspondence activity.

often, the thickness of the edges between them might decrease if (one of) the correspondents began to write even more frequently with someone else, or started new exchanges of letters. Additionally, the use of percentages will also interfere with the calculation of metrics. Small numbers of letters could give rise to large edge weights, larger than the ones of edges associated with larger numbers of letters. The formulas of the measures were not constructed with such a situation in mind — for the formulas, the edge weights should in some way be proportional to a measure of interaction or the quality of contact. These limits should be taken into account when interpreting the networks.

The second technique for reconstruction was the complementation of the networks by symmetrization of the edges. As noted in Section 4.1, the Lunar Society should be considered a tight group, and as mentioned in Section 4.2, in such a tight group one may assume reciprocity: members responded to each other's letters. As was mentioned in Section 4.2 as well, the contents of the Lunar letters support this idea. Based on the assumption, I think it is safe to suppose that two members wrote at least as many letters to each other during a five-year period as the highest weight of the two directed edges between them.[54] This observation could then be implemented to translate the maps of available primary source material to an approach of the correspondence activity network, by transforming the directed networks to undirected ones, in which the edge weights of the edges between nodes is given by the highest edge weight of the edges between them in the directed network (the edge weight in the complemented networks thus depicts the number of letters a node sent and the number it received, it depicts the number of letter-pairs, multiply by two to find the total number of letters exchanged). In this way you get a more realistic impression of the letter-writing rates between members and of the constitutions of individual member's correspondence collections. Another advantage is that an undirected edge might conceptually be easier to understand as a 'correspondence strength', which might be intuitively easier to translate to conclusions about 'social strength'. Also, an undirected edge is in general more suitable in the calculation of certain metrics. The crux of the method is that edges get restored based on the better-preserved correspondence collections of the members. Of course, these better-preserved correspondences are not all equally complete, so biases created by preservation and the collection process should still be taken into account during interpretation. Furthermore, it is important to realize that the edges between members for which for both not much correspondence has been found, might remain misleadingly thin, since neither of them is able to correct for the lack of preserved correspondence of the other. If there was no link at all found between two such members, and if they are (after complementation) both connected to a third node by an edge with a high edge weight, we may have located a promising place to look for undiscovered letters according to the triadic closure principle.

Since the aim of the five-year period networks in Network A was to summarize the primary source material corresponding to the social situation of the last five years, it makes sense to apply the complementation technique for each of these networks separately in order to translate them to correspondence activity. However, in the case of the accumulative network (Network D'), the moment to apply the complementation method is not as straightforward. As we know, the network slices in the accumulative network do not only show the edges of the last five years, but all edges up to that point. A first inclination might then be to just sum all the edges up

[54] The phrase 'at least' is important here: since it is not given that the letters associated with the lower edge weight are in fact responses to the letters associated with the higher edge weight, the actual number of letters exchanged might have been higher.

to a certain point, apply the complementation technique and to repeat this for each slice. The choice for a step size would in this case be just a matter of practical convenience. However, in this way you might underestimate the number of letters exchanged between people up to a point. This is because you would make the mistake not to remove a certain difference between the numbers of letters two people sent to each other (the edge weights of the two directed edges) by complementation with extra letters to correct for missing data, but by complementation with letters sent at a moment in time that is in fact too late as to reasonably expect them to be responses to the 'unanswered' letters that caused the difference. Let me make this more clear. Think of two correspondents, Alice and Bob, and two bars that keep track of the number of letters they sent each other according to our data (see Figure 4.4). If we would want to make the slice of the accumulative network of 1775, we would have a look at the bars (Figure 4.4a), see that Bob is behind on Alice, complement for this difference (pink bar), and construct the network. Our first inclination might then be to construct the slice of the accumulative network of 1780 by repeating this process, and to correct for some of Alice's letters that went missing (Figure 4.4b). However, if we now take a look at Figure 4.4c and Figure 4.4d (the arrows representing a letter pair: a letter and its response), we see why we underestimated the correspondence: in the last figure, Figure 4.4d we mistook letters sent by B between 1775 and 1780 for lost responses of B between 1770 and 1775. In one period the correspondence collection of the first correspondent might be more complete and in another period the one of the other; we can make use of this fact to detect and complement for more missing data if we do this for periods of time that are not too long, and if we use the complemented network of the last period as starting point for the construction of the next network slice.

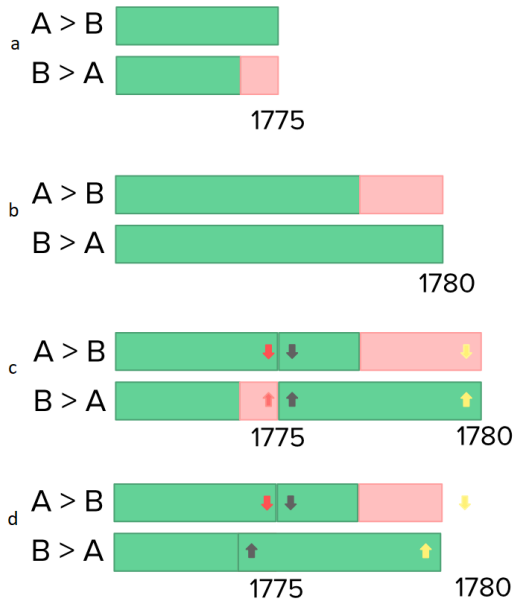


FIGURE 4.4: *An illustration of the importance of complementing an accumulative network in relatively small steps*

One could imagine that if the discrepancies between the two bars (Figure 4.4) might become quite large and that if at the same time the 'leading position' alternates a lot between the bars, that then the specific moment the score is checked has a lot of influence on the number of missing letters that gets inferred, which makes the

method less reliable. Fortunately, in the Lunar case the chance is very small to run into such a situation: in almost all correspondents pairs one of the correspondents is always 'leading' in the number of letters sent.[55] This definitely does not always have to be the correspondent for which in general more correspondence has been preserved, on the contrary, these well-preserved collections namely contain (for the obvious reason) mostly the *received* correspondence. A last remark about complementing accumulative networks, is that one should not make the period of time for which one complements too short either: you should not complement before people get the chance to respond. I think it would be a good rule of thumb to choose as step size for complementation a period between one and three years, depending on the estimated average response time in a certain time period and the quality of the data.[56] The chosen period length of five years for the Lunar case does of course not satisfy this rule of thumb, this is again due to practical constraints.

At first it might seem strange to 'make up' or 'guess' extra data by reconstruction, but reconstruction is in fact a method that is often applied in history: pottery is reconstructed from shards, the course of a war from fragmentary documents, world views from texts. The method of reconstruction is also not new for the field of network research (from the perspective of mathematics and computer science). There is in fact a quite substantial research strand that looks into the problem and investigates innovative methods to complement (or complete) networks. An example of such research is found in Kim and Leskovec's 'The Network Completion Problem: Inferring Missing Nodes and Edges in Networks' or Yuan, Stan, Warnick and Goncalves' 'Robust dynamical network structure reconstruction'. This type of research in the field of network science needs to be combined with knowledge of historical contexts, standards of historical research and the type of questions historians would like to study, in order to build a tool or design a method to reconstruct historical networks in an as advanced as possible way. Such a tool or method would use the discovered data as boundary conditions, and reconstruct the networks based on principles from network science, historical contexts, observations about empirical networks,[57] certain measures and calculations,[58] details about the construction of the data set,[59] and information about previously analyzed historical networks.[60]

After combining the blueprints drawn up in Section 4.2 (Network A and Network D') with the two methods of reconstruction, eight different networks could be constructed. I will list here only the four that were built during the project:

[55] If one correspondent is always 'leading', complementing in steps would give you the same result as just complementing at each time slice after summing the found data up to that point (the 'naive' procedure, as described in the main text). We know that for many Lunar correspondents pairs one of the writers is always 'leading', because many edge weights as given by the last slice of the uncomplemented accumulative network are equal to the ones of the last slice of the complemented network.

[56] One could even try to estimate relation-specific response times. This approach does however encounter problems if it are precisely the qualities of the relations that you set out to study, because such estimates presuppose knowledge of the qualities. Still, you might be able to make estimates of these response times by studying time periods for which it was noted that the preserved correspondence between people is fairly complete.

[57] One could for instance state that networks should be adjusted until they comply with a certain law that is observed to apply for empirical networks.

[58] One might perhaps be able to predict where links might be missing by calculating metrics like the resource allocation index.

[59] Ideally, one could for instance take into account which datasets are most reliable for certain time periods.

[60] Think for instance of pattern recognition and completion, based on patterns discovered in earlier research.

- Network A: The dynamic, directed, uncomplemented network constructed from a series of networks associated with meta-data bundled in periods of five years, in which edge weights represent absolute number of letters.
- Network B: The dynamic, directed, uncomplemented network constructed from a series of networks associated with meta-data bundled in periods of five years, in which edge weights represent relative numbers of letters
- Network C: The dynamic, undirected, complemented network constructed from a series of networks associated with meta-data bundled in periods of five years, in which edge weights represent absolute numbers of letters
- Network D: The dynamic, undirected, complemented network that portrays the accumulation of the number of letters in steps of five years, in which edge weights represent absolute number of letters.

Network C will be the main focus for interpretation and extraction of details about social and organizational structure. This network is connected to summarized social situations in five-year periods and it corrects for missing data by complementation. Since this technique erases potentially informative discrepancies — useful to detect undiscovered material, historians' biases, but perhaps asymmetric social relations as well — Network A was built to aid analysis (of Network C) with a map of the material actually found. Network B supports analysis by providing insight into the constitution of the sent correspondence of members by depicting relative edges. This is particularly useful to investigate nodes for which not much correspondence has been found. It is however best not to choose this network as the main focus for interpretation, because, as mentioned, one would run into trouble when calculating metrics, and useful information might go undetected if absolute values just play a secondary, supportive role. accumulative Network D was built with complemented edges, in order to depict the described (see Section 4.2) abstract epistolary network and map of life-long friendships as accurately as possible. This network is able both to facilitate in drawing conclusions about social and organizational structure, and to aid in investigating the development of the network as a whole in similar ways the growth of (other) empirical networks gets studied. For this reason, not only the metrics of Network C, but also the metrics of Network D were calculated. Networks that combined the two reconstruction techniques were not built. In such a case, one would first apply the complementation method, and afterwards transform the absolute edges to relative ones. Notice that this implies that the edges should stay directed during complementation, it would not be possible to create undirected relative edges, since relative edges depict a percentage of a node's total sent correspondence — they are node-dependent. A reason networks combining the two techniques were not built is that transforming absolute complemented edges — which were already corrected for missing data — to relative ones, does not necessarily create a more accurate image of the correspondence activity. What is more, they rather make the picture worse, since the ability to maintain absolute values was in fact a benefit of the complementation method. So, instead of providing more insight into the social situation, these type of networks would only bring more complexity: it is hard to study their foundations and find out what exactly is depicted and what the limits of the approach are. The reason that a directed uncorrected accumulative network or an accumulative network with relative edges were not built, is that undirected edges fit the interpretation of the accumulative network as an abstract epistolary network better. Furthermore, it strikes as problematic that

the total weight in a network constructed especially to study the growth of this network, is unable to increase, which would be the case for a network featuring relative edges.

Let us now turn to the next step of the translation: the conversions of the networks depicting correspondence activity to observations about social and organizational structure. As was stated in Section 4.1, networks can be studied at the level of nodes; at the meso-scale of patterns, connections and groups; and at the global level of overall structure. Therefore, our visualizations of correspondence activity are able to inform us on individual's 'letter-writing behaviour' (whom did one write with relatively often? in which periods did a person wrote less in general?), on the letter-writing rates we find between people (when did two people start to write each other more often? how did this behaviour change?), on patterns of letter-writing rates (can certain persons be identified as a letter-writing hub? was there a core group of active writers?) and on the general correspondence behaviour of the group (in which periods did the letter-writing activity of the group increase? with how many members of the group were the members in general in contact?). Each of these type of insights into correspondence activity could be translated to social and organizational conclusions in a different way, taking into account different types of historical contexts and different methodological considerations. However, in general the principle of the translation is similar for each case. As stated above, correspondence activity is not one-to-one related to social structure, since many other factors besides the qualities of relationships and the social situation could influence the observed letter-writing rates. Therefore, interpretation of the networks comes down to identifying these factors and taking them into account while deriving social structure from correspondence activity. An example would be to derive a strong friendship from the fact that a person who was known as shy wrote many letters to someone, even in less prosperous times. Another example is to detect the role of a 'social bridge' based on the fact that a certain Birmingham resident maintained much contact with people living outside the city. Let me list some elements that (ideally) should be considered in order to spot factors that could have influenced the observed letter-writing rates besides the qualities of relationships or social situations:

- Details about the data collection process and about the completeness of correspondence collections (of certain persons, in certain time periods), even after applying reconstruction techniques.[61] (Section 2.4 and Chapter 3)
- The specifics of the studied network models, including the technical details of the construction process and the particularities of the reconstruction methods, if applied. (Chapter 4)
- More general foundational and methodological considerations tied to network visualization and analysis.[62] (Chapter 4)
- Peoples' personalities. Since we translate correspondence activity to social conclusions by looking at how high a letter-writing rates were, we should have

[61] One might for instance want to weaken an observation that someone acted as 'letter-writing hub' if there has been much more correspondence for this person found than for others. (This correspondence set being so well-preserved might of course be interpreted as indicative of someone's importance, at least in the eyes of the ones that preserved it, although not necessarily in those of contemporaries.)

[62] Such as awareness of the pitfall to identify nodes depicted at the center of the visualization as 'at the center of the network', which is not necessarily true. (Lemercier, 'Formal', p. 293.)

an idea about what a relatively high and what a relatively low rate is for a certain person, which might be estimated by taking personalities into account.[63] (Section 2.5)

- Practical circumstances influencing the practice of letter-writing, such as the quality of the postal system, and the expenses of the post, of paper and of ink. Ideally these circumstances are both geographically and temporally specified.[64] (Section 2.3)
- Some ideas about persons' places of residence. If people lived in the same city, the chance is smaller that their social connection would express itself in letters. In other words: even if they were good friends, we might barely find any of their correspondence. (To an extent Section 2.3)
- Some awareness of other types of influential ties within the network, such as partnerships. These would for instance spark extra business-related mail between correspondents, resulting in higher edge weights. We should therefore be careful not to mistake a partnership for a close friendship (which does of course not mean that the one excludes the other). The letter-writing rates for business mail might be related to social and organizational structure as well, but in a different manner as personal correspondence. (To an extent Section 2.2)
- Attributes of the individuals, such as wealth (is one rich enough not to worry about the expenses of the post?), age (might one be too old to maintain one's correspondences at the same rates as in the past?) and perhaps education (would one that did not had much formal education experience more difficulties in letter writing, resulting for instance in lower letter-writing rates?).[65] (Section 2.5)
- Preferably one should have some general knowledge about the characteristics of social relationships and conventions in the period one is studying, including possible social constraints.[66] With this knowledge one might be able to establish what could reasonably be expected as 'appropriate' letter-writing activity for say, a close friendship or a leadership position within a group. (In other words: one should take into account the social and cultural contexts of the time period one is studying.)
- Events that might have influenced correspondence activity, both at the level of (inter)national events (events such as the French Revolution), at the local level (a happening in Birmingham) or at the personal level (journeys, sickness, emigration, a new invention, etcetera). (Section 2.1, to an extent Section 2.2, and Section 2.3)
- Information about the meaning of their correspondence connections, and their social ties in general, for the historical actors themselves. This includes for

[63] Simply put, a correspondence of twenty letters a year could be a sign of a very close friendship if one of the correspondents is socially withdrawn or dislikes writing, but the correspondence could just as well be explained as some insignificant exchange of letters for the social butterfly or letter-lover.

[64] It would for instance be important to know if a group started to write more often because they became more close, or because the postal system just became more reliable or cheap.

[65] In the case of the Lunar Society, I do not expect this last attribute to be that influential. The Lunars all seem to share similar letter-writing capabilities.

[66] Such as family ties inhibiting individual choices of social contacts, as was for instance the case in ancient societies. (Lemercier, 'Formal', p. 286.)

> instance knowledge about the ways in which the social connections expressed themselves besides in letter-writing: a general understanding of the type of social activities and interactions people might have been engaged in.[67] Regular meetings between people could for instance explain an observation of lower letter-writing rates than expected. (Section 2.2)

By merging the network visualizations with (historical) contexts, the networks are brought to live, preventing us to see them 'as graphs of relationships taken out of context and out of time, a mere dried skeleton of social life.'[68]

4.4 Building the networks with digital tools

Since setting up a DHSNA research design and assessing the practicability of DHSNA were both an integral part of the project, I will quickly summarize some technical details about the way the above described networks were constructed in order to offer the reader an impression of this process.

The construction started by preparing the data in such a way that they would meet the demands of the network designs and that they would be suited to be imported into Gephi — the software that was used to visualize the networks.[69] This was done by collecting the data for each five-year period in separate files, and by constructing for each file an adjacency matrix that depicted how much letters were sent from one member to another during this five-year period.[70] After that, the matrices were separately imported into Gephi to construct the network slices. For each slice a time interval was added and the Fruchterman-Reingold algorithm was used to determine the lay-out of the networks.[71] The choice of a lay-out algorithm is an important step in network visualization, since a well-chosen lay-out will ease interpretation, but each lay-out will in its own way also steer the interpretation of networks to a certain extent. The Fruchterman-Reingold lay-out was chosen for the Lunar networks because it depicted all nodes at equal distance from their closest neighbours, which created aesthetically-pleasing and clear networks, which prevented biases during interpretation, and, most importantly, which implied the networks would look similar for each time slice, which eased interpretation.[72] The next step was to combine all the network slices in one file as to create a dynamical network. A benefit of combining all slices in one file, is that Gephi will make sure the nodes will (at least with the Fruchterman-Reingold lay-out applied) be in the same place in each time slice. The scale of the thickness of the edges of the network was somewhat adjusted to improve readability. This is how Network A was created (Figure 4.5a).

To construct the other types of networks, practically the same scheme was followed. Only some minor adjustments were required. For Network B (Figure 4.5b), each value in the adjacency matrices had to be divided by the sum of the values of the row it was in, and multiplied by a hundred. The calculated relative values were rounded to integers, as to prevent the impression of false accuracy. We know of so many uncertainties during the collection process and suspect so much lost material,

[67] Lemercier, 'Formal', p. 289.

[68] White and Johansen, *Network Analysis*, as cited in Lemercier, 'Formal', p. 295.

[69] Gephi, `https://gephi.org/` (consulted at 8 August 2018).

[70] The row header listed the senders, the column header the recipients, the values within the table showed the numbers of letters sent. About the adjacency matrix, see for instance Wasserman and Faust, *Social*, pp. 150–153.

[71] Fruchterman and Reingold, 'Graph'.

[72] It is immediately clear which edges have become thicker, thinner, appeared or disappeared.

that it would be a mistake to pretend that this amount of precision for numerical values — calculated based on the uncertain data — would have any meaning. Network C (Figure 4.5c and Appendix C) was created by selecting an option to create undirected edges while importing the adjacency matrices in Gephi (note that this implied that the matrices became symmetric). To construct Network D (Figure 4.5d), first the data sets of the five-year period network slices of Network C were exported from Gephi. Then, the data set of each slice of Network D was prepared by 'summing the data sets' of Network C up to the point in time associated with the respective slice of Network D.[73]

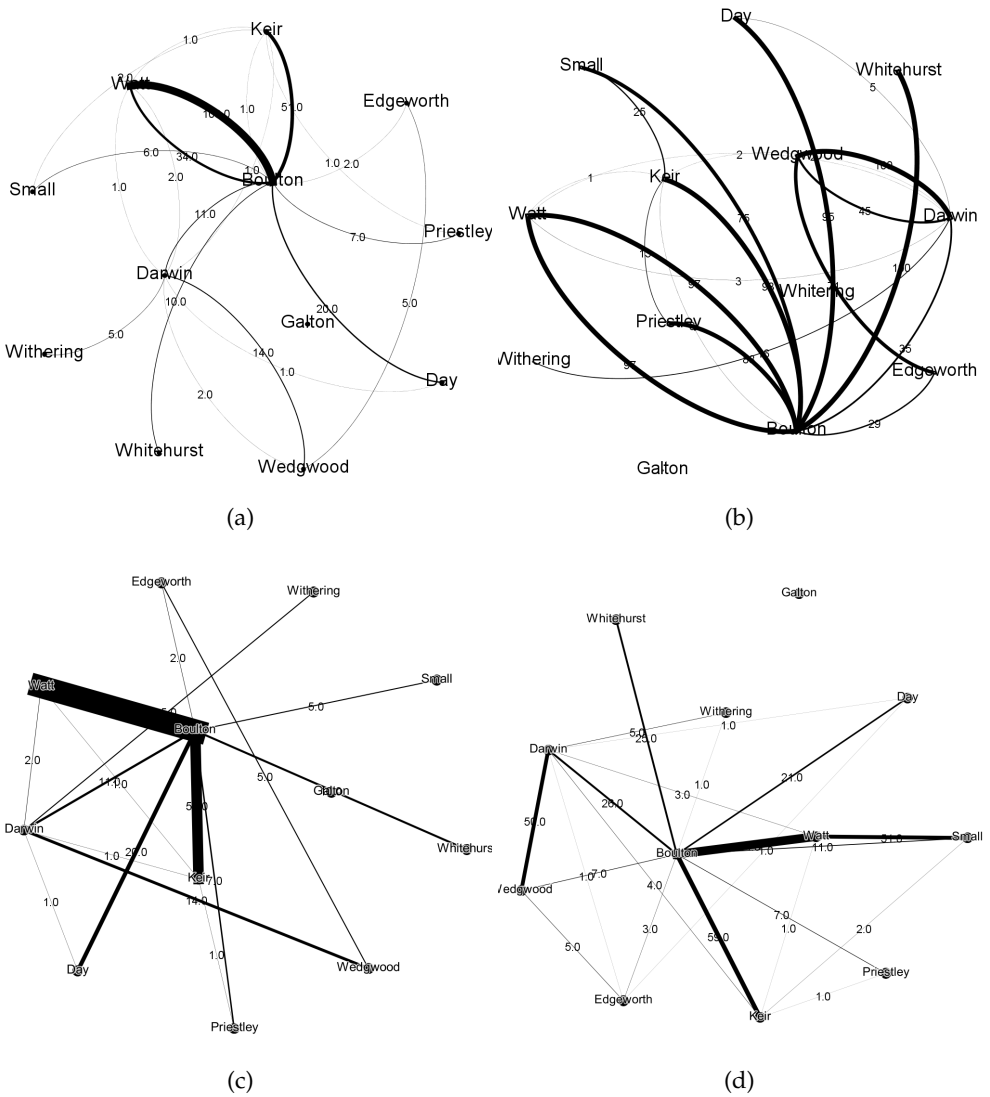


FIGURE 4.5: *Network slice 1775-1780 of Network A, Network B, Network C and Network D*: to compare the different network designs. Notice that the nodes are positioned differently in each slice.

[73] This comes down to adding the edge weights in the data set of the Network C slice associated with the point in time of the next Network D slice, to the ones in the data set of the previous Network D slice.

4.5 Observing the constructions with metrics and measures

Qualitative analyses
To ease the interpretation of the constructed networks, different qualitative and quantitative analyses can be carried out. Some qualitative methods include for instance detecting remarkable areas in the networks, such as interesting patterns, unexpectedly well-connected nodes, extraordinarily high edge weights, or asymmetric connections. Or one could for example look for nodes that did not have any connections with nodes associated with a well-preserved correspondence collection: what does it mean that these members did not show up in such well-preserved collections of others? Do we perhaps even have to doubt their membership?[74] Another qualitative method that could bring insights into the development of the social structure is for instance comparing the network slices of different years in order to spot new or changing ties. Speaking of comparisons over time, a benefit of this approach is that one might use what has already been learned about the nodes' social relations and their positions in previous slices to facilitate the interpretation of the next slices.[75] This principle could also be used for the qualitative analyses.

Quantitative analyses
To extract more potentially useful interpretative information from the networks, quantitative analyses were executed as well. Based on the dataset, different types of metrics were calculated. The metrics studied in this project could be divided into four categories:

- Node-level measures. To study characteristics of nodes within a network slice, and to study the development of these characteristics over time by combining the results for the separate network slices.
- Group-level measures. To identify possible subgroups within a network slice, and to study the development of the constitution of these subgroups over time by combining the results for the separate network slices.
- Network-level measures. To study characteristics of the overall network within a network slice, and to study the development of these characteristics over time by combining the results for the separate network slices.
- Distributions of the nodes' node-level measures within a single network slice. To study the constitution of the overall network within a network slice, and to study the development of this constitution over time by combining the results for the separate network slices.

By studying the node-level measures, one could learn more about the different social and organizational roles members might have taken up during different time periods. The group-level measures are useful to detect social subgroups such as clusters and cliques — perhaps there was a core group of active letter-writers within the Lunar Society? Or maybe some correspondence clusters were formed by members interested in the same kind of scientific topics at a certain time? The network-level measures are tied to the characteristics and the development of the social structure

[74] This will be discussed in further detail in Section 5.4.

[75] Might a low letter-writing rate between two people for instance be due to the fact that one of the correspondents had a long-lasting argument with the best friend of the other correspondent? Or how could we interpret a network slice knowing that a particular node has taken up a leadership role in previous years?

of the Lunar Society group as a whole. Lastly, the distributions come in handy to compare the network structure and its development with other (social) empirical networks. Interpreting and combining these four kinds of measures will provide observations about social situations.

When calculating metrics, it is important to keep in mind the specifics of the networks one is studying. As was mentioned in Section 4.2, the metrics conventionally used for social network analysis are not developed for networks with edges symbolizing the number of letters exchanged, but for edges depicting a social connection in general. Therefore, some of the metrics had to be reinterpreted in order for them to have meaning in our current case.[76] Of course, not all available network metrics have been calculated for the Lunar networks. Some metrics were not interesting in the Lunar Society context (although some of them might be of use to other historical research),[77] some would not make any sense in the context of the meaning of the edges, some would not bring any new insights on top of the ones already brought by other measures, for some the dataset was not large enough to give any meaningful results, and others would yield results that were too precise or calculated in a too complex way, which could not have been reconciled with the uncertainties of the dataset. Furthermore, it should be taken into account that in our networks, not all network slices are equally suited to be studied by a certain measure. For some five-year periods, not enough data is available — or: not enough letters had been exchanged — for the measures to have any meaning. This is not problematic at all, the purpose of metrics is to add information and insight, but in small networks these type of tools are not necessary to unravel the structures. For each metric, it had to be determined which of the four network types was best to use for the calculation. In practice, these turned out to be always Network C and/or Network D, both because of the interpretative value of the situations they depict and because they feature undirected edges. Ideally, one might have wanted to calculate some extra measures for Network A and Network B as well, but both directed and relative edges cause some trouble for constructing and interpreting the metrics, and it would have been too time-consuming in the context of this project. It is important to keep in mind that the metrics calculated for Network C and for Network D have (slightly) different meanings. If one wants to study for instance the development of a social role of a Lunar member, it is better to calculate this role (associated with a node-level measure) in each social situation depicting network slice in Network C and map these values, then to track the change of the associated measure's value through the accumulative network snapshot slices of Network D.

The metrics were calculated by using the NetworkX library in Python.[78] First a simple programme was written to convert data exported from Gephi to edge lists prepared for use in Python. Next to edge lists, some calculations required a node list as well (for normalization purposes). People were added to the list after they first sent or received a Lunar letter according to the database, and removed from the lists associated with Network C after their death, but always stayed on the lists

[76] Notice that the alternative — depicting social connections as to make the measures easily applicable — would have been much worse: as we know, in the Lunar case this would have resulted in completely connected networks, which are networks for which the metrics would make even less sense.

[77] The networks were for instance not large enough to study the properties of individual clusters (by calculating metrics just for these clusters), or to study the development of the networks in terms of clusters that become connected (in which case one could for instance try to identify a Gelling point, and investigate the interpretation of such a point in the context of historical networks.)

[78] NetworkX Python package, `https://networkx.github.io/` (consulted at 9 August 2018). Python programming language, `https://www.python.org/` (consulted at 9 August 2018).

associated with Network D. The code used to calculate the different measures and distributions can be found in the online resources set.[79]

Let me list the metrics that have been calculated (Table 4.1). I would like to refer to the documentation of the NetworkX library and to introductions in (social) network analysis for the specific (social) meanings, backgrounds and mathematical details of these measures.[80] The specifics of the relations depicted in the plots, laws and distributions can be found in McGlohon, Akoglu and Faloutsos, 'Statistical'. For each metric it had to be determined what their specific interpretation would be for the correspondence activity networks, and different types of choices and adjustments had to be made in order to make the metrics suitable for the current networks, including for the meaning of their edges. The interpretations are listed in Table 4.1, for the specific choices and adjustments (and the mathematical details) I would like to refer to the Python code and to the created graphs depicting the metrics. Both can be found in the online resources set.[81] Some remarks about shortest paths calculations will be mentioned here, because they relate to the interpretation of some important metrics.

TABLE 4.1: *Metrics and their interpretation in the context of the Lunar Society correspondence activity networks*

Metric	**C**	**D**	**Interpretation**
Node-level			
Betweenness	x		The extent to which a node was in between two letter-writing clusters or letter writers
Betweenness weighted	x		The extent to which a node was in between two letter-writing clusters or letter writers, edge weights taken into account
Closeness	x		A measure of a node's centrality within the correspondence activity network
Closeness weighted	x		A measure of a node's centrality within the correspondence activity network, edge weights taken into account
Clustering weighted	x	x	The extent to which correspondents of a node were corresponding as well, edge weights taken into account
Node degree absolute	x		The number of correspondents of a node
Node degree normalized	x		The number of correspondents of a node, the total number of nodes present in the network taken into account
Node strength / Node degree weighted	x		The number of letters sent/received by a node
PageRank	x	x	A measure for the importance of a node within the network, based on their number of correspondents and the importance of those correspondents in the network

[79] See Section 1.7 for the link.

[80] NetworkX documentation, `https://networkx.github.io/documentation/networkx-1.9.1/index.html` (consulted at 9 August 2018). Introductions to (social) network analysis are for instance the previously mentioned: Easley and Kleinberg, *Networks*, and Wasserman and Faust, *Social*.

[81] See Section 1.7 for the link.

Group-level			
Center	x	x	The core group of letter-writers
Periphery	x	x	The group surrounding the core group of letter-writers
Maximum clique	x	x	The largest group(s) of nodes that all correspond with each other
Network-level			
Average clustering	x	x	The extent to which correspondents of the nodes were corresponding as well
Average clustering weighted	x	x	The extent to which correspondents of the nodes were corresponding as well, edge weights taken into account
Average degree	x	x	The average number of correspondents of the nodes
Average node strength	x	x	The average number of letters sent/received by the nodes
Density weighted	x	x	A measure for the overall letter-writing activity (the average number of letters exchanged between all node pairs)
Diameter	x	x	A measure for the 'size' (or: the interconnectedness) of the correspondence activity network
Edge weight addition		x	The number of letters sent/received during the last five years
Number of edges	x	x	The number of correspondents pairs during the last five year (C) or up to a certain point (D)
Total edge weight	x	x	The number of letters sent/received during the last five years (C) or up to a certain point (D)
Number of nodes	x	x	Total number of (potential) correspondents in the network (according to the node list, see main text)
Transitivity	x	x	The fraction of the number of nodes that share a correspondent that corresponded themselves as well
Distributions and plots			
Node degree distribution	x		A distribution showing how many nodes had a certain number of correspondents in a specific network slice
Densification power law		x	The total number of correspondents pairs at a certain time plotted against the total number of nodes at that time
Edge weights power law		x	Depicting a characteristic the network, constructed in order to compare with other networks
Eigenvalue power law		x	Depicting a characteristic of the network, constructed in order to compare with other networks

Entropy/resolution plot	x	Depicting a characteristic of the network, constructed in order to compare with other networks
Total edge weight power law	x	The total number of letters sent/received up to a point plotted against the total number of correspondent pairs up to that moment

Some remarks about shortest paths calculations

Some metric and network principles rely on calculations of the shortest paths between nodes. Closeness centrality is for instance defined as the reciprocal of the sum of the shortest path distances from node u to all $n-1$ other nodes, normalized by the sum of the minimum possible distances $n-1$:

$$C(u) = \frac{n-1}{\sum_{u}^{n-1} d(v,u)}, \tag{4.1}$$

with $d(v,u)$ the shortest path length between v and u, and n the number of nodes in the network. Another example of a metric that relies on the shortest paths between nodes is the diameter of a network, and the associated observation that in empirical networks this diameter shrinks. However, in the case of the Lunar Society correspondence networks, metrics and reasonings based on the notion of shortest paths run into trouble. The underlying idea of the shortest path measures is that they interpret the paths as a measure of how connected nodes are — how easily they could reach each other. As we know from the discussion above: the Lunar Society networks as they are currently designed do not facilitate such an interpretation of the path lengths within the networks — the absence of past correspondence between Lunar members would not in any way inhibit them from reaching each other. For the metrics based on a shortest path length reasoning, an alternative interpretation was sought.

There is another important issue related to the shortest path calculations. Having the conventional purpose of the shortest path calculations in mind — a measure for how easily nodes could reach each other — one could think of two possible ways to define the shortest path within weighted networks. One way would be to take the edge weights into account as a measure of the quality of the connection (in other words: as a measure of how easy or fast interactions via this connection would proceed),[82] the other would be to neglect the edge weights and to only focus on the overall structure of the network. These two approaches could lead to significantly different results because the path of the best connections is not always the path of the least connections. Methods to mediate between these two extremes have been proposed, for instance by introducing a parameter to determine to what extent the edge weights should be taken into account.[83] Since the interpretation of the two approaches are both not clear in the context of the Lunar Society correspondence activity networks, the solution chosen in this project was to calculate both metric types and to have them both in mind during interpretation. By comparing them, it is easy

[82]Notice that if Dijkstra's algorithm is used to calculate the sum of the shortest paths, as is for instance the case for the closeness centrality measure in the NetworkX library, the edge weights will be interpreted as 'cost'. Since the Lunar correspondence activity networks demanded the opposite interpretation of the edge weights, the problem was solved by feeding the algorithm the reciprocals of the edge weights.

[83]For a description of this approach and for an explanation of the problem in general: Opsahl, Agneessens and Skvoretz, 'Node Centrality'.

to assess what the intermediate versions would have looked like, had one added a parameter.

Chapter 5

Interpreting the images: historical accounts and their comparison

Now that we have constructed the networks and calculated the metrics, it is time to find out to what extent their analysis is able to add to existing knowledge. The main question of the case study in this thesis is of course how much network analysis might be able to contribute to the Lunar historiography. In this context we will therefore investigate if the networks are in fact reliable enough for such contributions (Section 5.2), we will explore the networks for new findings and hypotheses (Section 5.2), and we will find out if the networks and metrics are able to decide on the four disputes among Lunar historians mentioned in Section 2.4. These four disputes are about the rise and decline of the Lunar Society (Section 5.1), certain social roles of the members (mainly Section 5.3, Section 5.2 to an extent), Lunar membership (Section 5.4) and the interpretation of the Lunar Society (Section 5.7). There are however a few alternative ways in which analyses of the Lunar networks might be able to contribute to existing studies. In Section 5.5 it will be studied if analysis of the Lunar networks could serve as a case study to teach us something new about another historical topic: the savant-fabricant interface. Furthermore, in Section 5.6 we will find out if Lunar network inquiry might be able to add to the study of the development of empirical networks — a strand within (social) network research — and if this study might be able to add to the exploration of historical networks.

5.1 The rise and decline of the Lunar Society

The literature
Historians do no agree about the Lunar Society's date of establishment. Smiles believed a definable society already existed in the mid-1760s.[1] Bolton agrees and states that the Society was founded about the year 1766.[2] Schofield recognizes the existence of a growing group of friends from 1765 onwards, but claims that the Society only properly began after the year 1775.[3] Robinson disagrees and states that Schofield 'provides no evidence for his assertion'.[4] Instead he opts that 'the Lunar Society was certainly in existence in 1772', but thinks that it might be traced back even further, perhaps starting already in 1765.[5] Uglow follows the tradition of the nineteenth-century historians by estimating a founding year of 1765.[6]

[1] Jones, *Industrial*, p. 89.
[2] Bolton, *Scientific*, p. 195.
[3] Schofield, 'Bicentenary', pp. 146–150.
[4] Robinson, 'Membership', p. 156.
[5] Ibidem.
[6] Uglow, 'Birmingham'.

There is no consensus among historians about the date for the end of the Lunar Society either. According to Jones, Schofield finds no record of any Lunar meetings after 1794, but Jones writes that this date should not be accepted as ending date, because of ample evidence to indicate fairly regular meetings into 1802.[7] In fact, he claims that the Society had become extinct only by the end of 1804.[8] However, Jones is wrong about Schofield's opinion on the date. According to Schofield, meetings were at least still held in 1799, and perhaps as late as 1803, although he does think that around this time the Society's character had changed significantly and that it no longer maintained the active work that once distinguished the Society.[9] In fact, according to Schofield the Lunar Society should be understood as *effectively* moribund or dissolved by 1798.[10] He furthermore states that 'though there are indications of a few casual meetings of the Society as late as 1799, references to the Society after the Birmingham riots of 1791 demonstrate a falling-off of the spirit characteristic of earlier associations'[11] Robinson criticizes Schofield's idea that something could be said about a spirit characteristic of earlier associations falling off and writes that '[t]he meetings in 1799, 1800, and part of 1801 were certainly neither causal nor irregular [...]. Until we know more about what went on at these meetings it is impossible to determine in what spirit they were conducted.'[12] Robinson claims instead that the society was not dissolved as late as 1802, and thinks it perhaps even existed in 1809. This last idea is based on a statement of contemporary Leonard Horner — first referred to by Smiles — which reads that: '[t]he remnant of the Lunar Society and the fresh remembrances in others of the remarkable men who composed it, are very interesting. The impression which they made is not yet worn out, but shows itself to the second and the third generation [...]'[13] Bolton quoted this same statement, but for him it was not a reason to conclude that the Society still existed in 1809. In fact, he does not opt a specific ending date at all, but states that the Society gradually dissolved as the century drew towards an end, because 'the few lingering survivors found its associations too painful to be continued,'[14] because the members had dropped off one by one. Uglow is also not definitive about an ending year, she estimates the Society to have been dissolved around 1800.[15]

Analysis

Light can be shed on both issues by studying the density metrics for Network C and Network D, and by investigating the number of meetings and the number of known Lunar activities over the years. Remember that the density of a network slice is a measure for the overall correspondence activity. This metric calculated for Network C shows us the letter-writing activity during a five-year period (Figure 5.1a), calculating it for Network D provides us with a more clear view on the rate of change in the amount of correspondence activity during the years (Figure 5.1b).[16] In graphs associated with Network C, the indicated years are the latest years in the five-year

[7] Jones, *Industrial*, p. 89.

[8] Ibidem, p. 90.

[9] Schofield, 'Bicentenary', pp. 157 and 158.

[10] Schofield, 'Membership of the Lunar Society', p. 128, as cited in Robinson, 'Membership', p. 156.

[11] Schofield, 'Membership of the Lunar Society', p. 214, note 17, as cited in Robinson, 'Membership', p. 156.

[12] Robinson, 'Membership', p. 156.

[13] Leonard Horner, as cited in Robinson, 'Membership', p. 156, as cited in Smiles, *Boulton*, p. 309.

[14] Bolton, *Scientific*, p. 217.

[15] Uglow, 'Birmingham'.

[16] Since Network D is an accumulating network, the density will always increase. However, the rate of increase shows if the correspondence activity grows or declines.

periods the depicted values correspond with. As we know, in the graphs associated with Network D the points just inform us about the state of the accumulating network in that specific year. Figure 5.2 depicts the number of meetings during a certain five-year period, again only the last year of this range is indicated. It is important to know that this figure draws on Jones' investigations, which means that his criteria for what counts as a Lunar meeting have influenced the image. It is however the most extensive overview of (known) meetings of the Lunar Society I encountered in the literature.[17] Figure 5.3a and Figure 5.3b center around the number of Lunar meeting activities which are known to us, depicted per time period and in total up to a certain point in time. I understand this number as a measure for how explicitly activities (during meetings) were discussed in correspondence during a certain time period (explicit discussion being the reason we still know about them), which I understand in turn as a measure of overall attention for and occupation with concrete activities by Lunar members. These two pictures have been created based on the mentioned list of activities of the Lunar Society (Table A.1). The table is a result of the work of Jones as well, so it might have been influenced by his criteria for what counts as an activity. Furthermore, the images should be understood as an impression of the numbers, because Jones does not state that his aim was to create a complete list and because some activities might have taken place during multiple meetings.[18]

In Figure 5.1a we see that the density started to rise from the period 1755–1760 onwards, peaks in the period 1780–1785, starts to decrease afterwards and continues to do so until 1810–1815. The way the density increases and decreases seems to approach exponential growth and decay. This observation is supported by the curve of the density metric for Network D, which approaches logistic growth. If we would solely concentrate on the density metric associated with Network C, we might want to conclude that it is more likely that the Lunar Society was founded in the mid-1760s, than in the mid-1770s. However, Figure 5.1b is able to provide us with more detail about the density growth. We notice that although the density started to increase from the period 1755–1760 onwards, it really took off in the period 1775–1780. One could argue that this conclusion is founded on a distortion caused by the fact that the density was low in the period 1770–1775, as shown by Figure 5.1a, however, the same observation about increasing growth would have been made if the value associated with the period 1770–1775 in Figure 5.1b would have been higher. Another alternative explanation for the increased growth would be that it was only due to an increase in business-related mail because of the steam engine partnership that was formed between Boulton and Watt in 1775, and to the involvement of Keir with the Soho manufactory from 1777 until 1781 (he managed the factory during the lengthy absences of Boulton and Watt, among other tasks).[19] However, if we compare the network slice of the period 1770–1775 (Figure C.1d) and the one of 1775–1780 (Figure C.2a) in Network C, we observe that these business-related letters are indeed well-represented, but that the growth of the network is definitely not limited to these ties. The connection between Keir and Watt is even surprisingly thin considering their work relation.[20]

This increase in the rate of growth of the density — or in other words, the fact that the correspondence activity started to grow faster — could be used as an argument

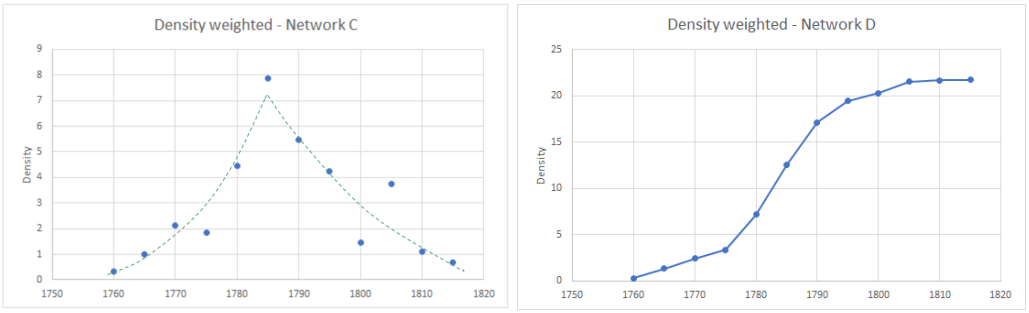
[17] Jones' study was published in 2008. To my knowledge, no new Lunar primary source material has been discovered in the last ten years (or at least not in significant amounts). Jones, *Industrial*, p. 90.

[18] Jones' list is not clear about how indicated ranges of years should be understood.

[19] Moilliet and Smith, 'Keir', p. 145. Uglow, *Lunar Men*, pp. 252 and 253.

[20] I think this must be due to lost correspondence.

for the mid-1770s as the period of establishment of the Lunar Society. Of course, the density increased in the period 1765–1770 as well, but the rate of the increase is similar to the ones in the period before and after. Therefore, this growth should probably just be identified as due to the development of the group of friends from which later the Lunar Society would spring. If one wants to argue that the start of the development of this group of friends should already be understood as the beginning of the Lunar Society, then one needs to defend why the mid-1760s are picked as starting moment, and not the early 1760s or even the mid-1750s, since the growth of correspondence activity was similar in those periods. Notice however that it is difficult to draw definitive conclusions about these very first periods, because the amount of data for these years is minimal. Based on these observations, I think we should conclude that the development of the correspondence activity supports the view that the Lunar Society properly began in the mid-1770s, but that there has been a growing group of friends at least from 1765 onwards, perhaps earlier. Since the growth of the correspondence activity is much higher in the period 1775–1780 than in the period 1770–1775, I think this evidence subscribes Schofield's estimate of 1775 as date of establishment more than Robinson's estimate for 1772. This view is supported by Jones' data about Lunar meetings (Figure 5.2a) and Lunar meeting activities (Figure 5.2b) as well,[21] since he counted just one meeting and one activity before 1775.[22]



(a) (b)

FIGURE 5.1: *Density metric for Network C and for Network D*

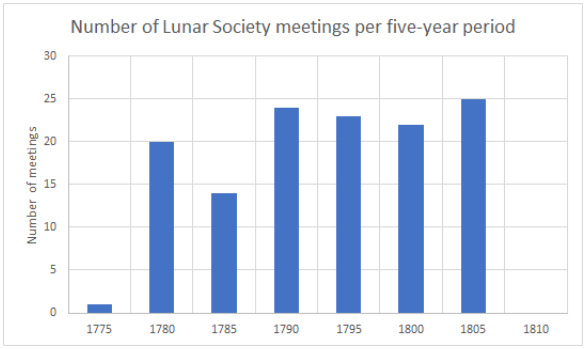
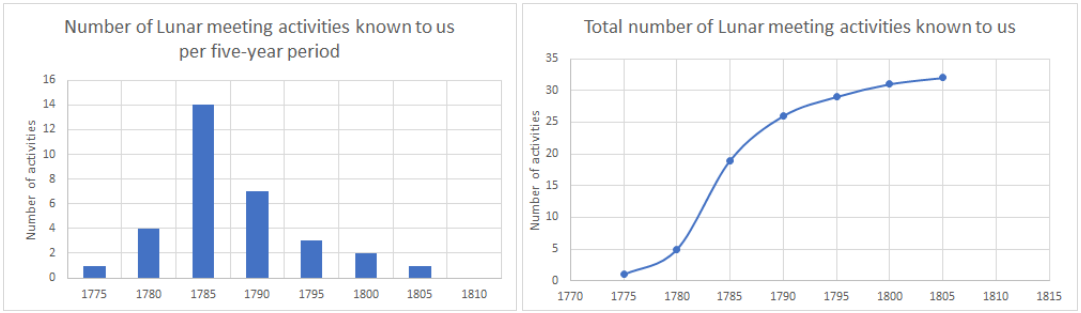


FIGURE 5.2: *Number of Lunar Society meetings per five-year period*[23]

[21] The fact that these two figures support the view is an extra argument against the claim that the increasingly growing correspondence activity is only due to the business-related letters of Boulton, Watt and Keir.

[22] In 1774 and 1771 respectively, which implies that Jones contradicts himself and that the 1771 activity should probably be understood as an activity of the developing group of friends.



(a) (b)

FIGURE 5.3: *Number of Lunar meeting activities known to us per five-year period and in total*

Let us now focus on the decline of the Lunar Society. The density metric for Network C (Figure 5.1a) shows that the density started to drop after the period ending in 1785. However, although the density might have been lower than in the previous period for the first time, during the period 1785–1790 it was still relatively high. In the density metric for Network D, we observe that the significant decline in the rate of the density growth started in the period 1790–1795, with the growth becoming even less between 1795 and 1805, with effectively no changes in the density anymore after 1805.[24] The visualizations of the numbers of (known) Lunar meeting activities depicts something similar. After the period 1780–1785, the number of meetings per period goes down, but in the next period 1785–1790, the number is still relatively high. Then, in the Figure 5.2b we see that the decline in the growth of the total number of meetings is centered around 1790, and from the first half of the 1790s onwards the growth comes to a standstill. A possible explanation for the observation that the graphs of the correspondence activity and the ones of the numbers of (known) Lunar meeting activities match that well, could be that there is just a better chance of discovering Lunar meeting activities in letters if there have been more letters exchanged during a period. We can however counter this thought by looking at Figure 5.2 and realize that in the years after the period ending in 1785, the meetings did still get mentioned in letters, but apparently these mentions were no longer accompanied by descriptions of activities executed during the meetings — perhaps because the members no longer performed concrete activities, or because the activities carried out were not noteworthy enough to write about in a letter. Speaking about Figure 5.2, it stands out that it depicts meetings still being held in the period 1800–1805. In fact, it was apparently the period in which most meetings took place. We have to keep in mind that the image is based in Jones' criteria and that some of the later meetings included people that we did not take into account as members (some Lunar sons for instance), still, some last remaining Lunar members of our list might have participated as well.[25] Considering these observations, we can conclude that if one bases oneself on the numbers of meetings that took place, one will find that the

[23]The small dip in the period 1780–1785 is due to a mistake in Jones' data: the number of meetings in 1781 is not depicted in his diagram (while his table of Lunar meeting activities, Table A.1, does list activities dated in 1781).

[24]If one looks at Figure 5.1a, one does see significant changes in the period from 1800 till 1815. The reason these are not (or barely) reflected in Figure 5.1b has to do with normalization: one calculates the number of letters exchanged per all possible correspondents pairs, in Network C there are around this time less nodes taken into account (because members died) than in Network D, which could cause some outliers.

[25]Schofield, 'Bicentenary', pp. 157 and 158.

Lunar Society ended between 1800 and 1805 (a closer look at Jones' data shows that the last meeting must have been in 1805).[26] However, if one focuses on correspondence activity or the attention and occupation with activities during meetings, one will find that the Lunar Society started to decline after 1790, had almost no activity anymore around the year 1800, and completely ceased to exist after 1805.

Extending this observation a bit further and combining it with the conclusions about the starting date of the Lunar Society, we might be able to explain the historians' confusion about the dates. Not only the different views on the ending year of the Society could be traced back to either a focus on (correspondence) activity or to meetings, it applies to the discussion about the starting date as well. Although there has been already a meeting recorded in 1774 (according to Jones' criteria), for Schofield the Society only properly started with the increase of (correspondence) activity (after 1775). Robinson instead picks the year 1772 because he thinks a first meeting must have taken place in that year in October.[27] The other historians do not take the start of 'official' Lunar meetings as criterion for the date of establishment, but instead they base their estimates on the start of the informal gatherings of the group of friends that took place prior to the organized Lunar meetings. Combining the different insights into the discussion about the starting date and about the ending date, we can conclude that Schofield focuses on (correspondence) activity, while for Robinson and Jones the Lunar meetings were most important. It is less clear what must have been the criterion for Bolton and Uglow, but I suspect it to be the formation of friendships and general informal meeting of the group of friends. With these insights in mind, it is easy to see why Schofield detected the spirit characteristic of earlier associations falling off from 1791 onwards, and why Robinson objects to the claim: the statement is true if you focus on (correspondence) activity, but if you concentrate on meetings, it is unfounded and premature '[u]ntil we know more about what went on at these meetings [...].'[28]

5.2 The development of the Lunar Society

The literature

Here I will give a brief summary of how and when the Lunar group came together, and how the group developed over the years according to the historical literature. The focus will be on the introductions, the involvement and the leaving of Lunar Society members. It is not meant to be a complete overview of the whole Lunar history including its accomplishments, struggles and events. The summary is based on Schofield's 'Bicentenary', Robinson's 'Membership', Uglow's 'Lunar' and *Lunar men*, Bolton's *Scientific* and Jones' 'Industrial'. Statements they all agreed on will not be cited (or at least: not disagree with, since not all accounts cover the same time period), citations will only be given in the context of their personal opinions or if other sources were applied.

Although both Darwin and Boulton already knew Whitehurst, according to Uglow the real first step in the development of the Lunar Society was that Darwin and Boulton met in the late 1750s, after Darwin moved to Lichfield in 1756: 'The first Lunar link had been forged.'[29] From this time on the trio was corresponding and they

[26] Jones, *Industrial*, p. 90.

[27] The evidence he provides, a quote from a letter from Keir to Boulton, is unconvincing. (Robinson, 'Membership', pp. 156 and 163.)

[28] Robinson, 'Membership', p. 156.

[29] Uglow, *Lunar Men*, p. 45.

sometimes met informally, according to Robinson (some of) these meetings were in the context of philosophical gatherings at Darwin's house.[30] Schofield adds to the description of these earlier years that the 'scant remaining correspondence' does not 'reveal much of the sense of group cohesion nor any of the centripetal tendency drawing others into the group' that would become apparent later.[31]

In 1765 Small was introduced to Boulton by a letter of introduction from Benjamin Franklin. Boulton and Small got along very well, and Small settled in Birmingham to become the Boulton family's physician. Over the years, Boulton's strongest friendship had become the one with Darwin,[32] and Boulton's new closeness to Small threatened Darwin and Boulton's friendship slightly.[33] However, Small was soon introduced to Darwin and they became friends well. Darwin and Wedgwood met in 1765 through their common efforts for rallying support for the development of the Trent and Mersey Canal.[34] By this time Wedgwood knew Whitehurst as well, and Boulton and Small probably too. The literature is not explicit about if this happened before or after Wedgwood met Darwin, and if it happened with or without Darwin's interference.

In 1766 (1765 according to Robinson) Edgeworth visited Darwin in Lichfield to discuss their mutual interest of mechanical inventions. During the visit, Darwin invited Small and Boulton at his house to meet Edgeworth. The historical literature seems to agree that the visit must have been the occasion that Edgeworth and Small met, however, Edgeworth himself recalls that he became acquainted with Small by the means of Keir,[35] whom he (presumably) met in 1767.[36] So either the visit of 1766 has not taken place, or Edgeworth's memory was at fault. Both Day and Edgeworth had been students in Oxford, and they met in 1766 and became good friends. Edgeworth introduced Day to Darwin, Whitehurst and Small (and to the rest of the Lunar group, although these meetings are not mentioned explicitly by the literature), probably in 1766 or 1767. Day very much appreciated Small.

In 1767 (or, according to Uglow, in 1766)[37], Keir visited Darwin, whom he was a fellow student with at the University of Edinburgh. He was introduced to Boulton, Small, Wedgwood and Whitehurst, and perhaps to Edgeworth as well. During the same year, Watt visited the Soho manufactury where he met Small and Darwin, Boulton was absent at the time. According to Robinson, it was Small who first established (epistolary) contact with Watt.[38] Over the next years, until he settled in Birmingham in 1774, Watt kept in touch with the Birmingham group through correspondence, especially with Small.[39] Around this time, Priestley was known to (some

[30]The evidence he provides for this claim, a quote by Anna Seward, is however unsatisfactory. Seward describes how a circle of philosophers gathered at Darwin's house, but her account could not be about a meeting in these earlier years, since 'Mr. Kier, of West Bromwich, then Captain Kier' and 'the accomplished Dr. Small of Birmingham' could not have been present at a meeting in Lichfield at that time, introductions had yet to be made. Furthermore 'The Rev. Mr. Michell [John Mitchell], many years deceased', was if fact still alive. (Robinson, 'Membership', p. 154 and Seward, *Memoirs*, pp. 16 and 17, as cited by Robinson, 'Membership', p. 154.) It is more likely that Seward refers to a later Lunar meeting, somewhere between 1768 (the year Mitchell died) and 1775 (the year Small died).

[31]Schofield, 'Bicentenary', p. 147.

[32]Uglow, *Lunar Men*, p. 80.

[33]Ibidem, p. 84.

[34]See Section 2.2 and Section 2.3.

[35]Edgeworth, *Memoirs*, vol. 1, p. 186, as cited in Doherty, 'Intellectual Friendship', p. 233.

[36]Doherty, 'Intellectual Friendship', p. 233. However, as we will see below, perhaps Edgeworth could have met Keir already in 1766.

[37]Uglow, 'Birmingham'.

[38]Jones, *Industrial*, p. 86.

[39]Schofield, 'Bicentenary', p. 148. Uglow, 'Birmingham'.

members of) the group, but was not yet involved.

By 1768, the nucleus of the Lunar group had come together according to Schofield.[40] Who should be seen as part of this nucleus differs a bit per historian, they seem to agree on Boulton, Darwin, Watt, and Small; with Day, Keir and Edgeworth at the border of the nucleus; about Whitehurst and Wedgwood there is no consensus.[41] According to Edgeworth, at this time, 'Dr. Small formed a link which combined Mr. Boulton, Mr. Watt, Dr. Darwin, Mr. Wedgwood, Mr. Day and myself together — men of very different character, but all devoted to science and literature.'[42] Notice that Edgeworth does not list Keir in this excerpt, he is however mentioned by him a little earlier in the text. The most diverging opinions are about Wedgewood's position:[43] Uglow and Schofield list him as a core member,[44] Jones, Robinson and Bolton think he is merely in the penumbra.[45]

Schofield states that during these early years, there are no signs that the group had become organized.[46] This changed in 1775 and in 1776, when the group was set on a firmer formal footing and activity was renewed, a development that seems to have been initiated by Boulton. According to Schofield, the reorganization was due to Small's death in 1775, he states that '[i]f the group was not to dissolve as spontaneously as it had been created, something must be found to substitute for that 'link which combined' its members. The substitute was to be the transformation of this association of friends into a society.'[47] Robinson however writes that he had been unable to find warrant for Schofield's assertion that it was Small's death that caused the group to be organized on a more formal basis.[48] More happened in 1775: it was also the year Boulton and Watt started their partnership, it was the year Withering moved to Birmingham to replace Small (by suggestion of Darwin), and it was the year Whitehurst left the Midlands for London. Before Withering moved to Birmingham, he had — next to Darwin — already met Boulton, Wedgwood, and was known by reputation to Priestley. Some rivalry developed between Withering and Darwin, and they ran into conflicts in 1784 and 1785. Whitehurst's move to London turned out to be to the advantage of the Society, because he came to serve as a London outpost for the group. During his years in London, he kept visiting Birmingham frequently. As mentioned above, in 1778 Keir started to work with Boulton and Watt and managed the Soho manufactury in their absence, this collaboration lasted until 1780.

In 1780 Priestley came to Birmingham and joined the Society. As mentioned above, Priestley already knew some of the members before his move. He had met Wedgwood during the 1760s, he had visited Soho, he had met Whitehurst in London, wrote with Boulton and Keir, and referred to the work of some Lunars in his publications. There are signs that with the introduction of Priestley the activity and the regularity of the Society renewed. Watt and Priestley worked both in collaboration and in competition. In the same year (or a year later according to Jones) Darwin

[40] Schofield, 'Bicentenary', p. 149.

[41] As we know from Section 2.5.

[42] Edgeworth, *Memoirs*, vol. 1, p. 186 as cited in Doherty, 'Intellectual Friendship', p. 233.

[43] See Section 2.5.

[44] Schofield, pp. 147 and 149. Uglow, *Lunar Men*, p. xiv.

[45] Bolton, *Scientific*, p. 197. Jones, *Industrial*, p. 87. Robinson, 'Membership', p. 158.

[46] Schofield, 'Bicentenary', p. 150. 'Organized' meaning regularly-planned meetings, use of the characteristic name, and identification with the society as a collectively operating body.

[47] Schofield, 'Bicentenary', p. 150.

[48] Robinson, 'Membership', p. 155.

moved to Derby. Galton was recruited to replace Darwin,[49] for whom visiting meetings became more difficult because of his new place of residence. Day married in 1780 and retired to land purchased near London, therefore he began to withdraw from Lunar occupations. In 1780 as well, or in 1782 (or in both years?),[50] Edgeworth returned to Ireland after being in England for a while.

The period 1775–1780 was a period of major professional and scientific activity for the Lunar Society, but the period 1781–1791 appears to have been the one with the most regular activity and the largest productivity.[51] The early 1780s were the most intellectually fertile, which could be due to Priestley's influence, however, as Jones reminds us, 'the 1780s was a decade in which the volume and speed of knowledge exchange — in all its forms — increased sharply.'[52] Towards the end of the 1780s, involvement with the Society waned: from 1786 onwards Boulton and Watt were overwhelmed with business and travel, Whitehurst died in 1788 and Day in 1789. Especially Whitehurst's death was a real loss in terms of Lunar involvement (as mentioned, Day already started to withdraw in 1780).[53]

In 1791, decline started after the Birmingham Riots, also known as the Priestley Riots. The rioters attacked Dissenters for their support of the French Revolution and for a couple of other issues.[54] Since the Lunar Society was perceived as associated with the Dissenters by the rioters, and of course mainly due to its inclusion of Priestley, the Lunar members became targets as well. The angry mobs shouted '[n]o philosophers — church and king forever', and citizens trying to escape the fury wrote 'no philosophers' on the fronts of their houses.[55] Priestley's house was attacked, Withering's house invaded, and Boulton and Watt armed their employees (Soho eventually escaped the rage). As a result, Priestley first fled to London, and emigrated in 1794 to Northumberland in America. The trouble came after a period in which the outbreak of the French Revolution had already put a strain on the Lunars' personal relationships. Wedgwood died in 1795, and Withering in 1799. So by 1800 the effective core of the Lunar Society was reduced to Boulton, Galton, Keir, and Watt, with Darwin, Edgeworth and Priestley in contact via correspondence. However, Darwin retreated, and Boulton, Watt and Keir were still occupied with their manufacturing businesses. In 1802 Darwin died and Boulton became house-bound because of physical incapacitation. The very last Lunar activity was in 1813: the Lunar library was balloted for.[56] Galton won.

Analysis

The purpose of this analysis is twofold: on the one hand it aims to test the literature with the networks, on the other hand it aims to test the networks with the literature. Since details about when people were introduced, moved or left a group are in general quite easy to find out and to check (by close-reading or by delving into records), we observe in the overview of the development of the Lunar Society as given by the historical literature almost no discussion about these kinds of points. There is no debate about when Priestley or Small moved to Birmingham, no discussion about

[49] According to Schofield, 'Bicentenary', p. 154.

[50] Schofield mentions two different years for Edgeworth's return to Ireland, this could be a mistake, or perhaps Schofield meant that Edgeworth returned to Ireland after a longer stay in England twice. (Schofield, 'Bicentenary', pp. 152 an 154.)

[51] Schofield, 'Bicentenary', pp. 151 and 154.

[52] Jones, *Industrial*, p. 91.

[53] Schofield, 'Bicentenary', p. 155.

[54] See Section 2.1 for the French Revolution.

[55] Bolton, *Scientific*, p. 212.

[56] See Section 2.2.

when Whitehurst left. Therefore we can use these type of details in order to investigate the reliability of the networks: are they able to reproduce the more basic insights that were derived by close reading of sources during earlier studies?[57] This is important to know because it gives us an indication of the reliability of the networks in general and thus about conclusions we might draw from them, and because it shows us if a systematic study of meta-data might be used to replace close reading in cases where that might be useful (such as comparing the development of many scientific societies, courts, or other groups). However, while comparing the literature's account of the development of the Lunar Society with the one as given by the networks, we can at the same time check for edges (or edge weights) not addressed by the literature: a quick exploration for new findings. What we unfortunately cannot do is try to solve questions about the years that were in fact ambiguous, by analyzing the networks in the way they are currently constructed: they are not suited for such fine-grained analysis — a network depicting a period of five years is not able to shed light on the issue if an event might have taken place a year earlier or later. The divergences are probably based on some mistakes and can presumably be easily solved with a comparison of the materials historians derived their years from.

Comparing the network slices of the periods 1755–1760 and 1760–1765 of Network C with the description of the development of the Lunar Society according to the historical literature, the first thing that stands out is that we observe 'the first Lunar link' between Boulton and Darwin only in the period 1760–1765, while we had already expected it to be visible in 1755–1760. Furthermore, the networks do not show us the alleged connection between Darwin and Whitehurst in 1755–1760 and the one between Boulton in Whitehurst in 1760–1765 we see neither. In other words, based on the networks we would not able to conclude that there was a three-way correspondence between Boulton, Darwin and Whitehurst. One should therefore wonder what the claim in the literature about this correspondence was based on. Did we miss some letters other historians did investigate? Have other historians mixed-up some periods (which would still not explain the lack of letters from Darwin to Whitehurst)? Are there references in the contents of letters that point towards correspondence between Whitehurst, Boulton and Darwin? Or do we have to conclude that the literature's claim is unfounded? It is true that for these first periods, we only found a very small number of letters (just eight), however, other historians had to base themselves on the same primary source material (although the references might have been in an undated or unaccessible letter of course). Still, the fact that we have found no indication for this correspondence at all would be a reason to check the literature's claim and to investigate on which source material it is based, even if it is only to add this material to our dataset. A claim about group cohesion or centripetal tendency like the one made by Schofield could not be checked because the networks are too small to serve that purpose. It would be possible to check it for larger networks by studying the development of the density metric and by investigating if the network is a growing cluster (or clique) within a larger, surrounding network. Lastly, there is a benefit of summarizing primary source material metadata in networks to be noticed in these periods: the letter exchanged by Darwin and Keir makes us immediately aware of the fact that they have known each other for

[57] Notice that contrary to earlier warnings that the networks should be treated as tools and not be understood as depictions of reality, we are in fact checking to what extent they mimic 'reality, as described by the historical literature'. This comparison is however done with the aim of improving analyses in which the networks are approached as tools to answer certain historical questions: knowing to what extent the networks reflect reality (as conceived by historical literature) helps in interpreting the networks and analysis results.

some years before they renewed their contact in the late 1760s. Such a detail would in a textual description of the development of a group probably only be mentioned in passing, if at all.

Turning to the network slice of the period 1765–1770, we notice again that a couple of social connections that are mentioned by the historical literature, are not reflected in correspondence activity according to the network (for instance the connection between Wedgwood and Whitehurst, or the one between Boulton and Edgeworth are not visible). As described above, these observations could provide both a reason to assume that data must be missing in our dataset, and a reason to check the literature's claims again — what were they based on? However, we should not forget that for some cases (almost) no correspondence activity despite (good) social contact might be exactly what one expects taking the historical contexts into account. A case in point is the situation of Small. In the literature we read that Small was one of the best friends of Boulton, and we get to know that Small was on good terms with Darwin, Wedgwood, Edgeworth, Keir and Day as well; in fact he is even described as the link which combined all these men together. However, none of these elements can be retrieved by studying the network slice. The only feature that we can observe is the extensive stream of letters exchanged between Small and Watt that was mentioned in the literature as well (Small was, in contrary to the claim of Robinson, not the first one to establish contact with Watt according to our dataset. Darwin wrote him a letter a year earlier). Apparently Small could be an active letter-writer if he wanted to, and the fact that his fellow Lunar men praised his warm personality makes the explanation that he was just not attentive enough to write his friends unlikely. A better explanation of the absence of correspondence activity would be that Small did not write his friends, because he saw them often in person. This at least would explain the lack of correspondence between Boulton and Small: they lived in the same city and as the family doctor and a general advisor, Small probably spoke to Boulton on a daily basis — there was no need to write letters. The same could apply to his relation with Whitehurst.

However, it becomes harder to explain his lack of written contact with Wedgwood, Darwin and the others. It is true that Darwin for instance did not live that far away from Birmingham, but that did not prevent them to write with Boulton. Perhaps people included their messages to Small in their letters to Boulton, as we see for instance happening when Darwin invited both Boulton and Small for a meeting with Edgeworth?[58] Perhaps we observe an effect due to the fact that there was no collection of correspondence found focusing solely on Small? All we know about his correspondence comes from sources that centered around Watt. This is however still not an explanation for the fact the other social links are not observed in the correspondence activity networks: the correspondence of Boulton, Darwin and Wedgwood have been well-preserved as well, these should have shown correspondence with Small, especially if there had been much contact between them. So, although personal contact might explain the missing letters between Small and Boulton (and Whitehurst), it does not explain the other absent links. We have to conclude that there was no way to have been able to derive Small's binding role purely on the constructed maps of correspondence activity. Furthermore, without having knowledge of Small being in non-written contact with the Birmingham group, there would have been no option to derive Small's role as broker by mediating the contact between Watt and the group — which would be the type of observation you would like a correspondence activity network to be able to deliver. What is more, based

[58] Darwin to Boulton, Summer, 1766, as printed in King-Hele, *Letters*, p. 40.

on the networks we would sooner conclude the opposite: that Watt was a broker in maintaining the contact between Small and the others.

An interesting feature that was not noted by the historical literature, at least not by the secondary sources that were consulted for the overview above, is the strong link between Boulton and Wedgwood. It was mentioned that they knew each other probably from 1765 onwards, but it is surprising that their correspondence activity is as strong as the one Boulton had with his best friend Darwin (in Network C, both Darwin and Wedgwood made up thirty-seven percent of Boulton's correspondence). Might it be due to the fact that Boulton and Wedgwood saw each other less often in person (Darwin living much closer to Birmingham)? Were they perhaps involved in some business together? Is the correspondence of Wedgwood extraordinarily well-preserved (but why do we not find his letters with his other social contacts then)? Or, might the interactions between Boulton and Wedgwood be closer than we thought? Based on the correspondence activity maps alone we cannot draw this conclusion definitively, but it does show how the networks could point us towards interesting new hypothesis to explore further by delving into the contents of sources.

Some last observations in the network slice 1765–1770 I will only shortly elaborate on. Firstly, the center group of the network as identified by NetworkX center algorithm (see the lists in the digital resources set, the link to this set is given in Section 1.7) is not similar to the core group identified by the historians. However, since the algorithm only lists Boulton, Darwin and Watt as members of the center group, I think it is best not to doubt the literature on this point and blame instead some missing edges for the discrepancy.[59] Secondly, by comparing the network slice of 1765–1770 with the one of 1760–1765, we see that the thickness of the edge between Darwin and Boulton remained approximately equal — apparently Boulton's new friendship with Small did not threaten his relationship with Darwin to such an extent that it influenced their correspondence. Furthermore, this relation was apparently also not threatened by the strong correspondence that formed between Darwin and Wedgwood, perhaps these letters included many canal-related messages, however, in other years (after the canal was finished) their correspondence activity remained high, especially in comparison with the other links. Maybe Darwin was the broker that mediated contact between Wedgwood and the Birmingham group? The fact that they were good friends, that both were involved in business or well-preserved correspondence are of course explanations as well. Another observation is that there have been no letters detected exchanged with Day, not even ones exchanged between the good friends Edgeworth and Day. Might this then be the unfortunate effect of the use of the name 'Day' as a common word? Was Day just not considered important enough to preserve his correspondence? We know at least that the lack of found correspondence is not due to the fact that sending mail was to expensive for Day, since he had inherited a large fortune.

If we study the network slice associated with the period 1770–1775, we observe that the number of (detected) epistolary connections has increased: the group of friends is becoming closer, and with it the chance of finding their correspondence has become larger. In fact, this is the first year in which all Lunars wrote at least with one other participant (Galton and Priestley were not recruited yet). To avoid repetition and because the number of edges per slice becomes higher, I will not list

[59] Notice furthermore that strictly speaking the algorithm is identifying the core of what has already been defined as the core group of the Lunar Society, since the criterion for adding persons to our networks was that we identify them as Lunar (core) member.

all connections that are missing according to the literature,[60] neither will I discuss for each edge the possible ways the specific edge weight came about, discussion of the other connections will serve as an example what kind of reasoning should be applied for such descriptions. I will however highlight some of the more interesting cases. First, it stands out that we no longer observe correspondence activity between Boulton and Wedgwood, while in the previous slice their number of exchanged letters was surprisingly high compared to the number Boulton exchanged with best friend Darwin. Furthermore, in this network slice, and in the subsequent slices as well, we notice that there is in fact correspondence of Day found. This observation however makes the lack of correspondence in the previous slice (1765–1770) only more curious: does our new finding mean that Day just did not write that much yet in this earlier slice? Or do we encounter here an example of the insight that correspondence goes missing selectively, and not in equal numbers over the whole range of the total collection? Another striking feature is that we suddenly do see correspondence between Boulton and Small, while we just concluded that this is unlikely because the two saw each other (probably) at a daily basis. The explanation for these letters is in fact quite simple: they did not see each other exactly *each* day, not when one of them was traveling. If we look up the details of these letters exchanged by Small and Boulton between 1770 and 1775 in the database, we see that they were sent during Boulton's trips to London and during Small's travels to Dundee.

In the next time period, 1775–1780, the group became again more close, which could be both derived from the increasing edge weights and from the increasing number of edges. The most striking features of this network slice are how well the partnership of Boulton and Watt is visible, and how clearly we see the collaboration of these partners with Keir reflected — that is, in his connection with Boulton, because his number of exchanged letters with Keir is surprisingly low, as was already mentioned above. These edges show that it is, as one would expect,[61] not possible to exclude all business-related mail from the analyses, which is fine because for these cases they do not distort the relationships: there was in fact a lot of cooperation between these people, and they must in fact have gotten along quite well.[62] Furthermore, it stands out that both Darwin and Boulton have a much higher degree than the other participants in the network (six and eight, instead of one to four). I think this type of correspondence activity shows their central role in binding the Lunar club, organizing the meetings, stimulating activity and 'invigorating the Lunar spirit'. However, we should remember that both Darwin's and Boulton's correspondence collections were especially well-preserved: we should tone down their roles as driving force behind the Society a bit. As we saw in the overview above, in the historical literature we read that Whitehurst became an outpost for his Midlands friends after he moved to London in 1775. This is however not reflected in the networks. For an outpost, we would expect to see more letters exchanged between him and the other Lunar men. We could argue that Boulton served as a broker and passed through the messages of the Midlands' residents to Whitehurst, but this is not supported by the visualizations either: in the period 1770–1775 Boulton and Whitehurst exchanged just as many letters as in the subsequent period. Another noteworthy

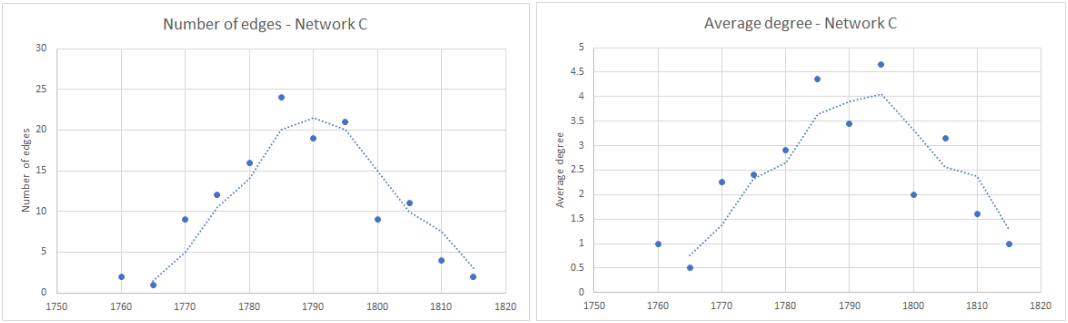
[60] Those missing edges are easily spotted by comparing the networks with the overview above, and for each missing link the same two insights apply: data might be missing here, and they present a spur to check the sources and the claim of the literature.

[61] See Section 2.3 and Section 3.2.

[62] It were the business-related letters between 'clients' and manufacturers that we wanted to exclude, for the reason that they would distort the links, in which we wanted to see just their personal relationships reflected.

observation is that that this is the first period in which we spot contact between Priestley and other Lunarians. We would have however expected to find some connections already in earlier times, since Priestley had been a friend of the group for a while already and he had for example met Wedgwood in the 1760s. Lastly, the network slice points us to a relation that might be interesting to investigate in further detail: the one between Day and Boulton. Both in Boulton's and in Day's correspondence, the exchanged letters with each other take up a relatively large part of their full collection of exchanged letters. Day was not the most likable person and the studied secondary literature did not point out a particularly close relation between the two, so what could be the reason of this increased correspondence? Might Day perhaps have funded some of Boulton's work during this time period?[63]

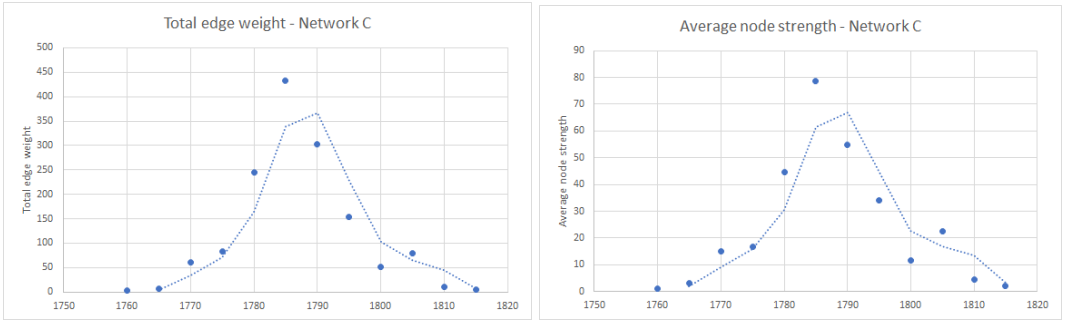
During the period 1775–1780 we already saw a significant increase in the number of (detected) correspondences between the Lunaticks, but in in the period 1780–1785 this number is even higher. In fact, it is the highest number of edges we will encounter in a network slice, although the average degree has its peak in another period (1790–1795) (see Figure 5.4a and Figure 5.4b). Both the total edge weight (which equals, as we know, the total number of exchanged letters) and the average node strength (the average edge weight per node) have the highest value in the period 1780–1785 as well (see Figure 5.5a and Figure 5.5b). These observations tie in with the literature's claim that the early 1780s were the most intellectually fertile years for the Lunar Society, and they support Jones' note that the volume and speed of knowledge exchange increased sharply during this time. However, the network slice could not support nor refute the suggestion that the increased activity in the specific Lunar case is due to the influence of Priestley. Notice that we spotted this upheaval in activity in this period, the previous and the next one, also in the figures studied in the first analysis (Section 5.1). This particular network slice (1780–1785) shows us the role the correspondence between Watt and Boulton might have played in the shape of the density metric graphs. It would therefore be interesting to investigate what these graphs would have looked like if we would not have included these sets of letters: would we still have come up with the same results? I suspect that we had, since the increase in degrees and in edge weights is not restricted to a certain region of the networks, it is however sensible to have in mind that the peak of the density metric graph (of Network C) would have been lower had the correspondence of Watt and Boulton been excluded (but that the overall shape would probably have remained similar).



(a) (b)

FIGURE 5.4: *Number of edges metric and Average degree metric for Network C*

[63] See Section 2.5.



(a) (b)

FIGURE 5.5: *Total edge weight metric and Average node strength metric for Network C*

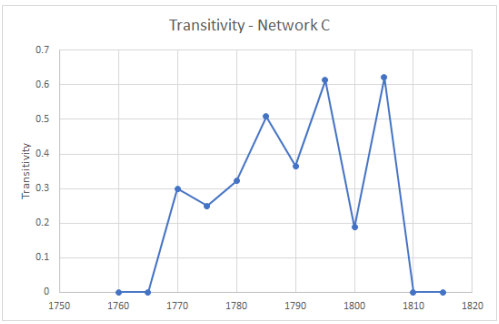


FIGURE 5.6: *Transitivity metric for Network C*

Some other observations about this period (1780–1785) are that we see that Galton is included in the network for the first time, and that we might find more evidence in this slice than in the previous one that Whitehurst started to act as an outpost, since his degree has increased. However, two of his new epistolary connections are with people that moved away from Birmingham, in other words, maybe he started to write (more) with them because he no longer encountered them on his frequent visits to Birmingham. Which brings us to another point: Darwin, Day and Edgeworth all moved away, which we see in the case of Edgeworth translated into more exchanged correspondence, but in the cases of Darwin and Day we do not. In the case of Day this might be due to the fact that he did not only move away, but withdrew from Lunar activities as well. The reason why Darwin did not start to write more is not clear, but I suspect that it has to do with the fact that his new place of residence, Derby, was not that far away from Birmingham. Another aspect of the network slice I would like to highlight is the substantial contribution of Wedgwood in the correspondence activity in the network. Not only is his degree higher than average, his edges all have relatively high edge weights as well. This could be due to the fact that Wedgwood lived quite far away from the others, or perhaps he did not (or almost never) visit meetings, as was claimed to be the case by Jones.[64] Either way, it provides food for thought in the context of the discussion about Wedgwood's membership. The final remark I would like to make is that it is interesting to see that, next to his correspondence with Wedgwood, who appears in this network slice to be an enthusiastic correspondent in general, Priestley corresponded mostly with Watt, even while they were living in the same city (some letters were however written

[64]Jones, *Industrial*, p. 87.

during travels). Might this be due to the issue described in the literature that Watt and Priestley both collaborated and competed in their scientific pursuits?

It was just noted that Wedgwood contributed significantly to the correspondence activity in the network during the period 1780–1785, and as we see in the network associated with the period 1785–1790, Wedgwood's contribution only increased. It very much stands out how many highly weighted connections he has with the other participants in the network. I do not expect that these high edge weights could solely be ascribed to a well-preserved correspondence collection or to the fact that Wedgwood lived a bit further away from the others (these possible reasons were mentioned above as well). In general, however, we see that both the number and the edge weights decreased in comparison with the previous network slice. This concords with the observation in the historical literature that involvement with the Lunar Society started to wane towards the end on the 1780s. We notice Day's withdrawal, but not yet his and Whitehurst's death. Watt and Boulton's occupation with their business is reflected in their highly weighted connection, however, it did become a thinner tie relative to the slice of 1780–1785.

According to the literature, the Lunar Society's decline started after the Birmingham Riots of 1791. Indeed, we observe some changes in the networks from the slice representing the period 1790–1795 onwards. In the first place, the number of edges starts to decline (see Figure 5.4a). The total edge weight was already lower in the previous slice, but this development continued in the one of 1790–1795, and in the next slices (see Figure 5.5a). However, it is noteworthy that although the total number of edges started to decrease, the average degree and the transitivity peaked (see Figure 5.4b and Figure 5.6). This should be interpreted as many connections per node, and many closed triads as well. Looking at the visualization of the network, we notice that this equals a well-connected network, in which each member was at least corresponding with three others. Part of the explanation of this phenomenon must be that the network around this time includes many people that moved away, or never have lived in Birmingham (Darwin, Edgeworth, Priestley, Wedgwood). Especially Priestley's unwanted removal from his Birmingham friends spurred much correspondence. As was mentioned before (Section 2.2), Priestley really went through a hard time adapting to his new situation without his philosophical friends nearby. Another (smaller) part of the explanation might be that people had much to discuss about the events that happened and about the future of their collaborations. What is not part of the explanation is that there might have been fewer Lunar meetings during this time, as we saw in Figure 5.2, this was not the case. What was however the case was that in general the 'Lunar spirit' started to wane, which might in the network for instance be illustrated by Wedgwood's decreasing letter-writing rates (notice that these decreasing rates are probably also due to the fact that Wedgwood came to age).

During the period 1795–1815, the network slowly fell off, until it ceased to exist completely. There are not that many noteworthy features about the network in this period that have not been addressed already in similar cases. Two issues are however interesting to mention. The first one is that we observe a small dip in the correspondence between Boulton and Watt in the period 1795–1800. This might be business or travel related, or perhaps the correspondence increased again in the period 1800–1805 because Boulton became home-bound in 1802. I suspected that this might be the reason for the sudden upheaval of letter-writing activity spotted between Boulton and Galton in 1800–1805 as well. However, thirty exchanged letters in total in five years does not seem to be enough to support a home-bound man.

Perhaps these letters were complemented by visits, perhaps there is a totally different reason for the increased letter-writing rates. It might be an interesting case to look further into by studying the contents of letters (or of course, to delve into more secondary material).

The aim of this analysis was to investigate the reliability of the networks and the conclusions that one might draw from them, by comparing the networks with historical literature to study if the networks were able to reproduce the more basic insights that were derived from the close reading of sources during earlier studies. At the same time, the networks were explored to look for new findings. We have to conclude that the networks were not able to reproduce all these more basic insights. In the first place, between some members a correspondence activity edge was missing, while based on the social relationships mentioned in the literature you would in fact expect an associated edge. Above we encountered three conclusions one might draw from this observation: we should suspect that data in our database is missing, the literature might be at fault and the sources for the unsupported claim should be checked again, or we should look for a historical explanation why the social relationship did not translate into correspondence activity. Secondly, some of the more complex situations (the ones that could only be derived by taking into account multiple edges and their mutual proportions) that one would like to be able to derive from the correspondence activity networks (such as broker situations), were not reflected in the networks in such a way as that they could have been derived without explicitly looking for them at that specific place or without prior knowledge of other aspects of the social structure in the period. However, although the networks were not able to reproduce *all* edges and social situations, they were able to reproduce *a fair share* of them. This share would however not be large enough to fully replace close reading for mining relations and structure in the mentioned cases where that might useful: too many relations and situations would then be missed. Still, the results show us that the networks should in general definitely not be fully trusted, but that they are not completely unreliable either. The networks could still be used as a tool (the goal was never to provide a fully reliable depiction of past reality), but this limited reliability should be taken into account both while assessing results and while executing analyses. The above comparison is useful in this last regard.

In our exploration for new findings during this analysis, we did not find features surprising enough to require a complete reinterpretation of the social and organizational structure of the Lunar Society. What was shown, however, is that the networks provide useful options to spot interesting new hypotheses to study in more depth by consulting other secondary sources or by delving into the contents of primary material. One should note that these new hypotheses are (mainly) to be found at the edge level: one finds unexpected edges or edge weights. New hypotheses about more complex social situations (the ones that involve multiple edges) are a lot more difficult to derive from the networks. For this purpose the networks are not complete enough (the unreliability caused by missing links just described) and there are just too many contextual factors that could have influenced the correspondence activity visualizations in one way or the other: the networks are too underdetermined to draw up hypotheses about complex social situations in a meaningful way.

5.3 The central role in the Lunar Society

The literature

In the previous section it was concluded that the chance is small to come up with

completely new hypotheses or conclusions about the social structure of the Lunar Society based on inspection of the network visualizations. However, as we saw already in Section 5.1, the networks could not only be used as a way to look for completely new findings, but also as a tool to shed light on existing discussions in the literature. Let us therefore in this section investigate what the network visualizations and their accompanying metrics might teach us about such a discussion in the literature: the one about who could be considered the central (perhaps: leading) figure(s) in the Lunar Society.

Studying the historical literature, we can identify three candidates for the central role in the Lunar Society: Darwin, Small and Boulton (of course we should not exclude the possibility of shared central roles, or subsequent central roles). Robinson is the historian who underlines most clearly a pivotal role for Darwin in bringing the group together, at least in the earliest years of the formation.[65] His view is supported by Uglow when she uses at the back of her book the phrase '[l]ed by the larger-than-life Erasmus Darwin', and by Bolton, who writes that '[t]he Patriarch of the Society was Dr. Erasmus Darwin, at least until he removed to Derby in 1782.'[66] However, both Uglow and Bolton subscribe other views about who carried out the binding role as well. According to Schofield, the Lunar group formed around Small (although there were some beginnings of the group in the form of Boulton, Darwin and Whitehurst's connection, but these are seen as negligible compared to the influence of Small in Schofield's eyes).[67] Uglow agrees when she writes that Small's 'natural diplomacy welded the group together.'[68] This central role for Small is subscribed by the quote taken from Edgeworth's *Memoirs* we encountered above: Edgeworth recognized Small as the connecting link as well. Clarke seems to suggest that although the idea for the Lunar Society came from Small, the one taking initiative for the actual organization of the Society was Boulton.[69] Doherty underwrites this view by stating that the Lunar men grouped around Boulton,[70] and Bolton lists Boulton as the (primary) founder of the Society.[71] This view is supported by the literature's claim mentioned above that Boulton was the one mostly responsible for the reorganization in 1775 and 1776, and it is underwritten by some evidence from primary source material as well: Boulton was the one addressed for giving notice that one could not attend a Lunar meeting,[72] and it appears to be the case that people mostly wrote to Boulton if they wanted to address the whole of the Lunar Society.[73]

Analysis

As previously mentioned, the visualizations and the metrics can strictly speaking

[65] Robinson, 'Membership', pp. 154 and 155.

[66] Bolton, *Scientific*, p. 199.

[67] Schofield, 'Bicentenary', pp. 147 and 150.

[68] Uglow, 'Birmingham'. Notice that this statement is not in contradiction with her claim that the Society was led by Darwin. Drawing a group together and leading a group are not necessarily the same kind of actions.

[69] Clarke, *Ingenious*, pp. 53 and 54, as cited in Doherty, 'Intellectual Friendship', p. 232.

[70] Doherty, 'Intellectual Friendship', p. 7.

[71] Bolton, *Scientific*, pp. 195 and 217.

[72] For example: Darwin to Boulton, 5 April, 1778, as cited in Bolton, *Scientific*, p. 199. Although a reason for Boulton often receiving these cancellations might also be that the meetings were often held at his house.

[73] Johnson wrote for instance: 'Mr Johnson will be happy to see any friends Mr Boulton will do him the favor to bring with him.' (Johnson to Boulton, September, 1787, as cited in Robinson, 'Membership', p. 170.)

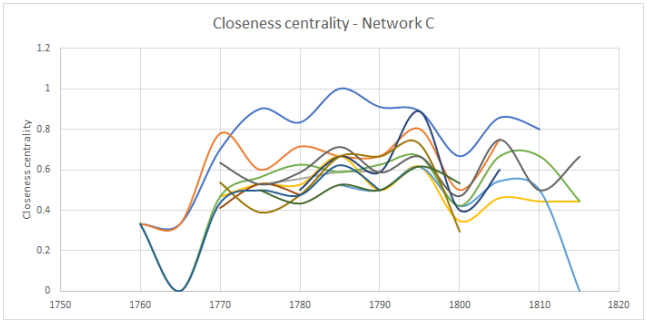
only teach us something about the centrality of figures in the correspondence activity network, which does not necessarily translate one-to-one to centrality in the Lunar social network. However, the correspondence activity network centrality could of course be used as an argument to support a claim that the figure was central in the Lunar Society in general.[74] A quick investigation of the constructed visualizations easily shows us that Boulton was the most central figure in the correspondence activity network. However, as we know, Boulton's correspondence has been extraordinarily well-preserved, so this result is trivial. To look for more detail we will delve into the matter a bit deeper.

As was explained in Section 4.5, the closeness metric could not be interpreted in the conventional way when applied to the correspondence activity networks. The metric does not provide a measure for a node's social centrality, neither for its epistolary centrality.[75] It does however serve as some sort of abstract measure for how active one has been in the letter-writing network: with how many people one has written and how much. It was also explained that in order to account for the two different ways in which a shortest path length could be interpreted, two closeness metrics should be calculated: one including edge weights in the calculation, one excluding them. The results of these calculations are shown in Figure 5.7a and Figure 5.7b. The two graphs depict the closeness metrics for the different members in the different time periods, each colour corresponding to a member (see Figure 5.8). Unfortunately, as one observes, the closeness metrics do not depict much interesting structure: the nodes all share a similar development of the closeness metric; as one would expect Boulton has over the whole time range the highest values for the measure; Small is not long enough present in the network in order to make any meaningful statements about his closeness centrality; and Darwin's graph gets lost in the bunch of other members' graphs that fluctuate around the same values (although Darwin's closeness centrality is a bit higher than the ones of the others during the earlier years). The reason why all the courses of the closeness metrics are similar, is in my expectation the fact that (almost) everyone was connected in the networks with Boulton in each time period, meaning that the shortest paths between nodes often have a length of two edges.

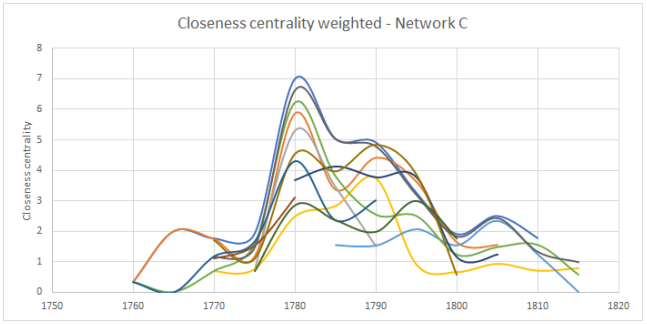
The betweenness centrality measure fortunately provides us more insight into the issue of the central figure(s). As mentioned above, betweenness centrality is a measure of how much a certain node functioned as a broker. In other words, it serves as a way to assess to what extent a Lunar member was in between two correspondence clusters, or just to what extent he was in the correspondence activity networks in between two other members. Notice again that this does not mean that the only way to correspond or to interact for those two other members was via this intermediary member. The betweenness centrality metric does however serve as a measure of the extent to which a member's correspondence activity was contributing in binding the network. Again two different metrics had to be calculated due to the two different interpretations of the shortest path lengths, the results are depicted in Figure 5.9a and Figure 5.9b. Of course, as expected, Boulton generally has the highest betweenness centrality values. It is however interesting to see that Darwin's values are relatively high during the earliest periods, and that they increase again towards

[74] Especially as one argues that the correspondence exchange is just as much part of the Lunar Society as the meetings and the experiments executed during these meetings. This point will be explored further later on.

[75] As mentioned before, the term 'epistolary network' is used for a network with edges that should be interpreted as the potential to correspond.



(a)



(b)

FIGURE 5.7: *Closeness centrality metric and Closeness centrality weighted metric for Network C*

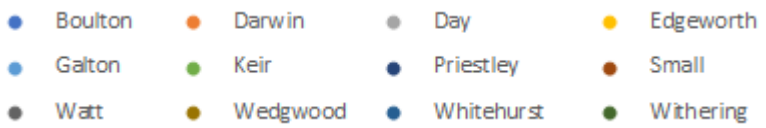
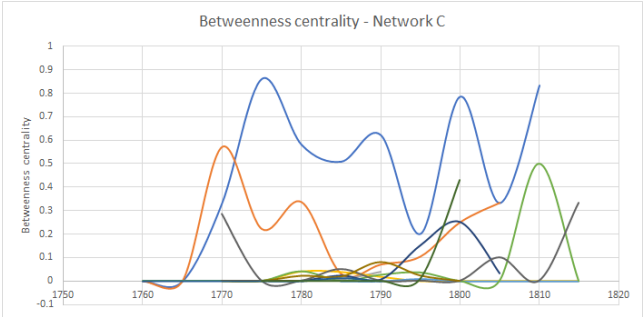


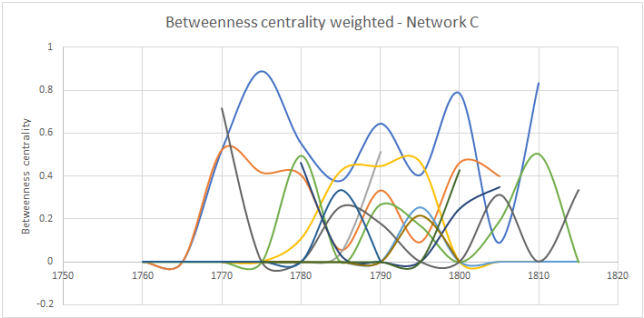
FIGURE 5.8: *Legend depicting the colours associated with Lunar members*

the end of the Lunar Society's existence. This result might be interpreted as supportive for the claim that Darwin made some crucial contributions to bringing together and binding the group of friends in the earlier years. Based on these graphs we could furthermore state that Boulton took over this primary binding role in the first half of the 1770s. In the weighted betweenness centrality graph, Edgeworth's values go through an interesting upheaval in the 1780s, but in the betweenness centrality graph for which the edge weights were not taken into account, we do not observe the same effect. The explanation for this sudden increase should therefore be sought in the highly weighted connection between Wedgwood and Edgeworth during these years (visible in the respective network slice visualizations). Since Edgeworth was not necessarily a central figure during these years — which I state because there are no indications for this view present in the network visualizations, nor in the historical literature — this immediately points us to the fact that we should treat the results we derive from the betweenness centrality metrics with care. For some slices the calculations are just based on a very limited number of letters, and missing links and missing edge weight (which previous explanations and analyses showed us we have to deal with) could very much distort the graphs.

A sign of a central social role would be that a Lunarian's binding actions have the effect that his friends get to know each other as well, and that they bond in such a



(a)



(b)

FIGURE 5.9: *Betweenness centrality metric and Betweenness centrality weighted metric for Network C*

way that they start to correspond with one another. In other words, a sign of a binding role would be that triads among a certain node close within a correspondence activity network. These closed triads would be translated to high values for the clustering metric. Since the clustering metric is in this way a measure for the extent to which someone is a central, or binding, figure, the clustering metrics for the Lunar members were calculated. The result is depicted in Figure 5.10. At first sight, this graph seems to prove Small's central role in the period 1770–1775. However, critically analyzing the associated network slice shows us that this peak in Small's metric is just caused by one closed triad, a closed triad that has such a strong effect only because one of the constituting edges has a high edge weight. For the same reason the metric of Watt has a similar peak in the period 1770–1775. One closed triad combined with one extraordinarily highly weighted edge are not enough to conclude a central role for Small, especially not since it would imply ascribing the same role to Watt, which would not match with accounts from the historical literature.[76] Unfortunately there is not much interesting structure in the rest of the clustering metric graph and the structure that is visible that could be explained by similar reasonings as the one above. I think we have to conclude that the networks currently investigated are not large enough to be meaningfully studied by the clustering metrics.

The last metric we will explore in the context of the issue of the central figure(s) is the PageRank of the members. The rank of a node is a measure of its importance, and is calculated based on the number of correspondents of a node and the importance

[76]Which we try to complement and/or correct, but we have seen in the previous analysis that corrections solely based on the networks would be difficult. Therefore we can keep the existing literature into account to aid the interpretation of the results.

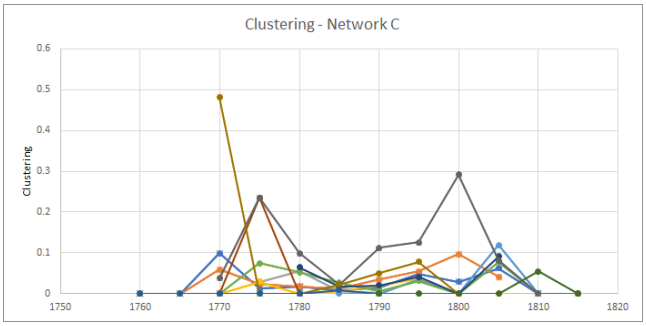
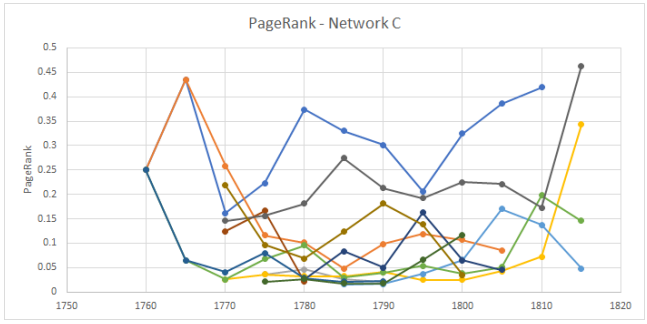


FIGURE 5.10: *Clustering metric for Network C*

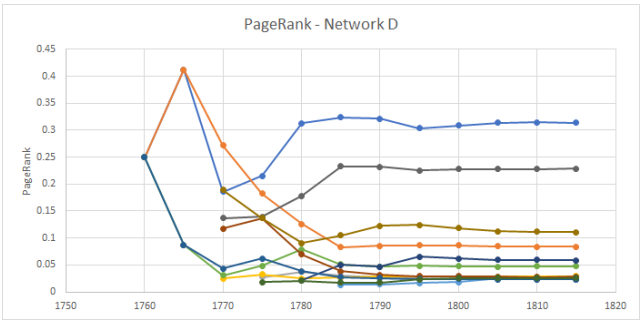
(the rank) of these correspondents in the overall network.[77] The PageRank was calculated both for Network C and for Network D, the results are shown in Figure 5.11a and Figure 5.11b. Here we observe some results that resemble earlier findings. Let us only focus on our three candidates for the central position. We see that Boulton and Darwin both started with the highest rank in the graph in the period 1760–1765 (not too many conclusions should be connected to this finding, Boulton and Darwin were the only correspondents in this network slice), then after this 'first Lunar link had been forged', their ranks drop with the inclusion of more group members. However, in the earlier years Darwin's rank drops more slowly than Boulton's rank and we get the impression that Darwin was the most important figure in these early years. Then in the periods 1765–1770 and 1770–1775, Small's rank peaks (although his peak is never the highest one, but keep in mind that not much of Small's correspondence has been found and that he lived close to many Lunar friends). As opposed to the peak in the clustering metric graph, in this graph the peak is in fact trustworthy, since the importance of the nodes Small connected with are taken into account: he might have corresponded (according to the networks) with only a couple of members, these members were in fact that important in the Lunar network that Small's rank could peak. After this upheaval of Small, we observe that Darwin's rank kept decreasing, but that Boulton's rank started to increase again. In the accumulating network the PageRank reached an equilibrium, in this ranking Boulton ended first, Darwin fourth and Small is at the bottom of the list together with some others.

From all these results I think we can conclude that Darwin was the central figure in the earliest year, that he brought the group together and forged the first links. Then after some years Small appeared on stage and he created a new impulse for the group's social development. Small's involvement did result in some small peaks in the metrics, but they could not compete with the larger effects created by the correspondence activity of Darwin and Boulton, because not that much correspondence of Small has been preserved. Still, Small's peaks are relatively high, both in comparison with his metric values in other periods and in comparison to other members. Then, from the time the group of friends started to show its fruitfulness in the first half of the 70s onwards, Boulton started to take up an organizing and binding role, with the reorganization and the increased activity starting in the second half of the 70s as results. There is however one last remark with respect to Boulton's position: we should tone down his central, organizing role a bit. Not just because of how much correspondence of Boulton has been preserved, but also because Boulton was in general a very social person that wrote with many people and made friends everywhere. This character trait shows of course even more why a binding and organizing

[77] To get a better idea of what exactly is calculated: the metric was originally developed to rank search engine results (web pages).



(a)



(b)

FIGURE 5.11: *PageRank metric for Network C and for Network D*

role came natural to Boulton, however, the trait implies as well that Boulton would probably have produced more correspondence while taking up this role than others would have, meaning that we should correct a bit for the character trait in order to assess more reliably the extent to which Boulton executed this role. Although these conclusions list multiple (consecutive) central figures, they do not conflict with the literature, but add to it by aiding in unraveling the different claims made by historians about who took up the central position and showing that these claims are not mutually exclusive. The metrics (that is: the betweenness centrality metric and the PageRank metric) by their clear graphic depictions were able to assist in pointing out shifts in the central roles and in indicating the periods when this happened. Thus, the conclusions might be strictly speaking not new, they do add to the literature by structuring and supporting it.

5.4 Membership of the Lunar Society

The literature

The discussion about membership of the Lunar Society has already been elaborately explained in Section 2.5, and it was shortly touched upon again in Section 5.2. In general, this discussion came down to the fact that membership was not well-defined, and that historians disagree about who precisely should be seen as a core member and who should be understood as merely part of the penumbra of visitors and correspondents. As was explained, in the absence of a clear, well-supported membership list we defined the group of members to be studied. In this section, I will quickly explore if there are signs within the visualizations and the metrics that one of the twelve defined group members might have been falsely included.

Thereafter, the case of Wedgwood's membership will be studied in more detail. Let me briefly recapitulate the main viewpoints in this discussion, the details of the stances can be found in the above mentioned sections. In Uglow's opinion Wedgwood was one of the five principal members. Schofield agrees and claims that Wedgwood's membership is without doubt. This view clashes with Robinson's, who thinks Wedgwood was only in the penumbra of the Society and should not be understood as a full member. Jones supports this statement, he calls Wedgwood a 'distant affiliate'.

Analysis
A first step to find out if some persons have been falsely included, is to study the center metric and the periphery metric. The center metric indicates the set of nodes that have an eccentricity equal to the radius of the network. The eccentricity of a node is the distance between that node and the node most distant from it in the network. The radius of a network is the lowest eccentricity present in the network. In other words, the center metric indicates the set of nodes which have the lowest eccentricity. The periphery metric presents the set of nodes that are not within the center set. The center and the periphery metric results can be found in the digital resources set.[78] Based on the assumption that people central in the correspondence activity network were central *enough* in the Lunar Society network to be included as members, we can use the center set to deduce the group of people for whom we at least do not have to worry about their membership. However, a quick look at this list shows quite different results for each time period and comparing the center set with the periphery set, we observe that in the period 1790–1795 there was not even a center to be distinguished from the periphery. The overall impression of these results is that we should take them with a grain of salt. So without taking this observation too seriously, the idea that one gets from the lists is that at least the membership of Boulton, Darwin, Watt and Keir should not be questioned. In this list only the certainty about Keir might strike a bit surprising, the others have always been seen as some of the most important members by the historical literature.

A slightly different metric to indicate core groups within a larger network is the maximum clique metric, which indicates the sets of nodes that constitute the largest cliques within the network. This metric has been calculated for Network C and for Network D; the results can be found in the digital resources set.[79] Within these lists we find similar results as with the center and periphery metrics: Boulton, Darwin and Watt are present in almost every maximum clique. Their clique is often complemented by Priestley, Wedgwood or Keir. It is interesting to notice that the maximum clique often approaches or equals Uglow's group of five principal members (Boulton, Darwin, Watt, Priestley, Wedgwood). I think this finding supports the insight developed in Section 5.1 that for Uglow the main focus while studying the Lunar Society was the friendships between the members and the formation of a group of friends. She concentrates on connections more than on meetings or correspondence activity.

Based on the center metric and the maximum clique metric the impression we thus get is that we should not worry about the membership of Boulton, Darwin, Watt, Keir, Priestley and Wedgwood. However, just these results would not even remotely be enough to erase all doubt about Wedgwood's membership raised in the literature, but before discussing that case in further detail, let us look into the

[78] See Section 1.7.
[79] Ibidem.

membership of the people that did not make it to the shortlist above, the one of Whitehurst, Withering, Small, Galton, Day and Edgeworth. Although, except for Whitehurst, there are no reasons to doubt their membership based on the historical literature or primary sources, it would not hurt to do an extra check, especially because we now have a new tool at hand to study the material. As suggested in Section 4.5, a method to find out if some people might have been falsely included in the membership list, is to look for people that did not pop up at all in the most well-preserved correspondence collections of other Lunar members (especially: the Lunarians for which there is no doubt about their membership). In this case, this idea translates to exploring if some persons have not written, or have barely written, with Boulton, Darwin and — to a lesser extent — with Watt, according to our dataset of found letters. Going trough the correspondence collections of the persons being investigated, it however stands out that they were all corresponding with at least one, but mostly two of these three people. Only Galton was not writing with either Darwin or Watt on top of his correspondence with Boulton. However, he makes up for this by maintaining contact with Keir and Priestley, who we also listed as being members for sure. Based on these analyses, we thus can conclude that the inclusion of eleven people on the list was justified, only Wedgwood's inclusion should still be scrutinized more closely.

With regard to the membership of Wedgwood, we should come to the conclusion that a decision about his inclusion in the Lunar group again depended on the fact if one's criterion focused on meetings or on correspondence activity and connections. The reason why Wedgwood's case is able to expose that historians used different criteria and to establish these criteria, is because (according to Jones) there is no presence of Wedgwood in the record of actual Lunar meetings, therefore he would be excluded according to the one criterion, but not necessarily according to the others. Jones, and Robinson as well, indeed excluded Wedgwood because he (apparently) did not visit any meetings. However, if one bases oneself instead on correspondence activity or connections, as Schofield and Uglow did, a strong case could be made for Wedgwood's membership.

To demonstrate this, we will first turn to the normalized node degree metric depicted in Figure 5.12. We observe that in the period 1780–1795 Wedgwood had one of the highest node degrees (he was just a little bit less well-connected than prominent members Darwin and Priestley). Furthermore, even more evidence for Wedgwood's large contribution to the overall correspondence activity we find in Figure 5.13, which shows the node strength of the Lunar men (node strength is a different name for the total number of letters exchanged within a period). Here we clearly see that Wedgwood has a higher node strength than all other members except for Boulton and Watt, including members for which we did not doubt their membership, such as Darwin and Priestley. The node strengths of Boulton and Watt are extraordinarily high because of their business-related mail and their well-preserved collections (the highly weighted edges are easily spotted in the network visualizations), so their high values do not mean that Wedgwood's value should be interpreted as relatively low. The best support for Wedgwood's importance in the correspondence activity network comes from the PageRank metrics. As we observe in Figure 5.11b the rank of the accumulative network — that could be understood as a ranking over all times — shows after it reached its equilibrium that Wedgwood ranked third. That is above Darwin and other persons which we indicated as definitely being members. Also in the PageRank metric for Network C (Figure 5.11a) Wedgwood's ranks were relatively high, at least during the years the Lunar Society flourished most. Based on these results it should be concluded that Wedgwood should certainly be included

as a member — that is, if one's criterion for membership concentrates on correspondence activity.

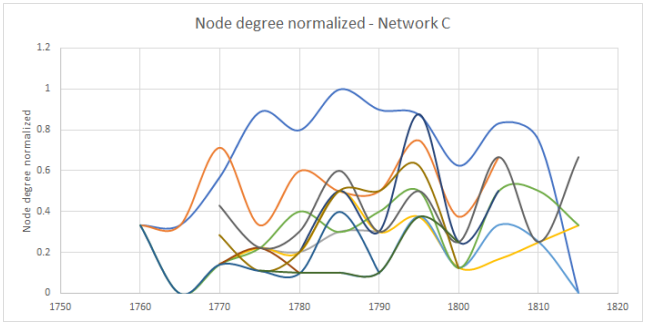


FIGURE 5.12: *Node degree normalized metric for Network C*

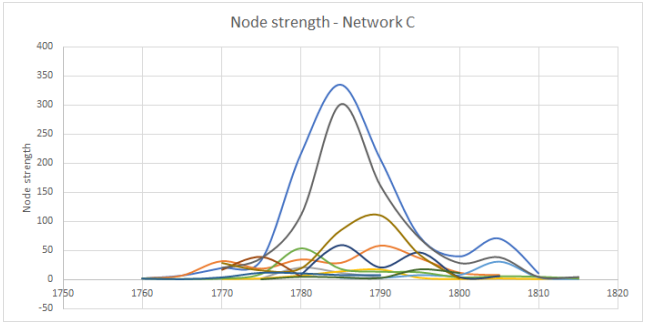


FIGURE 5.13: *Node strength metric for Network C*

5.5 Savants, fabricants, and the Lunar Society

Introduction

Up to this point we studied to what extent network analyses could contribute to existing studies by looking for new Lunar findings and hypotheses, and by trying to shed light on debates about the Lunar Society in the historical literature. There are however other ways in which network analyses centered around the Lunar Society could contribute to historical investigations. One of them is that the Society and its networks could be used as case studies to explore certain other historical topics. As announced in Section 2.3, this is what we will do in order to learn more about the savant-fabricant interface.

The Lunar Society should be understood as a group of savant-fabricants encapsulated within the wider eighteenth-century network of interacting savants and fabricants, as was explained in Section 2.2 and Section 2.3. Seen in this way, the Society is in fact part of the interface between the eighteenth-century savants and the fabricants. However, as was indicated as well, since some of the Lunar members were more savant, while others were more fabricant, the Society was also a micro version of the larger savant and fabricant network. This both means that the insights about the Society discussed in this chapter might teach us something about the larger network as well, and that we could study the savant-fabricant interface by studying the interactions between savant Lunar members and fabricant Lunar members within the Society. New insights about the interface might be acquired by exploring the mixing patterns within the Lunar correspondence activity networks.

Analysis
A mixing pattern describes the way one type of nodes tends to connect with other types of nodes. Mixing could be assortative, when nodes tend to connect with similar nodes, or dissortative, (if nodes tend to connect with dissimilar nodes). Often the node degree is taken as characteristic feature of the nodes. In a social network we observe for instance that nodes are inclined to connect with nodes with a similar node degree. However, it is also possible to study mixing patterns based on a node attribute. Then one investigates if nodes tend to connect with other nodes that have the same attribute, or that they avoid them.

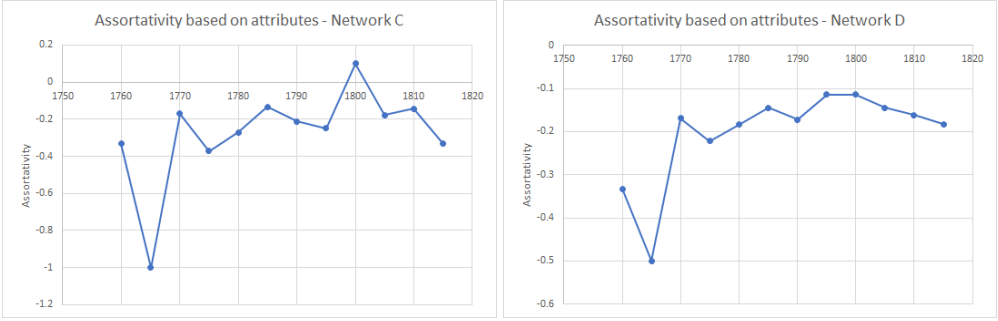
In order to explore the savant-fabricant interface, it was studied if savants tend to connect with savants, and fabricants with fabricants, or that the savants and the fabricants tend to connect more with each other than with 'their own group'. If we find out that the mixing is assortative, then this would support the conclusion that there were in fact two correspondence groups within the Society, savants and fabricants, that mostly communicated amongst themselves, but sometimes exchanged some information. If the mixing is neither assortative, nor dissortative, then we should conclude that the Society came together for a general love of knowledge exchange, but not specifically for the purpose of bringing two different strands of knowledge together. If however it turns out that the mixing is dissortative, we find support for the statement that different kinds of knowledge truly came together in the Lunar networks, and that the aim of members was to learn from members with different expertises.

The first step in studying the mixing pattern was to assign node attributes to each node. This attribute was either 'savant' or 'fabricant', based on how their associated member should be classified. The following members were listed as 'savant': Darwin, Priestley, Small, Withering, Edgeworth and Day. These members were labeled 'fabricant': Whitehurst, Boulton, Wedgwood, Keir, Watt and Galton. The criteria for this division were what the daily occupations of the members were, their primary interests, if they in fact produced goods and what kind of education they had enjoyed.[80] After adding these node attributes, the assortativity metrics were calculated, in which a positive value for a network slice corresponds with assortative mixing, and a negative value with dissortative mixing. The metric was calculated both for Network C and for Network D, the results are depicted in Figure 5.14a and Figure 5.14b. From the graph for Network C we can derive that the mixing was in almost every time period dissortative, and from the one for Network D we learn that the life-long, more abstract relations were mostly dissortative as well. From these results we can conclude that members aimed to correspond with members having different backgrounds than themselves. The savants-fabricants interface, at least according to this analysis of the interactions within the Lunar Society, was an interface in which the savants and the fabricants truly mixed.

5.6 Empirical networks compared to the Lunar Society

Introduction
In the previous section we encountered a way in which the Lunar networks could contribute to other scholarly areas besides the Lunar Society historiography. There are more such fields for which the Lunar networks could be of use: in this section

[80] See Section 2.5 for some backgrounds and biographical details about the members.



(a) (b)

FIGURE 5.14: *Assortativity metric based on attributes for Network C and for Network D*

we will explore the constructed networks in the context of the study of the development of empirical networks. This field of study investigates how real-world networks develop, and it looks for shared characteristics among these networks and their developments. In this way one could draw up 'laws' for the behaviour of empirical networks. Three such laws we already (implicitly) encountered: the observation that in real-world networks the diameter shrinks over time, the principle of triadic closure in the case of two strong ties, and the insight that nodes with similar degrees tend to connect. More observations like these could be made about the development of empirical networks, including more complex ones. Comparing the Lunar networks with these kind of laws shows us if the historical networks — in the way they are currently constructed and with the data available at present — follow the same patterns of development as modern-day empirical networks, and if not, in what manner they deviate. This type of information is for instance useful in the context of the network completion problem: if we get the impression that the development of historical networks tend to follow the same kind of laws as modern-day empirical networks (or if they approach such patterns, or if we understand how they deviate), we can use these insights in order to improve the inference of missing links and missing edge weight by including a prediction of the structure of the next slice based on the previous slice as one of the guiding principles for inference.[81]

Analysis

In this analysis I will compare the (development of) the Lunar correspondence activity networks with observations made about (the development of) empirical networks during experiments by network researchers McGlohon, Akoglu and Faloutsos.[82] For these experiments the researchers investigated a quite diverse set of networks, including unipartite, bipartite, unweighted and weighted (both in the interpretation of an amount and in the one of a multi-edge) networks. None of these networks were correspondence networks or social media networks, which both would be more comparable to the Lunar Society networks than for instance the citation networks, donation networks or a bipartite actor-movie network the researchers explored.[83] Still, the approach of McGlohon et al. seems to be general enough in order

[81] In other words: the (observed) development in the previous slices becomes a boundary condition and guiding principle for the (re)construction of the subsequent slices.

[82] McGlohon, Akoglu and Faloutsos, 'Statistical'.

[83] The datasets investigated included for instance paper citation details form *Arxiv*, user-movie links from *Netflix* and actor-movie relations from *IMDB*.

to compare the results with other types of empirical networks, especially because they present their results in a way that suggests they implied broad applicability. Except for one case, all empirical network observations are compared to findings in Network D. This is because McGlohon et al. investigated accumulative networks as well, although they did not make that explicit. Since one in general does not aim to study the social situation in certain periods, studying networks in their accumulating form is the usual thing to do for investigating development. Let me mention already at this point that we will observe that the networks are strictly speaking not large enough to develop clear patterns. Still, it is interesting to see what we can learn about the patterns that nevertheless do emerge. Especially because in general investigated historical networks are presumably smaller than the modern-day networks studied (because of the constraint data collection puts on the size of the historical networks).

The first observation to compare with the Lunar networks is the one that for many real-world networks their node degree distribution obeys a power law of the form

$$N(d) \propto d^{-\alpha}, \tag{5.1}$$

with $\alpha > 0$ and $N(d)$ the number of nodes with degree d.[84] Intuitively this 'law' makes sense: it states that there are in real-world situations many nodes with a low degree, and just a few nodes with a high degree. Interpreted for a social context this implies that there are many people with a few connections, and just a small bunch of people with many connections. For this comparison the node degree distribution of each network slice in Network C was created. These distributions can be found in the digital resources set.[85] An example is given by the depiction of the distribution belonging to the period 1775–1780 in Figure 5.15. We observe patterns that approach a power law such as (5.1) in the network slices of the periods 1765–1770, 1770–1775, 1775–1780 and 1795–1780. With some creativity we might spot the relation as well in the periods 1780–1785, 1785–1790 and 1790–1795, but for the period 1800–1805 the power law pattern is completely absent. In general the observation about the empirical networks thus applies for the earlier periods of the Lunar networks, but less or not for the later ones.

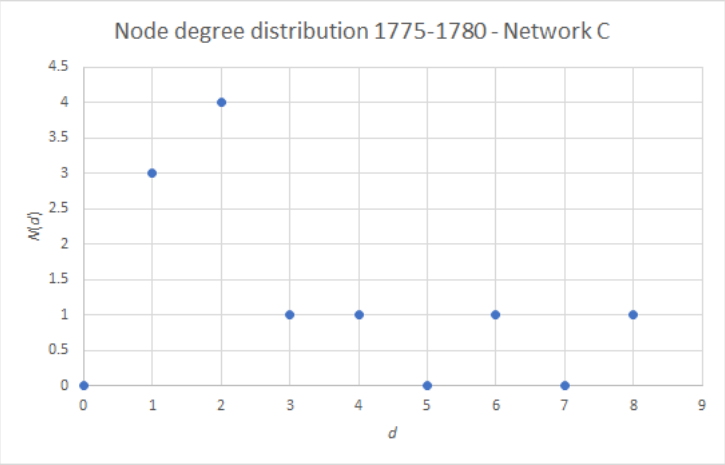


FIGURE 5.15: *Node degree distribution for network slice 1775–1780 of Network C*: the number of nodes with degree d plotted against degree d.

[84] McGlohon, Akoglu and Faloutsos, 'Statistical', p. 26.
[85] See Section 1.7.

Another observation about the development of empirical networks is that in a dynamic real-world network the total amount of edge weight up to a time t, $W(t)$, and the total number of edges up to that time, $E(t)$, relate to each other via the power law

$$W(t) = E(t)^w, \tag{5.2}$$

in which w is defined as the weight exponent.[86] McGlohon et al. refer to this phenomenon as the 'fortification effect':[87] the total edge weight increases faster than the total number of edges, the network becomes denser. That the relation between the total number of edges and the total edge weight would not be linear in the case of the Lunar Society correspondence activity networks is trivial. Such a linear relation would appear if each pair of correspondents would write an equal number of letters to each other and if they would do that just during one period. That is simply just not the case: people wrote during multiple periods — the edge weights kept increasing in the periods after the introduction of the edge — and their letter-writing rates vary over the years. The fact that we indeed observe such a non-linear relation in Figure 5.16 — $W(t)$ plotted against $E(t)$ for Network D — is thus not surprising. What is however remarkable, is that the relation approaches the power-law relation that well ($R^2 = 0.995$). It would be useful to investigate in further detail if this is a trivial result for the way in which Network D and the plot were constructed, or that it is a specific feature of our Lunar correspondence activity networks. In the experiments by McGlohon et al., the weight exponent w ranged from 1.01 to 1.5.[88] In the Lunar network we found a value of $w = 2.2$. To investigate if this value might had become closer to the ones established by McGlohon et al. by complementing the network, I calculated the value for the uncomplemented networks as well: there was no difference. Perhaps the value would approach modern-day values more if other edge inferring techniques were applied. We need to keep in mind, however, that it would be better to compare the Lunar weight exponent with ones of modern-day networks that resemble the Lunar network type better (modern-day messaging/corresponding activity networks for instance).

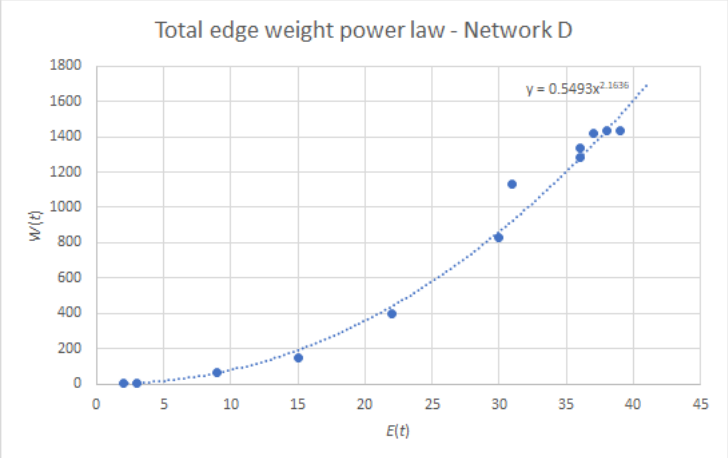


FIGURE 5.16: *Weight power law for Network D*: the total amount of edge weight at time t plotted against the total number of edges at time t.

[86] McGlohon, Akoglu and Faloutsos, 'Statistical', p. 28.
[87] Ibidem
[88] Ibidem.

The next relation McGlohon et al. found in their empirical networks is a correlation between the weight of a given edge, and the node strengths of the nodes it connects. The edge weight was found to be proportional to the node strengths of the connected nodes in the following way:

$$w_{i,j} \propto \left(\sqrt{(w_i - w_{i,j})(w_j - w_{i,j})}\right)^{\gamma}, \tag{5.3}$$

with $w_{i,j}$ the edge weight of a given edge and w_i and w_j the node strengths of the nodes connected by the edge, and γ an exponent.[89] Intuitively, in a correspondence activity network this relation should be interpreted as the observation that nodes that correspond a lot in general, will correspond much with each other.[90] In order to investigate this relation in the Lunar context, the edge weights $\{w_{i,j}\}$ were plotted against the right side of 5.3 for the last network slice of Network D. The result is depicted in Figure 5.17. Clearly, we do not observe an overall power-law relation. However, interestingly, there do seem to be 'local' power-law relations. We see such a pattern for instance in the regions with values 170–230 and 300–500 for the x-axis. The main outliers preventing an overall power-law relation seem to be the points associated with edge weights approximately higher than 50. One might interpret this observation as proof that data must be missing: for two nodes that would maintain such an active correspondence (that are connected by an edge with such a high edge weight), we should according to relation 5.3 had found higher node strengths for these nodes, in other words, we should have found more correspondence with others for these nodes. Perhaps this is an example of a type of relation that could be further explored as a way to complement networks: one might for instance want to investigate what happens with the associated networks if one keeps adjusting connections and edge weights until a graph like Figure 5.17 approaches a power-law relation.

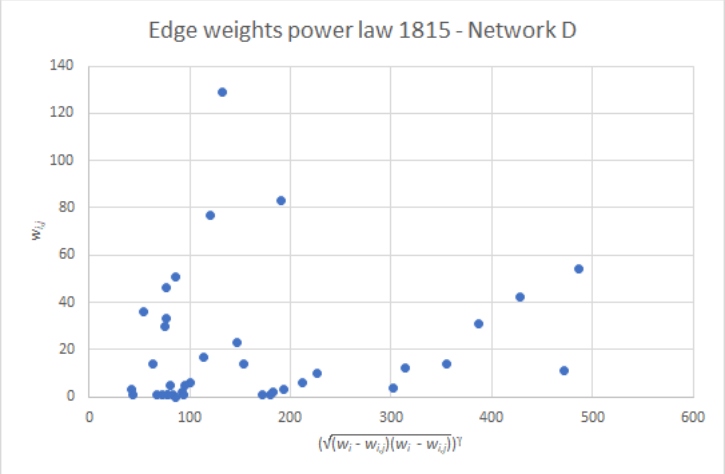


FIGURE 5.17: *Edge weights power law for network slice 1815 of Network D*: edge weights $\{w_{i,j}\}$ plotted against the values for $\left(\sqrt{(w_i - w_{i,j})(w_j - w_{i,j})}\right)^{\gamma}$.[91]

[89] McGlohon, Akoglu and Faloutsos, 'Statistical', pp. 28 and 29.

[90] McGlohon et al. make a useful comparison with Newton's law of gravitation: the force between two masses is proportional to the product of the masses. (McGlohon, Akoglu and Faloutsos, 'Statistical', p. 28.)

According to McGlohon et al., time-evolving empirical networks follow the 'densification power law', with which they mean the relation:

$$E(t) \propto N(t)^{\beta}, \tag{5.4}$$

with $E(t)$ and $N(t)$ respectively the number of edges and the number of nodes at time t, and with β defined as the densification exponent.[92] To detect this relation for the Lunar Society correspondence networks would again be a trivial result. One would find a linear relation between $E(t)$ and $N(t)$ only if each node connects with the same number of other nodes, and if that number of connections would not change over the years. Lunar members however kept making new connections after their introduction in the network, and they did that at different rates. Still the graph was drawn up, because it is interesting to compare the value of β with the ones of other empirical networks. The graph is shown in Figure 5.18. For the Lunar graph the densification exponent took on the value $\beta = 2.42$, this is a higher value than the ones McGlohon et al. found, which were all between of 1.03 to 1.7.[93] Notice that an exponential model would fit the development of the relation between $E(t)$ and $N(t)$ even better: the number of edges grew faster relative to the growth of the number of nodes than in the networks studied by McGlohon et al.

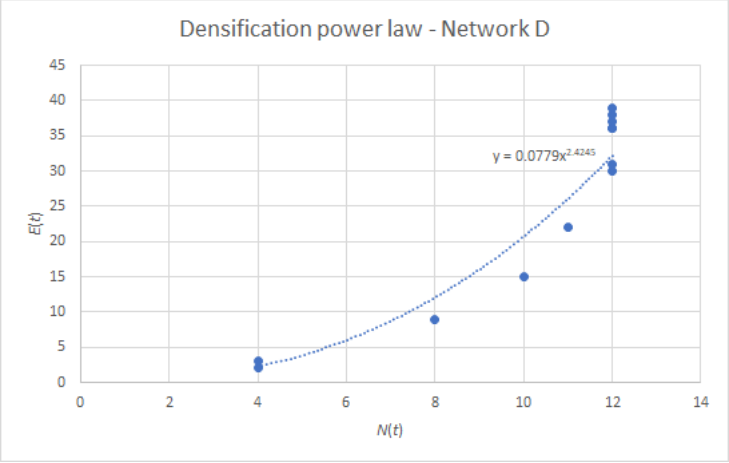


FIGURE 5.18: *Densification power law for Network D*: the total number of edges at time t plotted against the total number of nodes at time t.

The weighted principal eigenvalue power law observed by McGlohon et al. in their experiments, says that at time t the principal eigenvalues of the adjacency matrix of a network are related to the number of edges like:

$$\lambda_1(t) \propto E(t)^{\delta} \tag{5.5}$$

with $\lambda_1(t)$ the principal (largest) eigenvalue of the adjacency matrix of the network at time t, $E(t)$ the number of edges in the network at time t, and δ an exponent. In the empirical networks studied by McGlohon et al. the exponent δ ranged from 0.5 to 1.6.[94] For the Lunar Society correspondence activity networks a value of $\delta = 2.10$

[91] The point associated with the edge between Boulton and Watt has not been depicted (200; 663). Because the edge weight of that edge is very high, it would influence the scale of the graph in such a way as to make investigating the pattern of the lower values impossible.

[92] McGlohon, Akoglu and Faloutsos, 'Statistical', pp. 32 and 33.

[93] Ibidem, p. 33

[94] Ibidem, p. 38.

was found. The exponent is thus again higher than the ones detected by McGlohon et al., and again an exponential model could perhaps fit the Lunar data better, an impression we get from Figure 5.19: the graph in which the principal eigenvalues for the Lunar adjacency matrix are plotted against the number of edges at a certain time t.

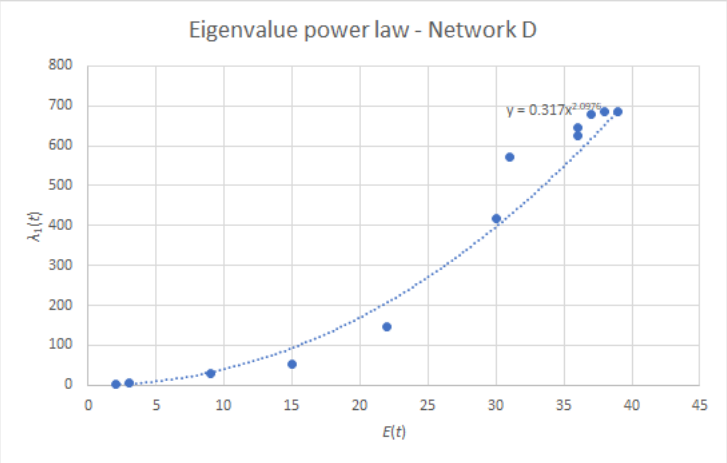


FIGURE 5.19: *Eigenvalue power law for Network D*: the principal eigenvalues at time t plotted against the total number of edges at time t.

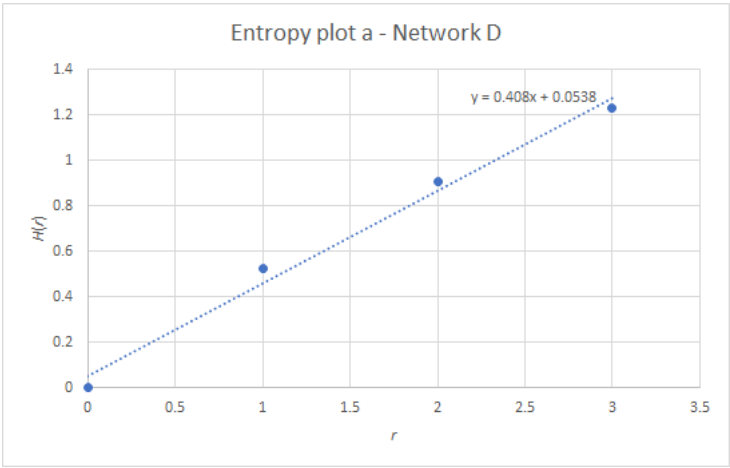
The last comparison between results of the experiments by McGlohon et al. and the ones from the study of the Lunar Society networks will serve the purpose of illustrating the limits we encounter for these types of investigations due to the small size of the Lunar networks. McGlohon et al. present a method to determine if the weight additions in a network are self-similar, and if so, if the additions are uniform or bursty. This method comes down to creating an entropy plot that plots the Shannon entropy $H(r)$ against the resolution r.[95] To calculate the Shannon entropy, first the time interval (of the dataset) is divided into 2^r sub-intervals, indicated by $k = \{1, ..., 2^r\}$. Notice that for each r the dataset is thus divided into a different number of sub-intervals. Then, for each interval k the edge weight addition $\Delta W(t)$ is determined and divided by the total weight $W_{total}(t)$ up to that point. This results in a series of fractions p_k for each value of r. Now for each of these series the Shannon entropy is given by:

$$H(r) = -\sum_k p_k \log_2 p_k. \tag{5.6}$$

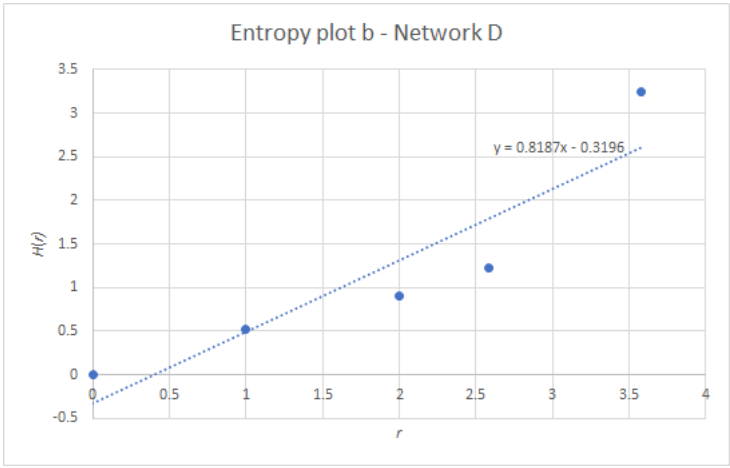
If the plot of $H(r)$ against r is linear in some range of the resolution, the weight additions are self-similar in that range and the slope of the graph then indicates if the weight addition was uniform or bursty. A fully uniform weight addition yields a slope of 1, the most bursty weight addition yields a slope of 0. McGlohon et al. stated that they found for their empirical networks in which the edge weight was defined as representing a multi-edge, slopes that were greater than 0.95 (uniform weight addition) and for the networks with edge weights interpreted as a certain amount, they found values down to 0.6 (bursty weight addition).[96] Since for the Lunar Society correspondence activity networks the edges are understood as multi-edges, we would thus expect to find a slope approaching 1, if the weight additions were indeed

[95] McGlohon, Akoglu, Faloutsos, 'Statistical', pp. 23 and 24.
[96] Ibidem, p. 36.

self-similar. Two versions of the entropy plots for the Lunar networks (both calculated for Network D) are depicted in Figure 5.20. The plot in Figure 5.20a includes $r = \{0, 1, 2, \log_2 6\}$ and the plot in Figure 5.20b includes $r = \{0, 1, 2, \log_2 6, \log_2 12\}$. We observe that the addition of an extra point — an extra value for r — has quite a significant influence on the conclusions about weight addition we would draw. The graph of Figure 5.20a is clearly linear, and thus we would conclude that the weight addition is self-similar. However, with a slope of 0.46 we have to understand it as very bursty weight addition, something one would not expect for edges interpreted as multi-edges. The graph in Figure 5.20b has a steeper slope and with a value of 0.82 it comes closer to our expectations. However, in this graph it is questionable if it is still 'linear enough': without being able to state that the weight addition is self-similar, we cannot make any claims about uniformity or burstiness either. Based on the graphs shown in the work of McGlohon et al. I expect that results would become more clear if more data is available. In this last analysis we thus encounter the limits imposed by the size of our dataset.



(a)



(b)

FIGURE 5.20: *Two entropy plots for Network D*: the Shannon entropy plotted against the resolution, subfigure a has four values for r, subfigure b has five values for r.

All in all, in this section we discovered that the development of the Lunar Society

correspondence networks often (but not always) resembled the patterns of development of modern-day networks, although in many cases that result was trivial and should be ascribed simply to the nature of the correspondence activity networks. When the exponents of power-law relations found in the experiments by McGlohon et al. were compared with the ones for the Lunar networks, we always observed that the ones for the Lunar networks turned out to have higher values. I think this corresponds with the more general impression from the comparisons that the Lunar networks grew faster than the networks investigated by McGlohon et al. A study of the figures in this section shows that in many cases the Lunar patterns were not that clear because of the small size of the dataset, unfortunately this is something we have to get used to in the context of historical networks. Despite the fact, of perhaps especially because of the fact, that the development of the Lunar networks did not always mimic the one of the modern-day empirical networks, we encountered some possibilities in which the observations about the development of empirical networks might be able to aid in the inference of missing links or missing edge weight.

5.7 Interpretation of the Lunar Society

Introduction
Three out of the four discussions in the Lunar Society historiography that were introduced in Section 2.4 have been addressed in this chapter up to this point: the debate about the Society's rise and decline, the questions about certain social roles among the Lunars, and the issue about Lunar membership. Only the discussion about the interpretation and the characterization of the group has not been focused on yet. Might it be possible to shed light on this debate with network analyses as well? I could not think of an analysis that would directly settle the issue definitively, however, by bundling the results of some of the previous analyses, we might be able to add a new perspective to the question.

Analysis
Section 5.1 and Section 5.4 shared a similar conclusion: the confusion that had arisen among historians about the issue of Lunar membership and about the one of the Lunar Society's begin- and end date, were both based on (implicit) use of different criteria. Due to the systematic and quantitative analyses of the primary source material, these different criteria came to light. We found out that Schofield concentrates on correspondence activity in determining when the Society rose and declined, or when someone could rightly be called a true Lunar member. Jones and Robinson on the other hand focused on the meetings in order to establish dates and assess membership. Uglow's criteria instead centered around connections, friendship and the formation of a group of friends (a cluster or clique).

If we now think again about these historians' interpretations of the Society that were described in Section 2.4, we realize — perhaps without surprise — that the criteria used by the historians are intrinsically connected with their interpretations. Schofield thought of the Society as akin to a technological research programme, so for him the 'meetings of the Society were comparatively unimportant'[97] and instead he concentrated on the actions of the members in working towards new findings and solutions. The Lunar focus of attention should in his eyes be found outside the meetings, in the members' individual research, in their collective endeavours and in their wide range of activities for bringing about industrialism and applied

[97] Schofield, 'Orientation', p. 410.

science. Jones, on the other hand, understood the Lunar Society in the Enlightenment tradition and perceived it as something like a civil conversation group or a masonic fraternity. With this interpretation in mind, it is clear why Jones' criteria centered around meetings: the focal point for a civil conversation group would be the moment that the group came together to have their civil conversations. In Jones' opinion it are then these meetings that provided the primary reason to join the Lunar Society. The Society not necessarily pervaded the members' daily lives with all kinds of activity (research, business, correspondence), but it presented a way for the Lunar men to 'leave their mundane, mercantile preoccupations at home when banding together in their monthly quests for enlightenment.'[98] Uglow's interpretation was less clear, but it was noted that it tended more towards Schofield's view than Jones'. Criteria built around connections, friendship and the formations of groups of friends does indeed fit the focus of attention on what happened outside the meetings that comes with the interpretation of the Society as a research programme. However, besides the hint given by the subtitle ('The friends who made the future'), the contents of her book show an attention for friendships and developing personal relations as well. Perhaps we should therefore change our previous idea that Uglow's interpretation came down to Schofield's point of view (but attenuated),[99] to the idea that she would subscribe to the view that 'the Lunar Society was a group of friends that shared a love for experiments', that 'came together simply through the pleasure of playing with experiments.'[100] In Robinson's case it is more difficult to tie his type of criteria to his interpretation. As mentioned, Robinson's account is somewhat similar to Schofield's as well, so according to the reasoning above Robinson's criteria would contradict his interpretation. However, it was also explained that Robinson's understanding of the Society was more flexible and inclusive, attenuating the programmatic industrial outlook and underlining the informal character. Because of this last point, because his criteria focused on meetings and because of the fact that we learned in Section 5.2 that Robinson emphasized that the origins of the Society should be found in philosophical gatherings at Darwin's house, I think we can now better understand Robinson's interpretation and should conclude that he understands the Society in the tradition of these informal philosophical gatherings. Robinson might have stated that we should not be dogmatic about specific meeting places, still, the get-togethers (that might have been more like monthly quests for laughs than about 'monthly quests for enlightenment') on itself should — according to our conclusion — in his eyes be seen as the focal point for the Lunar Society.

The disputes arose because of the historians' different criteria. So in order to find consensus, historians should agree about the criteria on which the decisions will be based. However, a historian that interprets the Lunar Society as mainly being about meetings, will not accept correspondence activity (or other activity outside meetings) or the formation of friendships as the focus for criteria. In the same vain will a historian that interprets the Lunar Society as a research programme not accept criteria centered around meetings. There might however be an alternative focus for criteria, one that might satisfy both the first kind of historians and the second kind: criteria centered around cooperation and identification.[101] Such criteria would take into account a person's participation in meetings, correspondence and collaborative projects, but only as a part of an assessment of someone's self-presentation. Did

[98] Jones, *Industrial*, p. 94.

[99] See Section 2.4.

[100] Uglow, *Lunar Men*, p. xv.

[101] To come back to the promise made in Section 2.5: these are the principles on which my criteria for membership of the Lunar Society would focus.

someone present himself as a representative of the Society to the outside world (and was he seen as such by others as well)? And were they were involved in developing the Society and in executing the Lunar Society's functions? In the context of the rise and decline of the Lunar Society the begin- and end date would be based on the moment that a clear group identity was formed and flattened out (for which correspondence activity and meetings could serve as indications, amongst other factors), and on the moment that the group started to present itself and act as one body in the outside world, and when they ceased to do so. Both kind of historians might agree on this center of attention for the criteria, because both the meetings and the correspondence activity would still be taken into account, be it however in an instrumental way.

This focus for criteria is connected to an interpretation for the Lunar Society that does not understand it as a research programme, as an Enlightenment conversation group, as a group of friends or as a series of informal philosophical gatherings, but as a collection of people that acted collectively, as a true *association* (the name 'Lunar *Society*' might have already given it away). 'Cooperation' should then be interpreted in the most literal sense of the word: operating together. In this interpretation the focus of attention is not the meetings or the activity outside the meetings, but it is the network in itself. The core of what the Society is, are in this interpretation the links that connect the people not (only) as friends, but as cooperators — binding them together in a way as to act in the outside world as one single body, as a node within the larger network of eighteenth-century science. More influence, authority and effect in the world of science and commerce were created by bundling forces and by working towards common goals. These common goals should in this sense however not be understood as necessarily being the collaborative (industrial) projects highlighted in Schofield's interpretation, but they should be seen as more broad and flexible. Three main goals for the Lunar Society as a body — three main modes in which the group cooperated and acted as a single actor — could be distinguished: the creation of knowledge, the justification of knowledge, and the dissemination of knowledge. By fulfilling these roles, the Society was an important player in the eighteenth-century landscape of the Industrial Enlightenment. In this way the tension between the industrial-types of interpretations for the Lunar Society and the Enlightenment-types gets resolved.[102] The Society was neither an industrial research establishment, nor an Enlightenment civil conversation group: it was an Industrial Enlightenment knowledge junction. Meetings and correspondence activity are in this view 'materializations' of the cooperations, which were just as much goal-oriented activities but in a polite style, as they were acts of civility but with a programmatic outlook.

In the primary source material we find some evidence that this interpretation and the ideas about the main goals of the Lunar Society were shared by contemporaries. Priestley wrote for instance to Withering that he had 'lately written to Mr. Watt, and desired him, or the Lunar Society, *as a body*, to make a proposal,'[103] and in Section 5.2 we learned that the whole of the Society was attacked during the Birmingham Riots, because they were associated with Priestley — the cooperation is taken accountable for the actions of its members. In the context of the main goals we observe for instance that Edgeworth underlined in his *Memoirs* the combined efforts in the creation of knowledge and the concept of the Society as a single body when he wrote that '[t]he knowledge of each member of such a society becomes in

[102] See Section 2.4.

[103] Priestley to Withering, November, 1791, as cited in Bolton, *Scientific*, p. 215. My emphasis.

time disseminated among the whole body, and a certain *esprit du corps*, uncontaminated with jealousy, in some degree combines the talents of members to forward the views of a single person.'[104] The Lunars' role in knowledge dissemination we already encountered in Section 2.2, where it was mentioned that the Society attracted many foreign visitors and that learned men used the Society to announce their discoveries, thereby recognizing its potential to spread their findings. Watt acted as a representative for the Society when he wrote to one of these learned men, Richard Kirwan, that 'according to your desire, I communicated it to our Lunar Society last Monday, who desire me to return to you their thanks.'[105] Although the characteristic did not play a role in their interpretations, historians did recognize the trait as well. Bolton stated for instance that: 'it [the influence of the Society] had stimulated inquiry and quickened the zeal for knowledge of all who had come within its influence, and this spirit diffused and propagated itself in all directions.' Jones used the nice phrase that: 'they acted as a kind of relay station.'[106]

The role of the Lunar Society in the justification of knowledge is not that much addressed in the historical literature, but there are many indications that the Society had an important function in assessing knowledge and in granting it a certain status. The Lunars served as a board of judges for ideas from outside the Society, only adopting and passing on the ideas if they acquired the Lunar seal of approval. Perhaps even more important was the Society's potential for members to get their own ideas endorsed and to grant them authority.[107] In this way the members did not only cooperate in developing ideas, but in reinforcing and defending these ideas 'in the outside scientific world' as well. We observe that the Lunarians propagated ideas as a group, acting as a single player in scientific discussions (of course this was not always the case). The observation that the group acted as a board for justification and that they adopted ideas as a body, becomes for instance clear from the affairs around the debate on phlogiston. Especially Priestley was an important player in this discussion, and we see that the Society was both involved in backing him up, and in assessing the ideas of other players as well — resulting in the fact that they did eventually change their opinions, but much later than others. That Priestley was looking for the approval and recognition of his Lunar friends we read for instance in Bolton's *Scientific*, when he wrote that: 'Priestley, as a friend of Watt, communicated speedily the result of his experiments, sometimes it is reasonable to believe, over the festive board of the Lunarians, and left the conclusions to be drawn by others.'[108] Priestley himself wrote in a letter to Wedgwood '[b]efore my late experiments, phlogiston was indeed almost given up by the Lunar Society, but now it seems to be re-established,'[109] underlining that the group took up views as a whole. Then, supporting this point as well, when the idea of phlogiston at last got abandoned, Catherine Wright writes to Withering that: 'He [Mr. Moore] tells me the Philosophers at Birmingham no longer allow of Phlogiston. Perhaps he Joked. I am always (?distressed to) hear of any Mistakes or Contradictions between Philosophers in any system of Philosophy. It puts me in fear that all Sublunary wisdom is imaginary.'[110] The phlogiston affair was not the only time the Lunars' acting as a group tied them to unsuccessful ideas, we observe it for instance as well when

[104] Edgeworth, *Memoirs*, as cited in Bolton, *Scientific*, p. 218.
[105] Watt to Kirwan, 14 November, 1783, as cited in Bolton, *Scientific*, p. 200.
[106] Jones, *Industrial*, p. 94.
[107] 'Lunar science is good science.'
[108] Bolton, *Scientific*, p. 206.
[109] Priestley to Wedgwood, 21 March, 1782, as cited in Bolton, *Scientific*, p. 207.
[110] Wright to Withering, 25 December, 1786, as cited in Robinson, 'Membership', p. 170.

Keir was dragged along into Watt's failing attempts in making alkali by a specific method:[111] there is a downside of being connected too.

[111] Moilliet and Smith, 'Keir', p. 145.

Chapter 6

Closing the curtains: conclusions and their spur for further research

6.1 Conclusions

The aim of this research was to explore the potential of Digital Historical Social Network Analysis as a historical method. Five conditions were established on which DHSNA should be judged in order to determine if it qualifies as a promising method: added value, reliability, practicability, scope and prerequisites. In order to investigate these categories and to map the difficulties and the opportunities of applying social network analysis to bodies of historical data, a case study has been executed. This case study centered around the Lunar Society, an eighteenth-century informal scientific society in England's Midlands. The question the case study focused on was to what extent DHSNA would be able to teach us more about the social and the organizational structure of the Lunar Society. In this chapter we will take stock to see how much the method was able to add to the Lunar Society historiography. We will combine these observations with discussions of the research design and evaluations of the research process to formulate an assessment of the potential of DHSNA as a historical method. As was stated in the introduction, because the aim was to investigate a (relatively new) method, these discussions of the research design and the evaluations of the research process are just as much part of research results as the answer to the question if DHSNA could add to the Lunar Society historiography, and together they constitute the input to be judged by the five categories.

The process of data collection consisted of several stages. First, Lunar letters were located in archival collections and in published correspondence, then the meta-data of these letters were gathered, after that the collected data was cleaned, and finally the database was evaluated. During the stage of entering the meta-data a crowdsourcings experiment has been carried out. The details about these parts of the research design and the discussion about them can be found in Chapter 3. Here I will only address the evaluation of the data collection process, previously elaborated on in Chapter 3 as well. The main conclusion about the evaluation of the data collection process is that one should not underestimate the amount of time and effort this research phase requires. The first few reasons why one might easily underestimate this amount of time and effort, is that some stages of the data collection process are easily overlooked (such as data cleaning) and because it is not always realized that data collection is not just a preparation, but already part of the 'actual research'. This is because many decisions during the data collection process require research and a sufficient amount of background knowledge before they can be made. The second reason is that the data collection process takes more time and effort than strictly necessary because — at least according to the experiences during this research project — the historical research infrastructure is as yet insufficient to meet the demands of

(large-scale) data collection. Some problems encountered during this research were for instance the lack of a sufficient central overview of the locations of collections, the dependence on outdated and low-quality web pages of archives, the absence of item-level descriptions in archival collections, and the shortage of international style conventions for the formulation of meta-data. In the context of DHSNA it is furthermore relevant to note that both crowdsourcing and data management, two topics related to data collection, are not without issues as well. Crowdsourcing struggles for instance with quality control and organization efforts, data management with suitable storage space and maintenance. Due to several factors in a data collection process uncertainties will slip into the dataset, the factors for this project were listed in Section 3.4.

The translation of the collected data to network visualizations and the calculation of their associated metrics were not straightforward. For both processes methodological and interpretative issues had to be considered. It is important to realize that networks built on the constructed dataset would not depict the social and organizational structure of the Lunar Society, because the edges would not symbolize social relations, but exchanged letters. However, neither would the networks show the correspondence activity of the Lunar Society members, because it became clear from details about correspondence preservation, the data collection process and the specifics of the dataset, that data must be missing. All we would be able to construct are maps of the data we collected. These maps can be useful — for instance to study historians' biases created by the constitution of the set of available correspondence — but, as said, they are not in itself proxies for the social structure: a number of exchanged letters is not one-to-one related to the strength of a social relation. Therefore the maps needed to be translated to observations about the social and organizational structure. In order to let the maps of our collected data approach a correspondence activity network more closely, two methods of reconstruction were applied (not at the same time): converting edges representing absolute numbers of letters to ones that represent relative numbers, and complementing the network by edge symmetrization. These methods were applied to two type of networks visualizing the collected data. One type of network depicted the social situations during periods of five years by summing and depicting the data for each of these five-year periods, the other network was accumulative and its network slices showed snapshots of the network at five years apart. Applying the reconstruction techniques and deciding on what would be the most useful network designs resulted in four kinds of constructed networks. The details about the construction procedure, including encountered problems and considerations, can be found in Chapter 4. A noteworthy insight to mention here is that it is important to think about the moment when to complement an accumulative network: the periods in between edge symmetrizations should be neither too short, nor too long. Observations about the social and organizational structure could be derived from the correspondence activity networks by interpreting them while taking into account details about the data collection process, methodological considerations and historical contexts. A breakdown of these factors is listed in Section 4.3. The process of interpreting the correspondence activity networks was aided by different qualitative and quantitative analysis methods. These last methods include the calculation and study of metrics. These metrics had to be reinterpreted in order to comply with the meaning of our networks. A list of the calculated metrics is depicted in Table 4.1 in Section 4.5. The most important evaluative insight about this part of the research process is that it asks the historian to learn new skills and to develop (new or adjusted) methods suited for the investigated historical case. There are for instance as yet no — or at least, they were not

encountered during this project — easily accessible DHSNA tools that could meet all historical wishes and demands without requiring much extra study and the development of skills that historians do not usually acquire as part of their regular training.

By analyzing the network visualizations and metrics it was investigated to what extent they could contribute to the Lunar Society's historiography, and to some other scholarly fields. The reliability of the network visualizations was explored by comparing them with the more basic details and insights about the Society's social and organizational structure in the historical literature — these are details that are (almost) not disputed and that could easily be verified with source material. The network visualizations could not reproduce all the more basic details and insights. Some edges that one would expect to find in the networks based on the historical literature were missing, which could be explained by missing data in the dataset, by a mistake in the historical literature, or by a historical explanation why the social relation did not spur (much) correspondence activity. Also some more complex social situations (involving multiple edges and including the proportions between these edges) could not be derived from the networks without much additional knowledge and the expectation based on the literature to detect these situations. As was noted in the Introduction and on several other occasions, network visualizations should never serve the purpose of just mapping (a certain part of) historical reality as completely as possible, but they should be used as tools to answer certain historical questions. However, an estimate about their completeness is important to assess their reliability as tools. In the case of our Lunar networks, it thus turned out that this reliability fell short. Still, the networks could be used as tools as long as these limits are taken into account.

Comparing the network visualizations with the historical literature did offer some options to formulate new hypotheses that might add to the existing historical literature. These new hypotheses should be understood at the level of relations between two people, thus being based on unexpected edges, unexpected edge weight, or the absence of edges. Unfortunately, the network visualizations were not able to spark new hypotheses about more complex social situations, the depictions were not reliable enough (as mentioned above, it was not even possible to derive all the more basic social situations already identified by the literature), and because there were for a visualized structure just too many different explanations when taking all the details about the data collection, methodological considerations and historical contexts into account. The network visualizations were not determinative enough to derive new hypotheses about social situations in a meaningful way. This unreliability and these different explanations are also the reason that the new findings at the edge-level had to be understood as new hypotheses, and not as new definitive discoveries: the networks do not offer this level of certainty.

Furthermore, it was investigated if analysis of the network visualizations and their accompanying metrics could shed light on four discussions among Lunar Society historians. These were the disputes about when the Lunar Society rose and fell, about certain social roles of members (especially about who was the most central figure), about Lunar membership (especially about the case of Wedgwood's potential membership) and about the characterization of the Lunar Society. It turned out that the analyses were not able to settle these discussions, so in this way they could not add to the existing historical literature. However, the analyses were able to unravel the debates, to uncover certain (implicit) criteria used by the historians, to structure the discussions and to support certain stances, so in this regard they could in fact contribute to the literature. The analyses not being able to definitively

solve the debates is precisely because of the fact that positions were based on different criteria: network visualizations and metrics can uncover these criteria, but they cannot decide on which criterion to use. We learned that positions in the debate about the rise and decline, and positions in the debate about membership were both dependant on the historians either focusing on meetings, or on correspondence activity, or on connections and the formation of a group. Based on the insight that the disputes arose because of different criteria — which are connected to different characterizations of the Lunar Society — an alternative focus for criteria was proposed, combined with an alternative associated interpretation of the Society: criteria centered around cooperation and identification, and the characterization of the Society as a true association — a group of people acting collectively as one body (in creating, disseminating and justifying knowledge). Other conclusions in the context of the four disputes were that Darwin, Small and Boulton were *all* central figures, but consecutively, and that the inclusion of all twelve people as Lunar Society members was justified, although in the case of Wedgwood only if correspondence activity was taken into account in deciding on membership.

It was also investigated if the network visualizations and metrics might be able to contribute to other scholarly fields. One analysis examined the use of the Lunar Society networks as a case study to explore broader historical topics. In this instance the mixing patterns in the Lunar Society networks were studied in order to investigate the eighteenth-century savant-fabricant interface. It turned out that the Lunar Society members that were more savant and the ones that were more fabricant tended to connect more with each other than among themselves, indicating that in the savant-fabricant interface within the Lunar Society the savants and the fabricants truly mixed. With these type of analyses the visualizations and metrics might thus be able to contribute to existing studies. The other scholarly field for which the added value of the Lunar Society networks was explored, was the one of the study of (the development of) empirical networks, a strand within the field of (social) network research. A result of this analysis was that (the development of) the Lunar Society networks did often resemble the (developmental) patterns of real-world (social) networks, although this seemed in some cases to be a trivial result considering the characteristics of Lunar Society networks. Two other results were a general impression that the Lunar Society networks grew faster than modern-day empirical networks, and that unfortunately the dataset was not always large enough to present clear patterns. The Lunar Society networks can add in these ways to the study of empirical networks by providing an opportunity to study historical empirical networks, at the same time we encountered options for observations about (the development of) real-world networks to serve as possible guiding principles for historical network complementation.

We now have gathered enough material to come to a verdict about the potential of DHSNA as a historical method. The network visualizations of the Lunar Society and their associated metrics brought added value by offering a clear overview of (collected) available correspondence; by illustrating certain social situations mentioned in the historical literature; to an extent by providing new hypotheses; by offering opportunities for contributions to other scholarly fields besides the one of the study of the Lunar Society (like the study of other historical topics, or strands within network research); and by shedding light on historical discussions by unraveling them and by uncovering underlying principles. What could not be done with the network visualizations and accompanying metrics was discovering new

findings with certainty; was formulating hypotheses about more complex social situations; was completely accurately depicting the correspondence activity of the Lunar Society; was deriving all the more complex social situations mentioned in the historical literature; and was solving the four disputes among Lunar Society historians. The described lack of reliability of the constructed networks is (part of) the cause for most of these issues. Furthermore, due to the meaning of the edges in our constructed networks, the network visualizations were not able to depict the social and organizational structure in itself, and neither could they depict knowledge flows. In the context of practicability the most important observations are that the DHSNA research process requires more time and effort than should be strictly necessary: the historical research facilities currently available are unsatisfactory, there are some unresolved (practical) problems, and for an unexperienced historian the method requires acquiring many extra skills and much extra background knowledge (for interpreting the networks). Combining these observations about added value, reliability and practicability, I think we need to conclude that DHSNA is not a suitable historical method to study tight historical groups (scope), that is, not until more advanced methods have been developed, the historical research infrastructure has been improved, and more easily accessible tools for historians have been created (prerequisites). At this moment, the insights that the network analyses could bring are not significant enough to outweigh the practical difficulties and the amount of effort the DHSNA research process asks for. An exception on this observation should be made: if one is an expert in a certain historical field (in other words, if one does not need to study many extra backgrounds) and if one already has some serious experience with social network analysis techniques, then the results would be worth the effort.

Does that mean that there is no hope for DHSNA? Not at all. Firstly, the above verdict only applies to the case of the tight historical group, the prospects for DHSNA in the context of looser groups are better. For the Lunar Society and similar tight groups, matters become more complicated because a social acquaintance network ('who knows whom') would be completely connected, and because a correspondence activity network is not a proxy for a social relations network ('who knows whom in what way'). However, in a group of people that is less tight (not completely connected), a correspondence activity network does in fact become a proxy for a social acquaintance network (with the risk of missing social links when correspondence is missing of course), and I expect that in such a group the correspondence activity network does become to resemble more closely the social relations network (if there is much diversity among the relations between people — as you would expect in a loose network — if the 'scale of friendship' is not as fine-grained as in a tight network of friends, then the number of exchanged letters suddenly becomes a better measure for the quality of relations). Secondly, there are many opportunities to meet the mentioned prerequisites. Many interesting ideas and techniques can be found within the fields of data science, computer science, (social) network science and sociology that are not yet applied within historical network research, but that are very promising (after translation to a historical context) in the quest for the advanced methods needed in order to study the more difficult types of historical groups effectively. Intriguing opportunities were encountered during the execution of this research project for which an elaboration within the project would have been outside the scope, but that did show that there is still much to discover for the field of historical network research. Furthermore, the suggestions previously put forward for improvements of the historical research infrastructure seem feasible, especially because efforts are already made towards this goal. Also for the creation of easily

accessible DHSNA tools there have already been some ideas proposed in the previous chapters, but the actual development of such tools might be more difficult than implementing improvements in the historical research infrastructure. Ideally one would develop a tool that combines different techniques useful for DHSNA: such a tool allows you to upload your data; provides options to easily create dynamical networks that are depicting the data summed per period or as snapshots (see Section 4.2); can complement the networks according to different combined principles (see Section 4.3); offers the possibility to calculate metrics; has an interface that is simple to understand and that lets you manipulate networks directly (for example: adding attributes); and eases network interpretation and comparison by supporting the option to depict networks constructed based on literature (or other previous knowledge) next to networks constructed based on gathered data. This last option would also serve educational, communicative and outreach purposes (as illustration of research results and as a way for people to interact with the material).

6.2 Further research

Let me to conclude list some ideas for further research that were spurred by the research project. The first set of suggestions is about ways in which the investigations of the Lunar Society networks developed during the project could be extended or improved. As was pointed out in Section 2.5, some historians listed Jonathan Stokes and Augustus Johnson among the Lunar Society members, but in the current research these men have been excluded for reasons explained in the section. As an extension of the examinations and to investigate the men's possible membership, it would be interesting to gather the correspondence of Stokes and Johnson with Lunarians and add these data to the networks. Other figures that would be interesting to add are the Lunar sons, also when one does not want to regard them as members. What would their connections with the (remaining) Lunar men look like? Do we perhaps observe that the sons replaced their fathers in the networks after the fathers passed away — do they take over the connections and role their fathers once were associated with? In Section 3.2 three adaptations of the Lunar Society networks were listed as ideas for further research: the first one was to use the gathered data about the locations of senders and the locations of recipients to construct geographical networks, the second one was to highlight letters of introduction in the networks to study for instance triadic closure, the third one was to include Lunar companies as separate nodes in the networks and to add business correspondence to the dataset. This last idea might for example be useful in investigating the savant-fabricant interface, or to study how personal correspondence and business correspondence related to each other. To examine in more detail the reliability and characteristics of the results of the analyses described in Chapter 5, one might want to rerun the analyses while excluding or moderating Boulton's total correspondence, or just Boulton's correspondence with Watt. In this way it can be studied how much influence his set of letters (exchanged with Watt) — much better preserved than the collections of other members — had on the results. As indicated, unfortunately it was not possible with the current networks to study knowledge flows. Developing a method that could in fact study these flows would open the door to investigating many intriguing research questions. This applies especially to the Lunar Society, since it could then be studied how different types of knowledge and ideas might have interacted with each other, and how knowledge and ideas spread through the Lunar network

(remember the idea for tracking the spread of ideas in a network mentioned in Section 4.3). It would become possible to engage with historians' question about the extent to which individual accomplishments by Lunar members should be related to the influence of the Society as a whole,[1] and it could be studied when knowledge did not flow — even within the Lunar Society there were secrets. We know for instance about a case during the time in which both Edgeworth and Watt were already writing with Lunar men, but were not completely involved yet. Both men were corresponding with Lunarians about steam engines, but they did not know about each others' work because the Lunar men did not wanted to divulge their correspondents' secrets (which illustrates again the point that a correspondence activity edge is not a knowledge flow edge).[2] Furthermore, it was noted by Jones that Boulton struggled with the tension between natural knowledge dissemination (a polite requirement) and practical knowledge transfer (often a trade secret).[3] The topic of knowledge flows and secrecy are related to the study about the ways in which and the extent to which Lunar men deliberately used their awareness of certain networks to influence certain events or perhaps to manipulate the structure of the networks themselves. Obviously, both would be intriguing research subjects. Lastly, instead of studying the exchange of letters, we could also learn about the Lunar Society and related historical topics by studying the flow of materials. To be able to study these flows, we do have to delve into all the contents of the correspondence, but perhaps it might be worth it. It would definitely be interesting to compare these type of edges with the ones symbolizing exchanged letters, exchanged ideas, or social relations.

The second set of ideas for further research is about different types of networks that might be interesting to study with DHSNA methods. In Section 2.3 a method was mentioned to construct the network surrounding the Lunar Society: collecting the complete correspondence of the members, identifying interesting figures that corresponded with multiple members, complementing the network with data about the correspondence of these figures, and repeating the process until the network has its desired size. Because this idea was outside the scope of the project, it was not executed, but it could be fruitful to develop further during another project. In this way Lunar membership could be studied in more detail (see Section 2.5 for the initial plan to identify Lunar Society members), it could be examined with what kind of people the Lunar Society was in contact (industrialists? family members? politicians? scientists?), and the interactions with some interesting boundary figures could be studied (such as Maria Edgeworth, to study the interactions of the Society with a female intellectual and a Lunar family member, or Benjamin Franklin, who brought some Lunarians together and wrote a lot with the Lunar men). Since the Lunar Society history is interwoven with the story of the connections between savants and fabricants in the eighteenth century, these type of investigations are especially of use to study these interactions. The network shared by savants and fabricants would in general be interesting to study in more detail, even without including the Lunar Society. Another way to explore the (English) eighteenth-century intellectual landscape would be to create a network of the connections between the different scientific societies, for instance a bipartite network that includes the societies and their members (many people were members of multiple societies). Another approach to study the other scientific societies besides the Lunar Society in more detail would be to create similar correspondence activity maps for those societies as were made for the Lunar Society. In this way the Lunar Society's networks could also be compared with these

[1] Schofield, 'Bicentenary', p. 153.
[2] Schofield, 'Orientation', p. 412.
[3] Jones, *Industrial*, p. 89.

other networks to spot if their structures were common or not. These comparisons could be extended with ones that compare the networks of scientific societies with networks of other types of organizations and historical groups.[4] A scientific society that provides a particularly interesting opportunity for a historical network research is the Royal Society, their archives include for each person that became a member a record of whom had recommended this person: these relations would be interesting to visualize with a network.

The last set of suggestions considers ideas specifically related to the field and the techniques of DHSNA. The most important recommendations for further research have already been mentioned in the previous section. These are the improvement of the historical research infrastructure (specific suggestions can be found in Chapter 3), the development of easily accessible tools for DHSNA (specific suggestions can be found in Chapter 3, Chapter 4 and the previous section), and the creation of more advanced DHSNA methods by exploring more techniques from other fields concerned with network research. A technique I would like to highlight as especially promising for the field of DHSNA is the one of block modeling, a method extensively used within social network research. For this technique social roles are interpreted as characterized by common relational patterns, social roles could thus be recognized by identifying these patterns. In Section 4.3 the potential role of pattern recognition in complementing historical networks was already mentioned, and it might also be of use during the interpretation of networks (in Chapter 5 we observed how hard it was to draw conclusions about more complex social situations, maybe this technique might solve a part the problem). Perhaps a function for pattern recognition and social role identification could be added to the suggested DHSNA tool described in the previous section. It would be even better if such recognitions were improved each time a new historical network was analyzed with the tool and the user corrected mistakes made by the tool based on comparisons with additional material. Another strand of network research that might be of special interest to the field of DHSNA is the network completion problem that was just referred to and that is more extensively discussed in Section 4.3. Lastly, it is important to have in mind that the development of DHSNA, and maybe we should say the one of Digital Humanities in general, is accompanied by several discussions regarding the character of the field and scholarly practice. Does the academic publication perhaps need to be redefined in order to include developed software or just a set of visualizations as well? On which institutional doors should the digital scholar knock for funding? All in all: there is still a lot to explore.

[4] Take however into account that in the Conclusions section above DHSNA methods were discouraged as long as the prerequisites are not met or the researcher does not have experience with both the historical field of investigation and the DHSNA techniques.

Appendix A

Activities of the Lunar Society

TABLE A.1: Activities of the Lunar Society [1]

Date	Activity
1771	Erasmus Darwin's speaking automaton
Spring 1775	Experiments on time pieces
Early 1776	Experiments to determine the nature of heat
April 1779	Optimum design for a horizontal windmill
Summer 1779	Improvements to Erasmus Darwin's letter-copying machine
Januari 1781	Carl Scheele's research into heat transfer
Januari 1781	Chemical composition of inks
Februari-March 1781	Repetition of James Watt's kettle experiments
April 1781	Joseph Priestley's experiments igniting a mixture of inflammable air and common air with an electric spark
Juli 1781	Chemicals analysis of white spar
Early 1782	Experiments to determine the composition of water or steam
October 1782	James Smeaton's experiments with circular motion from steam engines
December 1782	Joseph Priestley's experiments on chalk
February-May 1783	Water to air experiments of Joseph Priestley and James Watt
November 1783	Richard Kirwan's communication of the discovery of Prussian blue by Carl Scheele
November 1783	Decimal weights and measures
December 1783	James Watt's experiments with boiling water under pressure
November 1784	Joseph Priestley's experiments on the decomposition of water
December 1784	Hot -air and hydrogen balloon experiments
Winter and Spring 1785	Experiments with the distillation of the spirit of nitre
September 1785	Richard Kirwan's communication of a new gas (phosphine)
June 1786	The theory and practice of the education of children
January 1788	Replication of the water experiments of Antoine Lavoisier and others

Date	**Activity**
April 1789	Latin inscriptions for Matthew Boulton's George III recovery medallion
May 1789	Analysis of a black substance sent by the Rev. Bretland
December 1789-January 1790	Decomposition of water with the aid of an electrical machine
Summer 1790	Replication of the Amsterdam experiments of Paets van Troostwijk and Deiman on the analysis and synthesis of water
February 1791	Joseph Priestley's experiment to demonstrate that water and nitrous acid consist of the same elements
1796	A humorous piece about the phlogiston debate, composed by William Withering
August 1797	Resistance to heat and cold of Lisbons lamp glass
February 1804	The electric meridian; the composition of platina

[1]This table was published in Jones, *Industrial*, pp. 92 and 93.

Appendix B

Two Lunar letters

A letter from Boulton to Keir[1]

March 1st, 1777

Dear Sir,

I sent you about a fortnight ago some gilt scraps and some plated scraps, which are so regular and uniform in their goodness as to afford the means of making accurate comparisons of different modes of refining. We have now a large quantity upon hand of both gilt and plated scraps, and therefore should be glad, if your method answers to your satisfaction, to send them to you. Mr. Jackson's report of the plate is, if I remember right, 8,5 of silver in the pound.

About a week ago I sent in a box directed for you a silver coffee-pot and lamp, which I beg you'll do me the favour to permit Mrs. Keir to so far indulge me to accept as a token of my love — I believe I had better say—for her husband; and yet, in spite of the mischievous graces, Mrs. Keir is so good a woman that I can-not see any impropriety in her receiving it as an offering made by me to all the female virtues.

Pray, where were you the last full moon? I hope you were not in-fluenced by any influenza to stay at home. I saw Darwin yesterday, at Lichfield. He desires to know if you will come to Soho on Sunday, the 3rd March, in which cafe he will not fail to meet you, although he says he has inoculated some children which will probably be ill about that time. Yet if you will come he will be at Soho by eleven o'clock, when I propose to make several motions to the members. Pray God bless your fireside, and preserve it from smoking and falling chimneys, and every other terrestrial evil.

I am, dear Sir,

Yours sincerely and affectionately,

Matthew Boulton.

[1] Boulton to Keir, 1 March, 1777, as cited in Moilliet, *Sketch*, p. 56.

A letter from Keir to Boulton[2]

Soho, Oct 29th 1778

To M. Boulton

Dear Sir,
I have just now received yours of the 23d.
1. I shall observe what you say respecting the Navigation Engine.
2. I acquainted you in my former letters that Bedworth Engine goes on extremely well, but Wm Murdock having been fetched away to make the patterns, no decisive & accurate trials have been made.

[...]

No orders for buttons.
Orders enough for plated goods & paintings.
Mr Aubert has received the Telescope & paid for it.
I rejoice to hear of the prosperity of Chase-water.
James Keir.

[2]Keir to Boulton, 29 October, 1778, as cited in Tann, *Selected*, p. 174.

Appendix C

Network C

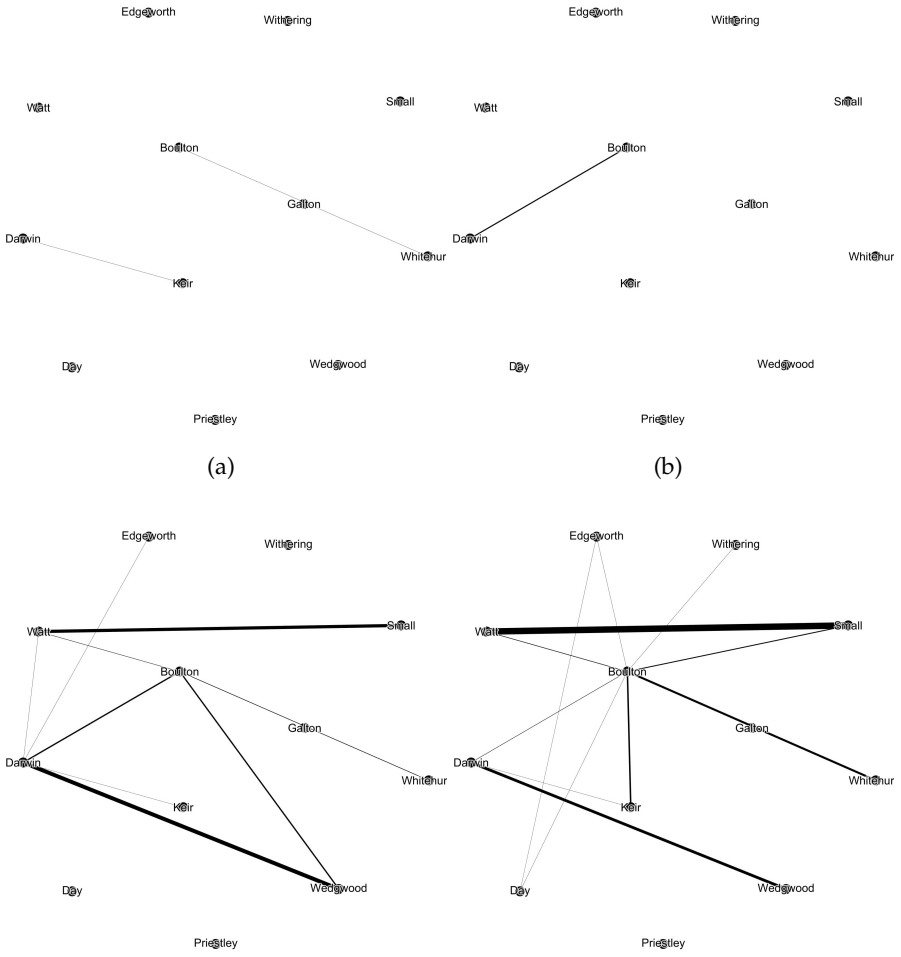


FIGURE C.1: *Network C 1755–1775*: slice (a) 1755–1760, (b) 1760–1765, (c) 1765–1770, (d) 1770–1775.

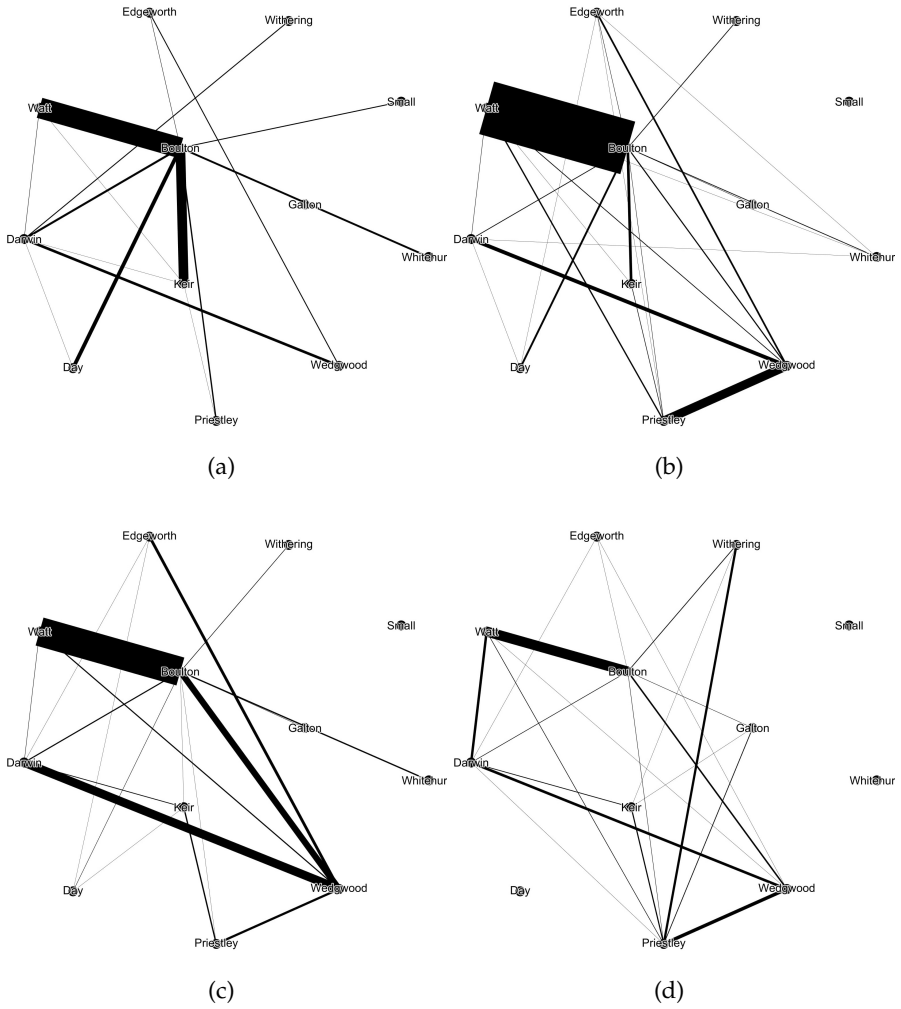


FIGURE C.2: *Network C 1755–1795*: slice (a) 1775–1780, (b) 1780–1785, (c) 1785–1790, (d) 1790–1795.

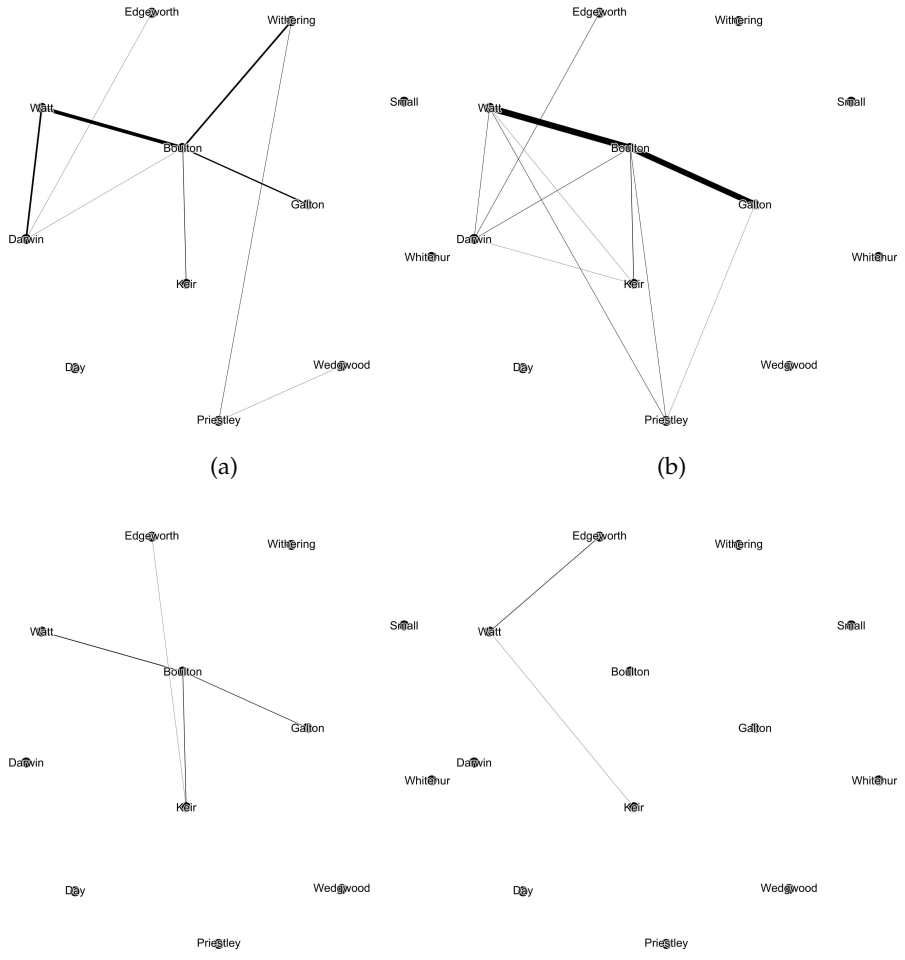


FIGURE C.3: *Network C 1795–1815*: slice (a) 1795–1800, (b) 1800–1805, (c) 1805–1810, (d) 1810–1815.

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