

Digital thinking tools for better decision making



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Introduction and guidance

Introduction and guidance

This free badged course, *Digital thinking tools for better decision making*, lasts 24 hours and contains eight 'sessions' of study. You can work through the course at your own pace. If you have time for more than one session, there is no problem with pushing on to complete a further study session. The eight sessions are linked to ensure a logical flow through the course.

This is a course about *thinking*, not computers, but occasionally you will be using the programming language Python as a sort of 'big calculator' to underpin your critical thinking with some simple sums. The other software you use will mostly just involve using your web browser.

You will be able to test your understanding of the course through the end-of-session interactive quizzes. The quizzes at the end of Sessions 4 and 8 will provide you with an opportunity to earn a badge to demonstrate your new skills. You can read more on how to study the course and about badges in the next sections.

After completing this course, you should be able to:

- describe how digital thinking tools extend our natural capabilities
- use digital thinking tools to find information
- use digital thinking tools to analyse information
- use digital thinking tools to reason about information
- discuss the future of digital thinking tools in relation to artificial intelligence.

Moving around the course

In the 'Summary' at the end of each session, you will find a link to the next session. If at any time you want to return to the start of the course, click on 'Full course description'. From here you can navigate to any part of the course.

It's also good practice, if you access a link from within a course page (including links to the quizzes), to open it in a new window or tab. That way you can easily return to where you've come from without having to use the back button on your browser.

The Open University would really appreciate a few minutes of your time to tell us about yourself and your expectations for the course before you begin, in our optional [start-of-course survey](#). Participation will be completely confidential and we will not pass on your details to others.

What is a badged course?

While studying *Digital thinking tools for better decision making* you have the option to work towards gaining a digital badge.

Badged courses are a key part of The Open University's *mission to promote the educational well-being of the community*. The courses also provide another way of helping you to progress from informal to formal learning.

Completing a course will require about 24 hours of study time. However, you can study the course at any time and at a pace to suit you.

Badged courses are available on The Open University's [OpenLearn](#) website and do not cost anything to study. They differ from Open University courses because you do not receive support from a tutor, but you do get useful feedback from the interactive quizzes.

What is a badge?

Digital badges are a new way of demonstrating online that you have gained a skill. Colleges and universities are working with employers and other organisations to develop open badges that help learners gain recognition for their skills, and support employers to identify the right candidate for a job.

Badges demonstrate your work and achievement on the course. You can share your achievement with friends, family and employers, and on social media. Badges are a great motivation, helping you to reach the end of the course. Gaining a badge often boosts confidence in the skills and abilities that underpin successful study. So, completing this course could encourage you to think about taking other courses.

How to get a badge

Getting a badge is straightforward! Here's what you have to do:

- read each session of the course
- score 50% or more in the two badge quizzes in Session 4 and Session 8

For all the quizzes, you can have three attempts at most of the questions (for true or false type questions you usually only get one attempt). If you get the answer right first time you will get more marks than for a correct answer the second or third time. Therefore, please be aware that for the two badge quizzes it is possible to get all the questions right but not score 50% and be eligible for the badge on that attempt. If one of your answers is incorrect you will often receive helpful feedback and suggestions about how to work out the correct answer.

For the badge quizzes, if you're not successful in getting 50% the first time, after 24 hours you can attempt the whole quiz, and come back as many times as you like.

We hope that as many people as possible will gain an Open University badge – so you should see getting a badge as an opportunity to reflect on what you have learned rather than as a test.

If you need more guidance on getting a badge and what you can do with it, take a look at the [OpenLearn FAQs](#). When you gain your badge you will receive an email to notify you

and you will be able to view and manage all your badges in [My OpenLearn](#) within 24 hours of completing the criteria to gain a badge.

Get started with [Session 1](#).

Session 1: The rise of digital thinking tools

Introduction

We shape our tools and, thereafter, our tools shape us.

(John Culkin, 1967)

I cannot teach anybody anything. I can only make them think.

(Socrates, c. 470–399 BCE)

Figure 1 shows an iconic road viaduct across the River Tarn in France, which is the tallest bridge in the world.



Figure 1 The Millau Viaduct in southern France

This outstanding architectural achievement would not have been possible without tools and mechanisation.

But, what tools? And what mechanisation? Some tools are physical, such as the diggers, concrete mixers and cranes that are used to do the heavy lifting. But some tools are mental such as ideas about the design, based on engineering knowledge about these structures. However, there are also digital tools, which do for thinking what machines can do for lifting. They extend and empower our ability to solve mental problems, rather than merely physical ones.

Digital tools made possible the sharing of design principles and ideas, the modelling, sharing and approval of the design, and the realisation of the project. They supplied a kind

of mental ‘heavy lifting’ which helped the project team conceive, design and build the elegant bridge that soars above the Tarn valley.

This course is about how digital technology has changed the way we think about problems, by offering ‘mind tools’ that can help us to find solutions. They can help us share information, filter and process that information, discover new facts, invent new ideas, visualise solutions, and share the fruits of our thoughts with other people worldwide.

In this session you will look at what is meant by a digital tool, then at how tools have evolved, and the ways in which they can extend human thought.

You might not have thought of the software you use in that way. But, as you work through this course, you will see that many of the programs and apps you probably use are indeed tools that help you think – often more smartly.

By the end of this session, you will be able to:

- say what critical thinking is
- use a pros and cons table
- outline how digital thinking tools evolved
- list some ways in which digital thinking tools extend human capability.

The Open University would really appreciate a few minutes of your time to tell us about yourself and your expectations for the course before you begin, in our optional [start-of-course survey](#). Participation will be completely confidential and we will not pass on your details to others.

1 Tools, from stone to digital

Mind tools represent a towering achievement of human progress. Some of them have become familiar everyday activities, such as searching the internet, which we have already come to take for granted. So we seldom stop to think how amazing they are, and how powerful, if used wisely.

It is possible to disagree with this optimism though. Today’s world presents us with more and more information, often from multiple sources that conflict with one another. Digital technology has been responsible for the exponential growth in the volume of information that faces us, and the difficulties of absorbing it, and knowing what is reliable and what not. Online discussions can end up as slanging matches, with opinions replacing arguments. As a result, many writers despair of the digital world that has been created and argue that it has made us *worse* thinkers, not better ones.

The key to realising the benefits of digital thinking tools is **critical thinking**. Critical thinking sets out to judge issues objectively. It involves collecting relevant information, considering both sides of a question, weighing up the evidence in the light of what you know, and applying critical thinking skills to reach a conclusion. Critical thinking is an essential skill. So let’s get going and do some.

Activity 1 Weighing up pros and cons

Allow about 15 minutes

A simple but often surprisingly effective way of weighing up arguments for and against something is to write down all of the points in favour and all of the points against, and simply count them.

You can do this using a word processor and setting out the pros and cons in a table, or more simply with a pen and paper, whichever you prefer.

To make it interesting, here's something controversial – *election silence*. In some countries there is a ban on political campaigning close to an election. This could extend to forbidding even the public use of a candidate's name.

Draw up a pros and cons table for election silence. Try to be as impartial as possible. To get you started, Figure 2 shows one pro and one con.

ELECTION SILENCE	
PRO	CON
VOTERS HAVE TIME TO REFLECT	VIOLATES FREE SPEECH

Figure 2 Pros and cons

Discussion

Some people will have concluded that election silence is a good idea on balance, some not. That's fine because there is no clear and final answer. That's why some countries have an election silence rule and others don't.

This activity is very valuable though, because you have been doing *critical thinking* – thinking for yourself, in a measured and structured way, and trying to be objective. When people do this, the evidence is that they tend to make better decisions. In later sessions you will meet other structured ways in which you can assess information and weigh up arguments.

1.1 Tools

A tool is something used for a particular purpose or purposes – an **implement**. For example, Figure 3 shows the oldest human-made object in the British Museum.



Figure 3 A stone tool from the Olduvai Gorge in Tanzania, approximately 1.8 million years old

This tool was probably used for chopping and illustrates two key features of tools. They are physically separate objects from the person who uses them, and they extend what that person can do. A chopper is like an extension of your body that lets you do something you couldn't do without it. You might cut down a tree for example.

Over the prehistoric period, tools evolved and diversified, as shown in Figure 4.



Figure 4 A selection of prehistoric farming tools

So far, these tools only extended physical capabilities. At some point people discovered that tools can also extend mental function.

1.2 Mind tools

Figure 5 shows some tokens which are believed to have been used for keeping track of property. They date from the first millennium BCE.



Figure 5 Clay tokens from ancient Assyria

Each particular shape might have stood for a certain object, such as a basket of corn or an animal. For example, three baskets of corn might have been represented by three 'corn basket' tokens.

The invention of tokens was a major step because they extend the power of the mind. They can be used as thinking tools in three ways:

- **Record keeping** – three 'corn basket' tokens is a way of *remembering* about three baskets of corn.
- **Communication** – three 'corn basket' tokens is a way of *sharing information* about three baskets of corn with someone else.
- **Calculation** – pushing two groups of tokens together is a way of *computing* that three baskets of corn and two baskets of corn equal five baskets of corn (Figure 6).

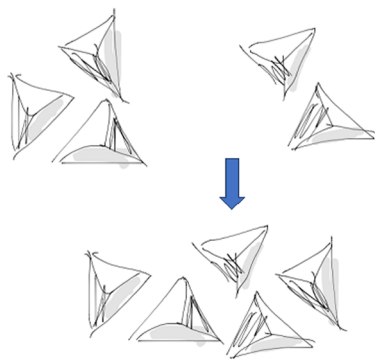


Figure 6 Three and two makes five

Activity 2 Software programmes as tools

Allow 10 minutes

Fast-forwarding about three thousand years, today there are software programs that can act as tools in the same three ways as the early tokens described above.

Think of some examples of software, running on computers or as apps on tablets and phones, which can be used as tools for one or more of the following functions.

- Record keeping
- Communicating information
- Calculating

Try to think of at least two examples for each purpose. In some cases, the same program might meet more than one purpose.

Discussion

Here are some examples. You will probably have thought of others.

- Record keeping: spreadsheet, database, note-taking programs and apps, calendars.
- Communicating information: Skype, social media (such as Facebook, Twitter, WhatsApp, Snapchat, etc.), email, wikis, websites.
- Calculating: calculator apps, calculators on the web, spreadsheets, special software such as that used by scientists.

The answers to Activity 2 are all examples of thinking tools that have been created using modern digital technology. But between the use of simple tokens and the arrival of digital technology came writing, books and the invention of printing.

It is easy to see how this contributed to record keeping and communication. You only have to think of account books and letters, for example. Writing made information *persistent*, so that it could be preserved over time. It also made information *portable*, so that it could be carried from place to place. Writing also helped with calculation.

1.3 Tools for arithmetic

The simple idea of calculating with tokens developed over time into devices such as the **counting board**. This is a special table on which calculations are made using counters. Interestingly, counting boards sometimes had a chequerboard pattern, like a chessboard, and the modern word *exchequer* (as in *Chancellor of the Exchequer*) derives from this.

The invention of writing also led to the use of written calculations. In Figure 7 you can see both methods. The person on the right is using a counting board. The person on the left seems to be calculating with something similar to the Hindu–Arabic numerals used today. (The female figure in between is a ‘personification’, representing Arithmetic.)



Figure 7 Early calculations from Gregor Reisch (1508), *Margarita Philosophica, Arithmetica*

The next section looks at something closely related to tools: mechanisation.

2 Mechanisation

Another important idea is that it may be possible to build a machine that will help us perform a given task. A machine does more than just help us carry out the task; it actually carries out some part of the work for us.

2.1 Mechanical arithmetic

Counting boards and paper calculations are some way from the digital thinking tools of the 21st century. But they did lead to another breakthrough – the realisation that calculations can be **mechanised**. Moving counters on a board, or doing pen-and-pencil calculations, are mechanical processes. They do not have to be carried out by a human being – they can be **automated**.

Figure 8 shows a modern replica of what might have been the first mechanical calculator described. This was the ‘arithmetical instrument’ invented by German professor Wilhelm Schickard, who wrote about it in letters between 1623 and 1624. Devices like this owed much to the technology used to make clocks. They had moving parts, gear wheels and other mechanical components.

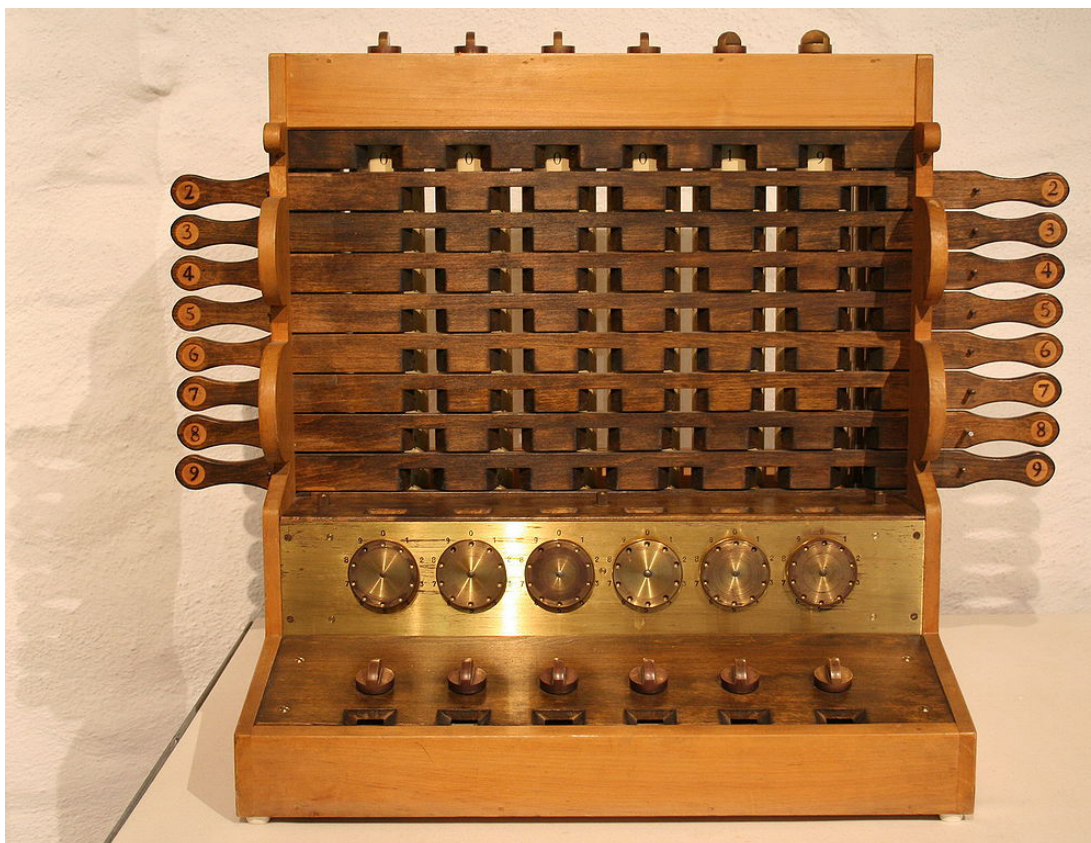


Figure 8 Replica of Schickard's arithmetical instrument

However, it was not until 1851 that a commercially successful calculating machine was launched. This was the arithmometer, which could do all four operations of arithmetic: addition, subtraction, multiplication and division.

The Gentleman's Magazine wrote about it in 1857. (Note that the word 'calculators' in the final sentence refers to human calculators.)

Instead of simply reproducing the operations of man's intelligence, the arithmometer relieves that intelligence from the necessity of making the operations. Instead of repeating responses dictated to it, this instrument instantaneously dictates the proper answer to the man who asks it a question. It is not matter producing material effects, but matter which thinks, reflects, reasons, calculates, and executes all the most difficult and complicated arithmetical operations with a rapidity and infallibility which defies all the calculators in the world.

The author of this article regarded the arithmometer as performing mental tasks; in other words as a tool to aid thinking. It extended human capabilities by doing arithmetic much faster and more accurately than had been possible before.

2.2 Digital technology

The arithmometer and other mechanical calculators were *digital*, in the sense that they operated with the digits 0–9. However, the word is mostly used today to refer to calculations carried out by devices that represent numbers internally using only the digits 0 and 1. You can think of this as corresponding to 'on' and 'off'. This two-digit system can represent all numbers, and it is much easier for electronics to deal with.

Moving from mechanical parts to electronics was a major breakthrough. Since their invention, digital devices have become much faster, more reliable, smaller and cheaper than their mechanical predecessors.

However, digital technology is more than just arithmetic. This is because 0s and 1s can be used to represent many types of information.

Activity 3 Types of information

Allow 10 minutes

List some non-numerical types of information. To get started, recall the information you have received in the last day or two. What forms did it take?

Discussion

Your list might include:

- writing
- audio
- video
- photographs and other images
- graphs and charts
- diagrams.

So, digital systems can handle most (possibly all) kinds of information. Once information is represented digitally, it can be *processed*. This is because activities such as sorting a list of words, searching the internet, using a computer to draw a pie chart, 'photoshopping'

a snap, writing an email message, editing a sound file, and countless others can all be reduced to mechanical operations with 0s and 1s.

Digital information is also 'superportable'. It can be sent over much greater distances, and at much greater speed, than is possible with written or printed information.

The next section explores various ways digital thinking tools can extend what you can do.

3 Levers for thought

Like the prehistoric farming tools you saw earlier in Figure 3, digital thinking tools have diversified in many ways. Some are very specialised and only do one thing. For example, an app that acts as a clicker and helps keep count of how many times something happens. With each click, it ups the count by one. Other software is more general-purpose. For example, you can use a spreadsheet for many different things: calculating, storing information, graphing, and so on.

A useful way to think of digital tools can be in terms of the key properties that help extend our natural capabilities (Figure 9).

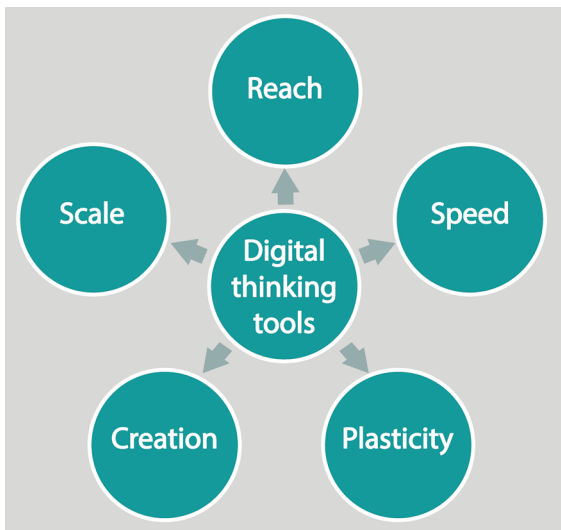


Figure 9 Five properties of digital tools

3.1 Scale

Scale refers to the fact that digital tools let us gather, access, store and analyse gigantic amounts of data. For example, CERN's (the European Organization for Nuclear Research) Large Hadron Collider project collects data about 600 million particle collisions per second (Figure 10). The data is then distributed for analysis to a network of computers around the world, and worked on by scientists worldwide.



Figure 10 The 'server farm' at CERN in Switzerland

3.2 Reach

Reach refers to the fact that digital technology allows us to share data easily with potentially millions of other people around the globe. It also allows us to collect data from spacecraft at vast distances away from Earth. For example, [NASA's New Horizons project](#) is sending back information from the edge of the Solar System (Figure 11).

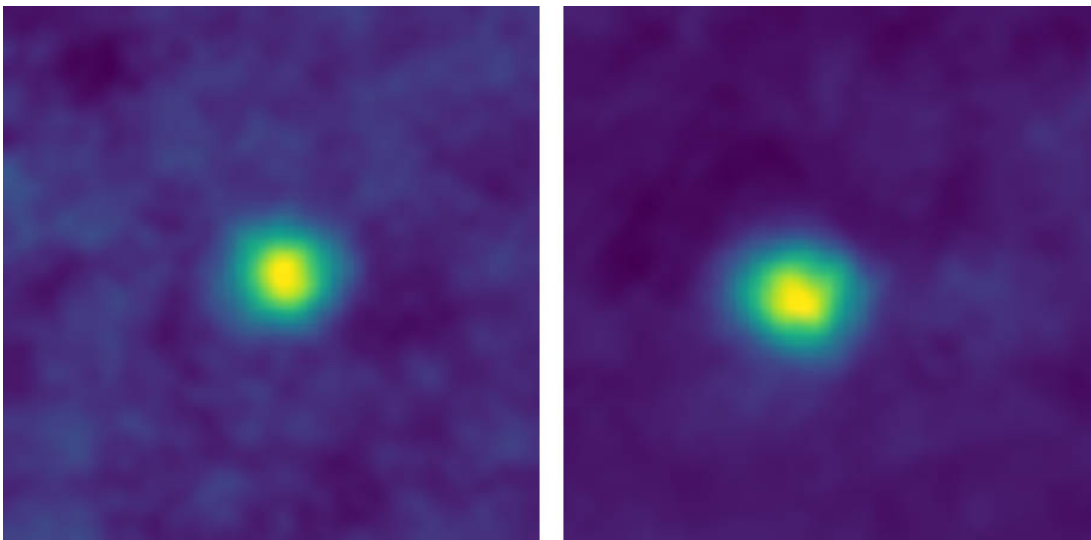


Figure 11 Two objects from the Kuiper Belt, beyond Pluto

3.3 Speed

Speed refers to the rate at which information can be processed. Mechanisation often brings about huge increases in productivity. For example, in the 19th century, harvesting a ton of grain took 25 person-days. Someone driving a modern combine harvester takes six minutes to achieve the same (Norberg, 2016). This is a productivity increase by a factor of 2000.

The productivity increase in processing data is massively greater. It's hard to make direct comparisons, but the arithmometer mentioned earlier astonished people by its ability to multiply two eight-digit numbers in 18 seconds. Today, the processing unit in a typical smartphone can carry out the equivalent of 5 billion such operations per second.

3.4 Creation

Creation refers to the fact that digital tools let us create data, in many forms such as text, tables, charts, images, sound and video. Digital tools allow us to generate pictures of objects that do not exist in the world; set up virtual laboratories in which no one's safety is at risk; do virtual experiments that we could not afford in the real world; and set up models of almost anything imagined and run simulations with them to see what happens.

3.5 Plasticity

Plasticity refers to the fact that information in digital form is easy to re-form and reorganise. It can be edited and processed almost endlessly – think of editing digital photographs in Photoshop. In addition, changes are quick and easy, and can be undone. If you don't like a modification, you can simply discard it – and the cost is insignificant. Identical information can be presented in many different views. This allows us to discover new facts from old data, and to communicate important insights to other people by means of infographics.

To illustrate how a different viewpoint may suddenly reveal something you hadn't suspected before, consider Figure 12.

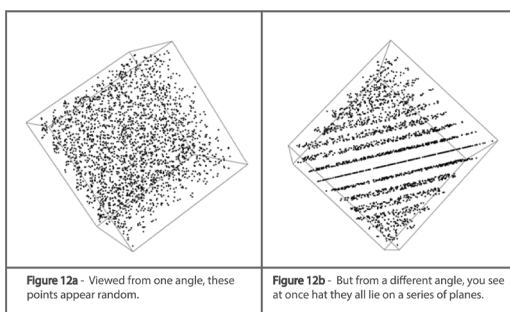


Figure 12a and 12b A set of points seen from two perspectives

Activity 4 The power of infographics

Allow 20 minutes

Watch the following video of Dave McCandless talking about how infographics help make sense of information.

Video content is not available in this format.

Video 1



Can infographics contribute to critical thinking?

Discussion

Infographics are a tool that can help us deal with information overload by compressing a mass of detail into a picture that can be grasped quickly and easily. Once the information is captured as an infographic, new perspectives can emerge. Infographics can be made interactive, so that people can explore the data for themselves.

Near the end of the video, McCandless presents an infographic that represents ideas rather than data, and compares how left-wing thinkers and right-wing thinkers visualise society. Producing this infographic made him recognise the perspective of people at the other end of the political spectrum from him, because not doing so would have led to a biased graphic.

This might remind you a little of the pros and cons technique: the structure of what we are producing forces us to be more objective and analytical. This suggests that infographics may indeed contribute to critical thinking.

4 This session's quiz

Now you've reached the end of Session 1, you can try a short quiz to help you reflect on what you've learned.

[Session 1 practice quiz](#)

Open the quiz in a new tab or window (by holding down Ctrl [or Cmd on a Mac] when you click the link) then come back here when you've finished.

5 Summary of Session 1

In this session you learned that critical thinking is an essential skill in a digital world. You were also introduced to:

- a useful tool for weighing up arguments – the pros and cons table.
- how digital thinking tools evolved, just as physical tools did, to allow humans to extend their capabilities.
- how digital thinking tools extend human capability in terms of scale, reach, speed, creation and plasticity.
- infographics, which are one kind of thinking tool that can not only bring new insights, but also encourage the kind of balanced objectivity that is the essence of critical thinking.

In Session 2 you will learn new ways of searching for information and assessing the reliability of the sources you find.

6 Looking forward

Over the coming sessions you will see a range of ways in which digital tools can help us think about the world. Running in parallel you will also be introduced to ideas and techniques that will help you to develop your abilities as a critical thinker, be able to evaluate digital information and reach conclusions by weighing up evidence.

Video content is not available in this format.



Video 2

Session 2 *Getting to grips with information* looks at searching various sources of information and ways of narrowing your searches to make the results more relevant. On the critical thinking front, you will be introduced to fact-checking sites, and learn a structured technique for evaluating websites.

Session 3 *The big calculator* introduces the Python programming language as a convenient and powerful way of finding an answer to questions such as 'Is it true we could fit everyone in the world on the Isle of Wight?' You will learn about Fermi problems – a technique for getting surprisingly good 'ball park' answers to a whole range of problems. You will also learn that there are reasons why snap judgements are often flawed and a more structured approach can lead to better decision making.

Session 4 *Reasoning with argument maps* picks up the idea of using a structured approach to reach conclusions based on evidence. This lies at the core of critical thinking and closely related to the pros and cons tables from Session 1. Argument maps take the idea further and represent the evidence for and against a proposal as a special type of diagram that lets us understand how the various bits of evidence are related to one another. You will learn, with a worked example, how creating an argument map can help you with writing a reasoned conclusion.

Session 5 *Reasoning with sets* looks at Euler diagrams and how they can be used as reasoning tools. It also looks at sets in Python, and how to reason about the size of sets. It goes on to explore two classic examples in which most people's intuitive estimates about probabilities are badly mistaken, and explains them using Python simulations and Euler diagrams.

Session 6 *Digital argument mapping* continues the topic of argument mapping introduced in Session 4. It discusses the benefits of using digital tools for argument mapping: the many ways digital argument mapping extends our natural capabilities. You will also learn about how to use such tools in practice. In Session 4, you saw how to go from an argument map to a short text with a reasoned conclusion. In this session you will go in the other direction: starting with a text, you will learn how to uncover the underlying argumentation by creating an argument map for that text.

Session 7 *Argument mapping in action* takes ideas and skills you met in earlier sessions and shows how they can be used to think critically about some controversial issues of the

online world. This session also looks at collaborative argument mapping and its relationship with voting. Finally, it looks at how implicit knowledge or beliefs need to be taken into account before you can interpret an argument map.

Session 8 *From thinking tools to AI* looks at the relationship between artificial intelligence and digital thinking tools. It traces the history of thinking machines, from a medieval dream through to the AI developments of the 21st century, and examines the suggestion that AI will make humans redundant. It argues that focusing on AI supremacy runs the danger of ignoring the more immediate dangers arising from AI making decisions using opaque algorithms and biased data.

You can now go to [Session 2](#).

Session 2: Getting to grips with information

Introduction

Ctesias writes that in the same country [Ethiopia] is born the creature that he calls the mantichora which has a triple row of teeth meeting like the teeth of a comb, the face and ears of a human being, grey eyes, a blood-red colour, a lion's body, inflicting stings with its tail in the manner of a scorpion, with a voice like the sound of a panpipe blended with a trumpet, of great speed, with a special appetite for human flesh.

(Pliny the Elder, AD 23–79, Natural History, Book 8, p. 30)

No modern reader would seriously believe this story (see Figure 1). Why did Pliny think it was worth passing on? Why was he not more sceptical?

Pliny was only using the best information he could get hold of. And perhaps he had no reason to reject what appeared to be a fact.



Figure 1 A manticore

This example illustrates two key questions about information:

- How can you get hold of it?
- How do you know whether or not to trust it?

You are already familiar with search engines such as Google, and with websites such as Wikipedia. But in this session you will learn things you might not have known about them. You will also meet new sources of information.

When Pliny lived, in the first century, there were only a few tens of thousands books altogether in the world. Today, the US Library of Congress holds about 100 million items. Any internet search may return millions of hits. This introduces a third problem, one that Pliny probably didn't have: if you have *too much* information, how can you filter it?

In this session you will also look at ways of evaluating information and assessing its credibility. Simply being able to find information is useless unless you can decide whether to believe it.

By the end of this session, you will be able to:

- use Google operators to fine-tune your information searches
- appreciate the limitations of both traditional and online reference sources
- apply strategies for comparing and critically evaluating websites.

1 Be a super-Googler

Today, anyone looking for information on the internet will probably start with a search engine often Google search.

Google currently processes about 40,000 search requests a second, which amounts to over 1,200,000,000,000 a year. Given that the population of the world is about 7,600,000,000, you can calculate that the average per person is $\frac{1,200,000,000,000}{7,600,000,000}$

which works out to about 160 searches per person per year.

Although it has several smaller rivals, and is blocked or banned in some countries, Google is dominant among search engines.

In this section you will mainly be learning ways to make your Google searches more efficient. But some of the same ideas may work with other search engines too.

The familiar way to use Google is just to enter one or more words (query terms) and submit the search (Figure 2).



Figure 2 Google search

However, just entering a simple keyword can often generate a very large number of results, many of which are not relevant to your current enquiry. So, Google provides a whole series of **operators** which let you fine-tune your search.

Activity 1 Using Google operators

Allow about 15 minutes

In this activity you will look at examples that explore some of the most useful operators.

Exact phrase

Try searching on: tallest tree in the universe

You will get some hits containing this phrase but also others to do with the oldest/smallest/widest tree/rollercoaster/thing in the world/that every existed/in California, and so on.

Now try searching with: "tallest tree in the universe"

The quote marks make Google look for the exact phrase "tallest tree in the universe".

Excluding a word

Try searching on: slings and arrows of outrageous fortune

Many hits will mention *Hamlet*, since this is a well-known quote from that play. But perhaps these are not what you are after! You can use the – operator to exclude the word Hamlet. Try searching on

slings and arrows of outrageous fortune -Hamlet

This time, you should find that none of the hits mention Hamlet.

Wildcard

Next, search on: tallest * in the world

This will look for *all* the tallest things in the world.

Alternatives

Try searching on: lion tiger

This will look for pages including both words. You can search for pages containing *either* word by using the OR operator. Note that OR must be in uppercase letters. Try searching on lion OR tiger and see the difference.

Site

Try searching on: lion site:gr

The operator restricts the search to a particular internet domain, in this example gr, which is the top level domain for Greece. All of the hits will be pages from sites in the gr domain.

The domain ac.uk represents academic institutions (universities, libraries, museums, etc.) in the UK. Try searching on: tiger site:ac.uk

This time you should get pages about tigers from sites in the ac.uk domain.

Year

To search for pages from a given year or years, you can use the ... operator. Try these searches

electric cars 2017...2017

steam cars 2000...2010

This doesn't work perfectly because it can also find results that simply mention the specified years, but it is generally useful.

Now have a go at the next Activity where you will combine operators.

Activity 2 Mix and match

Allow about 10 minutes

The operators introduced in Activity 1 can be combined in various ways. Try these searches and then some of your own.

"tiger tiger burning" site:ac.uk

pet -dog -cat

"smallest dog in the *"

"swan of *" –shakespeare

"* of *" -university

Warning: playing with these searches can become addictive!

In the next section you will learn about the 'filter bubble'. By tailoring results based on what they know of us search engines may narrow our horizons.

2 Beware of the bubble!

Not only does Google look for websites that match the search request you enter, it also looks for sites that match *you*. Based on your search history, location and any other data it holds about you, it tailors which results to display, so that eventually you might end up trapped in your own private 'bubble', which limits your horizons.

Similarly, Facebook's 'News Feed' shows you 'stories that ... are influenced by your connections and activity on Facebook'.

Activity 3 The filter bubble

Allow 8 minutes.

Watch this TED talk on the 'filter bubble' by Eli Pariser.

Video content is not available in this format.

Video 1



Many people see filter bubbles as a threat to democracy. This is because they may result in us only sharing ideas with like-minded people, so that we are not exposed to differing points of view. We simply end up having our existing opinions and beliefs continually reinforced.

In his [farewell address](#), President Barack Obama spoke of the 'retreat into our own bubbles, ... especially our social media feeds, surrounded by people who look like us and share the same political outlook and never challenge our assumptions ...'.

Activity 4 Reflecting

Allow about 2 minutes

Having watched Eli Pariser's talk, take a few moments to consider whether you are in a filter bubble.

Do you think you are getting a balanced information diet?

2.1 Bursting the bubble

It is possible to free yourself from the filter bubble, at least to some extent. For example, you can delete your Google search history. But doing this also has a downside. In future, your search results may be less relevant to you. Similarly, you might refuse Google permission to use your location. But then if you search for retail outlets, you won't find the local ones you were after.

Probably the simplest way to do a search that won't be filtered by your history is to use a site such as DuckDuckGo, which is a search engine provider that claims not to track you.

Activity 5 Using DuckDuckGo

Allow about 5 minutes

First, go to Google and do two or three searches that you think might be influenced by any information Google has about you. Then find the site DuckDuckGo.com and use it to do the same searches and see whether there is any difference.

Discussion

For example, I did a search on the keyword 'Brexit'. With Google, the three top stories found were all from *The Guardian* newspaper, whereas at DuckDuckGo they came from MSN News, the *Daily Mail*, and The Washington Post. It is hard to be sure but this suggests that the Google search is probably aware of my physical location, and may also be influenced by the fact that I often read articles on *The Guardian* website.

The next section looks at the dream of bringing all human knowledge together in one place and at the development of encyclopedias.

3 A short history of encyclopedias

The idea of gathering together all human knowledge goes back a long time, at least as far as ancient writers such as Pliny and Aristotle. During the Middle Ages, many encyclopedias were compiled by Muslim, Chinese and European authors (Figure 3).



Figure 3 The cover of a 14th-century encyclopedia *The Ultimate Ambition in the Arts of Erudition*, by Al-Nuwayri. The original book was 30 volumes long, and covered subjects as diverse as clouds, flamingos, hair dyeing and radishes.

The invention of printing made it possible for many more copies of encyclopedias to be produced. The word encyclopedia seems to have been used first in 1559, when Pavao Skalić published his *Encyclopaedia, or Knowledge of the World of Disciplines* (Figure 4).

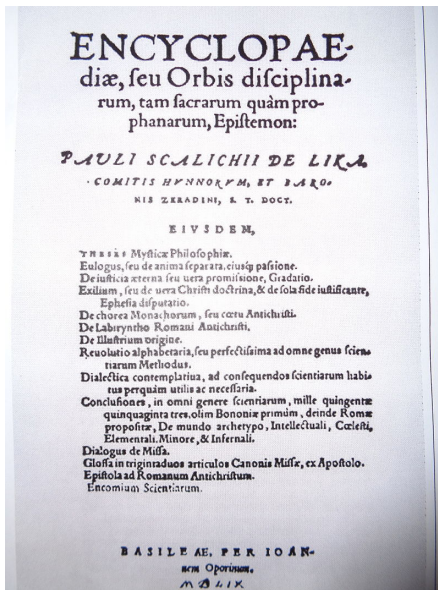


Figure 4 The title page of Skalić's encyclopedia (1559)

The 18th century brought the first modern encyclopaedias. One of the best-known is the Encyclopaedia Britannica, first published in Edinburgh 1768-1769.

From its original three volumes, the [Britannica](#) has grown today to 40 million words, covering about half a million subjects. From 2010 it was no longer produced in printed form and has become an online encyclopedia.

Activity 6 Visit Britannica

Allow about 10 minutes

Visit [Encyclopaedia Britannica](#) online and browse some of the 'Trending Articles'.

Traditionally, modern encyclopedias like the Britannica set out to be authoritative (Figure 5). Most articles were written by recognised experts in their field. The more than 4000 contributors have included 110 Nobel prize-winners. Britannica and similar encyclopedias became famous as reliable sources of trustworthy information, a sort of 'gold standard'.



Figure 5 Advertisement for the 11th edition of the Britannica, with a headline emphasising its status as a reliable reference source.

With the rise of the internet, a different kind of encyclopedia emerged. The best known of these is Wikipedia, which started in 2001, but there are many others, often specialising in particular subject areas.

3.1 Using Wikipedia

Wikipedia follows a quite different model from traditional encyclopedias. Instead of being a for-profit company, it is a [non-profit charitable organisation](#), funded by donations.

In traditional encyclopedias, an entry is either the work of a named individual or attributed to an editorial team. In contrast, Wikipedia content is 'crowd-sourced'. The articles are the work of numerous unnamed volunteers. Each entry is usually the work of multiple authors, who are not individually credited. Anyone can register and start writing immediately.

This means that Wikipedia articles can be revised essentially in real-time. There is no approval process of the kind that applies to a traditional encyclopedia, where all changes are reviewed before they go live. Instead, Wikipedia relies on other volunteers to correct or clarify any inaccurate content.

This can make Wikipedia vulnerable to hoaxes, or to articles being edited to promote commercial interests or political agendas. This, and the fact that the authors are unidentified volunteers, has made many people cautious about how reliable Wikipedia is as an information source. However, many studies and comparisons have broadly supported the accuracy of Wikipedia, at least as a starting point for finding out about a topic.

Activity 7 Investigating Wikipedia page history

Allow about 10 minutes

Since anyone can edit a Wikipedia article, there is an obvious risk of hoaxes, vandalism, promotion of particular interests or opinions and other misuse. To counteract this, Wikipedia keeps a complete record of every change that has been made to an article. This means that it is always possible to undo malicious changes. Also the full history of the article can be accessed, something that can be useful to researchers.

Find a Wikipedia article on any subject that you are interested in. At the top right there is a 'View history' tab (Figure 6).

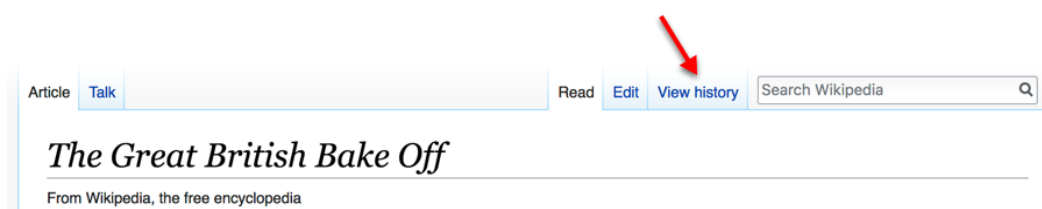


Figure 6 'View history' tab on Wikipedia

Clicking on this will display a list of changes made to the page, by date and time (Figure 7). Of course, Wikipedia is always evolving, so if you revisit this page, it will look different.

The screenshot shows the Wikipedia page for 'The Great British Bake Off: Revision history'. At the top, there are tabs for 'Article', 'Talk', 'Read', 'Edit', and 'View history', along with a search bar. The title 'The Great British Bake Off: Revision history' is prominently displayed. Below the title, there is a link to 'View logs for this page'. A search box for revisions is present, with filters for 'From year (and earlier): 2018', 'From month (and earlier): all', and a 'Tag filter' dropdown. Below the search box, there is a list of revisions. Each entry includes a link to the revision, the date and time, the editor's name, the number of bytes, and the change in bytes. The first revision is by 'Mr. Gustafson' on 21:34, 25 July 2018, with a change of +639 bytes. The second revision is by 'Drmargi' on 08:00, 23 July 2018, with a change of -19 bytes. The third revision is by '114.23.145.183' on 07:28, 23 July 2018, with a change of +2 bytes. The fourth revision is by '114.23.145.183' on 07:27, 23 July 2018, with a change of +17 bytes. Below the list of revisions, there is a link to 'Compare selected revisions'.

Figure 7 Page history on Wikipedia

The key at the top explains how to view a particular version. Other options let you see the statistics about the page, search the page history and access other information. The 'Revision history statistics' in particular are well worth looking at (Figure 8). They give you a good idea of just how many edits have been made to a Wikipedia article (Figure 9).

This screenshot is similar to the one in Figure 7, showing the same Wikipedia page. However, a red arrow points to the link 'Revision history statistics' in the 'External tools' section. The link is highlighted by the red arrow, which originates from the bottom left of the image and points towards the link text.

Figure 8 'Revision history statistics' link on Wikipedia



In the next section you will meet a different way of searching for information using an engine that generates answers dynamically rather than just displaying existing information.

4 WolframAlpha

The content of encyclopedias and other reference works such as dictionaries is essentially static. Of course, books have new editions and the content of Wikipedia and similar websites is very fluid. But when you look something up, what you see already exists. It isn't generated dynamically.

WolframAlpha works differently. It takes your query and tries to use natural language processing to make sense of it. Then it gathers data from its own sources and from other sites. It then applies algorithms to the results, to calculate a dynamic response to your question. It describes itself as a 'computational knowledge engine'.

In the next activity you will first use WolframAlpha to compare two kinds of dinosaur and then experiment with queries of your own.

Activity 8 Ask WolframAlpha

Allow about 15 minutes

Go to the [WolframAlpha](https://www.wolframalpha.com) website. You will see a search box and several clickable buttons. These take you to demonstrations of WolframAlpha's capabilities (see Figure 10).

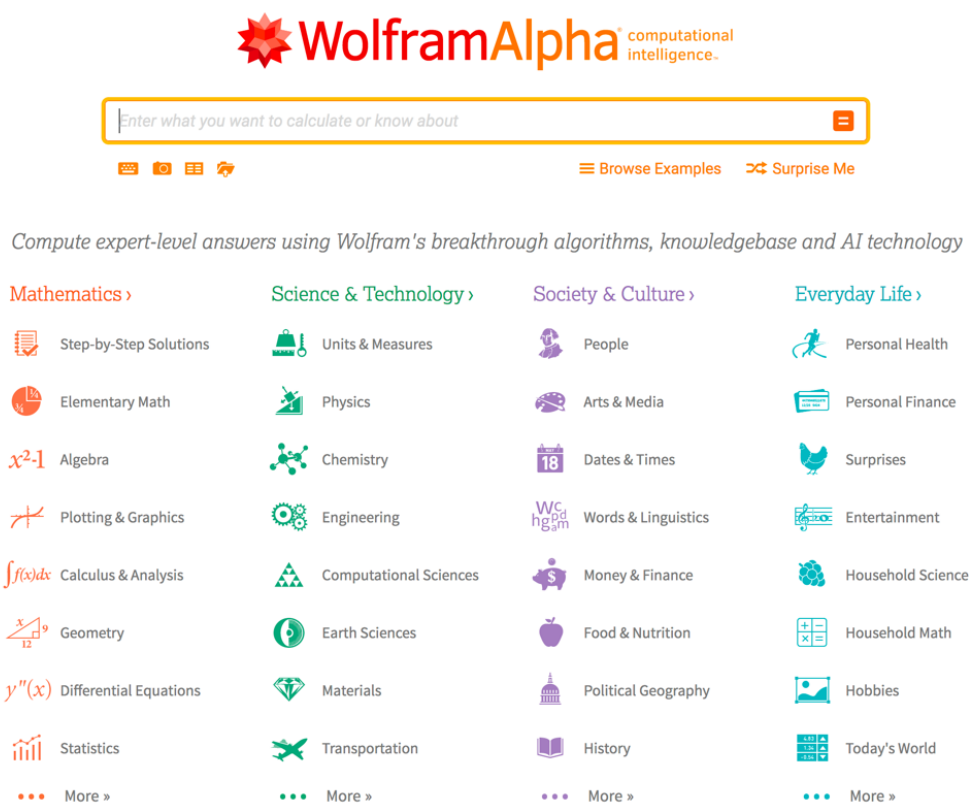


Figure 10 WolframAlpha home page.

In the search box, enter
tyrannosaurus, stegosaurus

and press Enter. After a few seconds, a side-by-side comparison appears, with a table of data, images of skeletons, descriptions of the animals, and a graph showing how many times the related Wikipedia pages have been visited over time.

This is a relatively simple query though. More impressive is when Alpha uses natural language processing. Try these searches:

- how many words in Hamlet
- how many monsters in Loch Ness
- cells in a human body
- meaning of life

It is easily confused though. For example, it can't really make sense of the question why did the duck cross the road

Crossword and Scrabble™ enthusiasts will find it useful. Try typing crossword

Alpha is good at statistics and numbers generally, for example

- Olympic medals
- deepest lakes
- Wales
- 2017 Roman numerals

If you explore Alpha further, you will find it is often surprisingly useful, especially in technical and scientific areas. But it is not an infallible oracle, and some of its interpretations are very wide of the mark.

The next section looks at cross-checking different sources of information and what can go wrong.

5 Triangulation

No information source taken on its own can be considered completely reliable. Any article will reflect the perspective of its author. Another author might have written something quite different. There are often disagreements and controversies among experts in a field.

Before you can decide what the facts about a subject are, you need to look at different sources and cross-check them: to **triangulate**. This is not always straightforward. In the next section you will see that some sources should be given more weight than others. You will also learn about a scheme for evaluating online information.

One difficulty is that if you find information in one place and look for confirmation, you may come across something that seems at first to support the original source. But closer examination may show that it is not independent confirmation.

A famous example is Steven Jay Gould's 'Case of the Creeping Fox Terrier Clone'. While reading about *Eohippus* (Greek for the 'dawn horse'), a small prehistoric horse (Figure 11), Gould was surprised to find that so many books said the animal was 'the size of a small fox terrier'. What was the reason for this choice and the close agreement between authors?

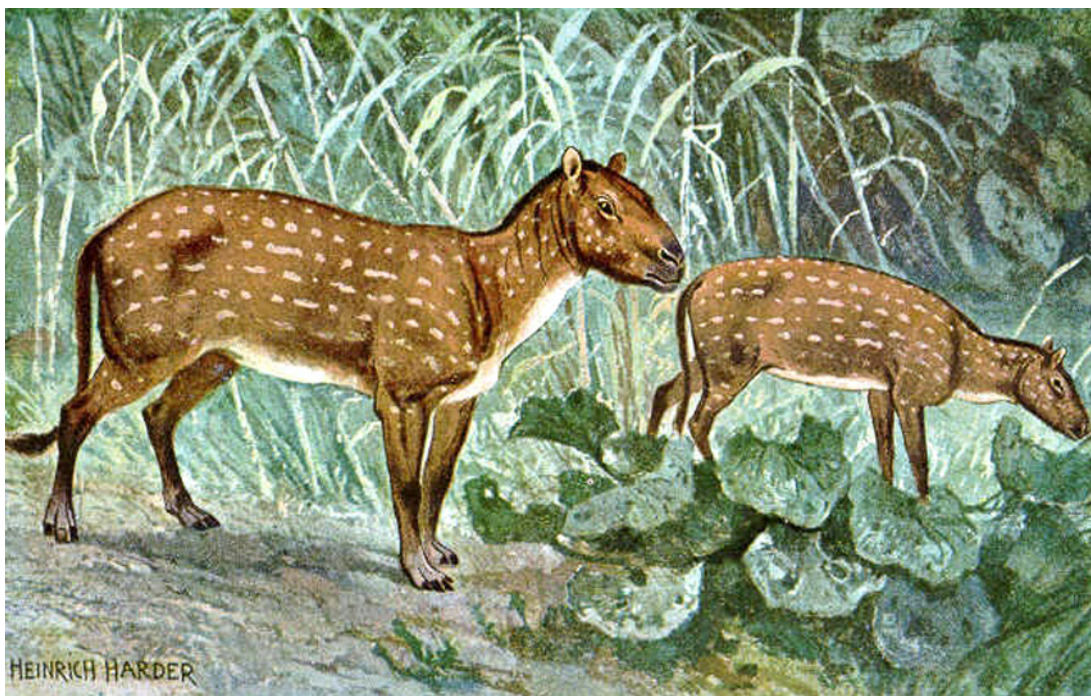


Figure 11 Reconstruction of *Eohippus*

Gould found that the fox terrier comparison seems to have been made originally by Henry Fairfield Osborn in 1904 in an article called 'The evolution of the horse in America'. Subsequent writers were unlikely to have much idea of how big a fox terrier really is, because it is not a common breed. So the likelihood is they just copied Osborn's description, without examining it much.

Similarly, you will often find several websites that agree closely about a topic, seeming to reinforce one another. However, further investigation may reveal that they are not independent and all refer back to one source.

In the next section you will learn about ways of evaluating information sources.

6 Evaluating websites

When cross-checking, you also need to take into account the fact that not all websites are equally reliable or authoritative. For example, the information they present may be inaccurate or out of date. It may be a hoax, or written by someone trying to promote a biased point of view, or even with the deliberate intention of misleading.

You might think of setting up a committee of 'gatekeepers', a bit like the editorial board of the *Encyclopaedia Britannica*, who could decide what was wrong and what was right. But, apart from the practical difficulties of agreeing who would sit on such a committee, the scale of the internet makes it very challenging. Whereas the *Britannica* holds about 44 million words, in January 2018 the [worldwide web](#) had about 4.3 billion indexed pages, containing around a trillion words.

However, there are several respected fact-checking sites. In the next activity you will look at two of them.

Activity 9 Fact-checking websites

Allow about 10 minutes

Fact-checking websites tend to focus on matters that affect politics or public policy, especially anything controversial.

Pick one or two issues that are currently being debated in the media, preferably one where the facts are disputed. Then see whether the following sites say anything about them. One has a UK focus and the other is more US-orientated.

- [Full Fact](#)
- [Snopes](#)

At first sight, Snopes may seem to concentrate on rather trivial stories. To dig deeper, you can do a search on a keyword or a website address, and then filter the results by time period or author.

However, rather than rely on fact-checkers, you might like to develop your own 'radar' for evaluating websites. Several checklists exist for doing this, including PROMPT, which was developed at The Open University. The PROMPT checklist is shown in Table 1.

Table 1 PROMPT checklist for evaluating websites

Presentation	Is the material well presented? Are grammar and spelling right? Are layout and style clear, readable, and consistent across the website's pages?
Relevance	Is the website likely to answer your question? Does it have any kind of description or introduction to help you decide?
Objectivity	Do the author(s) make their position clear? Do they have a special interest, such as commercial, political, personal belief, and so on?
Method	Often a website presents journalism, the results of a survey, or scientific information, and so on. What methods were used? How were the facts gathered? How was the survey done? What is the research evidence?
Provenance	Is the author or source of the material clear? Is the website owned by a trustworthy body, such as a university, a public service broadcaster, a

professional body, an international organisation, a government department, a respected company? Do other websites you trust link to this one?

Timeliness Do the pages have a date to indicate when they were produced, or last updated? Is the information out of date, or is the date not critical for the question you are trying to answer?

This next activity gets you using the PROMPT criteria to evaluate websites.

Activity 10 Using PROMPT

Allow about 15 minutes

Choose a question that is probably hard to answer, such as 'How many kinds of dinosaurs existed?'. Do some internet research to try to answer it. Don't spend too long on this – a maximum of 15 minutes.

As you visit websites, try to do a quick mental check of the answers to each of the PROMPT criteria in Table 1 above. It is often worth scrolling to the bottom of a website's home page, where there is often an 'About us' link, and other information relevant to the PROMPT criteria.

7 This session's quiz

Check what you've learned this session by taking the end-of-session quiz.

[Session 2 practice quiz](#)

Open the quiz in a new tab or window and come back here when you are done.

8 Summary of Session 2

In this session you looked at:

- how information can be obtained and some ways to assess its quality.
- how to use Google operators to fine-tune internet searches.
- filter bubbles and a possible way to avoid them.
- a short history of traditional encyclopedias, how Wikipedia compares and Wikipedia page histories. You then went on to learn about WolframAlpha, a different kind of online reference source.
- strategies for thinking critically about the reliability of websites. These include triangulation, fact-checking websites and applying the PROMPT framework for evaluating websites.

In Session 3 you will find out how the Python programming language can be used as a sort of 'big calculator', without needing any programming knowledge, and how this can be applied to a range of interesting questions.

You can now go to [Session 3](#).

Session 3: The big calculator

Introduction

It is often said that all of the people in the world could stand on the Isle of Wight, which is a relatively small island off the south coast of England. Can this be true? How could you check it for yourself?



Figure 1 Standing room only?

In this session you will learn how to use Python – a sort of big calculator – to investigate questions like these. Often it is not possible to reach exact answers. So you will look at how to estimate some of the information in order to get a result that is good enough to answer the question concerned.

On the way, you will learn skills to help you estimate the true figures behind a range of social statistics and assess whether people's first reactions are accurate.

By the end of this session, you will be able to:

- use the Python interactive console to calculate answers to problems
- use the 'Fermi problem' approach to generate good estimates even when you don't have much information
- discuss the 'wisdom of crowds'
- describe the key differences between fast and slow thinking.

1 Meet the interactive shell

The next activity introduces you to the Python system you will use to do calculations.

Activity 1 Warm-up time

Allow about 10 minutes

During this session you will use an interactive shell, also known as a console. One of these shells has been provided for each activity where you need to do calculations. The first console is below.

Interactive content is not available in this format.

Brython is just a particular version of the language Python. This is being used as it is easy to include a Brython console on a web page.

The console above is live and you can use it to do calculations. Try it now. Click the mouse just to the right of the prompt

```
>>>
```

When you see the flashing cursor type in a simple sum such as `1+1`, so that you see this in the console:

```
>>> 1+1
```

Now press the Enter (i.e. Return) key.

Python does the calculation and prints the result. It then moves to the next line and displays the prompt again, showing that it is waiting for further input from you.

```
>>> 1+1
```

```
2
```

```
>>>
```

The Python console can be used in a very similar way to a calculator. However, on a computer keyboard, there are no \times or \div keys, so instead you have to use `*` and `/`, respectively.

Try a few calculations of your own before going on. Remember, the same sequence is repeated:

- You enter something at the prompt `>>>` and press Enter.
- Python works out the result and prints it.
- Then it moves on the next line and displays the prompt again.

Like a calculator, Python works out multiplications or divisions before additions or subtractions.

```
>>> 1+2*3
```

```
7
```

```
>>>
```

If you want a different order, you use brackets. Anything in brackets is performed first.

```
>>> 1+2*3
```

```
7
```

```
>>> (1+2)*3
```

```
9
```

```
>>>
```

Python can calculate with decimals and produces either an exact answer or one that cuts off after a certain number of digits.

Try the following divisions (remember that in the console you have to use / for division).

- $1.2 \div 3$
- $12 \div 3$
- $2 \div 3$

You may notice that the last digit is not always correct. This is common in computer arithmetic. It happens because computers represent numbers using 0s and 1s, instead of the more familiar decimal system. This is seldom an issue and won't matter for the calculations you will be doing

Try some calculations of your own. It doesn't matter much what you choose. The aim is just to play around and get comfortable with working in the Python console.

A handy feature of the Python console is that it always stores the result of the previous calculation. To access the last result, type an underscore `_`. Try this for example:

```
>>> 60*60
```

```
3600
```

```
>>> _
```

```
3600
```

This is useful for chaining together a series of steps without having to enter the whole calculation at the start. The calculation above found the number of seconds in a hour. Instead of just displaying the result again, you can use `_` to access the value.

Multiplying it by 24 then gives the number of seconds a day, 86,400.

```
>>> 60*60
```

```
3600
```

```
>>> _*24
```

```
86400
```

Of course, if you prefer, you can enter the whole calculation at once: `60*60*24`.

Now move onto the next activity below where you are asked to calculate the total number of seconds over a period of time.

Activity 2 Geological time

Allow about 10 minutes

Using the console below, calculate the number of seconds in:

- one year (assume a year is exactly 365 days)
- 900 years.
- 65 million years.

Interactive content is not available in this format.

Discussion

- a. You can work it out like this:

```
>>> 60*60*24*365  
31536000
```

- b. Then you can use the answer from (a) and multiply by 900:

```
>>> _*900  
28382400000
```

- c. The best way to find the seconds in 65 million years is probably to repeat the calculation from (a) and multiply by 65,000,000:

```
>>> 60*60*24*365*65000000  
2049840000000000
```

2 Putting the console to good use

There is an old joke about an attendant in a museum of palaeontology. Asked by a visitor how old a particular dinosaur skeleton was, he replied '100 million and 5 years'. 'That seems very precise,' said the visitor. 'Well,' the attendant replied, 'it was 100 million years old when I started here, and that was 5 years ago.'



Figure 2 A dinosaur skeleton

The large dinosaurs became extinct roughly 65 million years ago (Figure 2). The last answer in Activity 2 represents that number converted to seconds. But, of course, the number 65 million is only right to the nearest million. So, if you were asked how many seconds it is since these animals died out, a sensible answer might be 2,000,000,000,000,000.

Writing a very large number like this out in full is slow, and it is very easy to miscount the zeros at the end. The answer is to use **exponential notation**. Here, all of those trailing zeros can be replaced by an 'e' (for 'exponential'), followed by the number of zeros that have been replaced.

So the number 2,000,000,000,000,000 can be written as $2e15$. Python recognises exponential notation, which is useful when working with large numbers.

Now you can tackle the question asked in the Introduction. *Could* all the people in the world fit on the Isle of Wight?

Activity 3 The Isle of Wight

Allow about 15 minutes

There are various ways to tackle this question, but the simplest is probably to take the area of the Isle of Wight and divide it by the number of people in the world. The answer will represent how much space each person would get on average if everyone was crammed on the Isle of Wight. Asking whether or not this is enough space for a person to stand on will then answer the original question. Would the average footprint be enough?

The inputs – the area of the Isle of Wight and the world population – don't need to be known very accurately. You only need rough numbers.

a. Using Google, or WolframAlpha, find:

- the area of the Isle of Wight, in square metres
- the current world population, in billions.

Answer

From Google, the area is 380 million square metres, and the population was 7.5 billion in August 2017.

b. Use the Python console below to divide the area by the population. You can use exponential notation: 380 million can be entered as 380e6 (because a million is 1 followed by 6 zeros) and 7.5 billion as 7.5e9 (because a billion is 1 followed by 9 zeros).

Answer

380e6 divided by 7.5e9 gives 0.050666666666666665. This represents just a little over 0.05 of a square metre. Could you stand on that?

c. To relate 0.05 square metres to something familiar, find the area of a sheet of A4 paper.

Interactive content is not available in this format.

Answer

A sheet of A4 paper has an area of about 0.06 square metres. So, sharing the Isle of Wight among the world population would give them less than the equivalent of an A4 sheet of paper each.

This certainly isn't enough. In fact, the maximum safe crowd density is normally reckoned to be 5 per square metre (Keith Still, 2019), giving each person 0.2 square metres, the equivalent of about three sheets of A4 paper.

So the average space per person isn't enough and the population of the world couldn't fit on the Isle of Wight.

Here are more questions that can be answered using a similar approach.

Activity 4 Drive me to the Moon

Allow about 15 minutes

The British cosmologist Fred Hoyle (1915–2001) once pointed out that if there was a road at right angles to the ground, and you could drive your car upwards along it at 100 km/h, you would touch the edge of space after only an hour.

How long would it take to get to the Moon, if the road extended to it, and assuming the same speed of travel? Give the answer in months, assuming a month is 30 days.

- a. Guess the answer. Don't do an internet search. Just think and then guess. How far away is the Moon? Could you be there next week? Next year? In your lifetime? In a thousand years?

- b. Now calculate an answer, using the console below. You will need to find the distance to the Moon. Then you can divide by the speed, and that will give the number of hours.
- c. Once you have the number of hours, convert that to days, and then to months, assuming a month is 30 days.
- d. You aren't looking for an exact answer. This is just a thought-experiment, intended to get a rough figure, and to see if your initial guess is in the same ballpark.

Interactive content is not available in this format.

Discussion

The average distance to the Moon is 384,400 km.

Dividing this by 100 gives the number of hours the trip would take.

To convert that to months, first divide by 24, then by 30.

To the nearest month, driving to the Moon would take 5 months.

Tip: you can round a number to the nearest whole number using the round function, like this.

```
5.338888888888889
```

```
>>> round(_)
```

```
5
```

As an interesting comparison, the circumference of the Earth is a little over 4000 km. So, at 100 km/h, it would take only about half a month to circumnavigate it.

Applying the same approach as before, answer the following question about mice and elephants.

Activity 5 Of mice and elephants

Allow about 15 minutes

How many mice would weigh the same as an African elephant?

First, write down a guess. Then do some internet research, to find the mass of an elephant and a mouse. There are different kinds of African elephant. For the purposes of this problem, you should choose the heaviest one.

The mass of the elephant will probably be given in kg and the mass of the mouse in g. Before you can compare the two, you will need to convert the mass of the elephant to g.

Once you have the two masses, you can use the Python console to divide one number by the other, to find how many mice would weigh the same as an elephant. Give your answer to the nearest thousand mice.

Interactive content is not available in this format.

Discussion

The mass of an African bush elephant is about 6000 kg.

The mass of a mouse is about 19 g.

First, convert the elephant's mass to g.

Then divide the result by 19.

```
>>> 6000*1000
```

```
6000000
```

```
>>> _/19
```

```
315789.4736842105
```

```
>>>
```

To the nearest thousand, the answer is 316,000, which is over a quarter of a million mice!

Tip: you can round a number to the nearest thousand using the round function with an extra input, like this.

```
315789.4736842105
```

```
>>> round(_, -3)
```

```
316000.0
```

```
>>>
```

To round to the nearest million, you would replace the -3 with -6, reflecting the fact that a thousand is 1e3 and a million is 1e6.

The next section introduces a technique for finding reasonable estimates even when there is very little information to work from.

3 Fermi problems

The Italian scientist Enrico Fermi (1901–1954) was famous for doing rough calculations based on very little information and getting surprisingly good estimates.

A famous example of his was: 'How many piano tuners are there in Chicago?'

To tackle this, Fermi made reasonable assumptions about:

- what proportion of households have a piano
- how many times a year a piano will be tuned
- how long it takes a piano tuner to tune a piano
- how many hours a piano tuner works per year.

Combining these estimates with the number of people in Chicago, he arrived at a figure of 225. For comparison, according to WolframAlpha, the actual number in 2009 was 290. Taken with the fact that the population of Chicago has shrunk since Fermi's day, this means his estimate was a bit low. But still it is a remarkably good 'ball park' figure, given how little information he began with.

3.1 Using the Fermi method

Here is an example of using Fermi's approach to estimate the number of doctors in the UK who are general practitioners (GPs).

Assume that:

1. Each GP spends 20 hours a week in individual appointments with patients. This seems a reasonable estimate because GPs have many other duties.
2. Each GP works 44 weeks a year, allowing for holidays.
3. Each individual appointment takes 10 minutes.
4. The average person sees their doctor three times a year.
5. There are 65 million people in the UK.

The 65 million people will between them need 65 million times 3 appointments, giving 195 million appointments.

Each appointment lasts 10 minutes, so the total time is 195 million times 10 minutes, or 1950 million minutes.

Each GP spends 20 hours a week on individual appointments, for 44 weeks. This gives a total of 44 times 20 hours, or 880 hours. Multiplying by 60 gives 5280 minutes.

Now, dividing the number of patient minutes per year by the number of GP minutes per year gives an estimate of the number of GPs needed.

Here is the complete calculation in Python.

```
>>> 65e6*3
195000000.0
>>> _*10
1950000000.0
>>> patient_minutes = _
```



```
>>> 44*20
880
>>> _*60
52800
>>> gp_minutes = _
>>> patient_minutes/gp_minutes
36931.818181818184
>>> round(_,3)
37000.0
>>>
```

When the total number of patient minutes has been found, it needs to be stored while the number of GP minutes is calculated.

In Python, you can do this by attaching a label to a result. The label can be anything but using `patient_minutes` is a good choice because it makes it obvious what it represents. Similarly, `gp_minutes` is a good choice for the GP minutes.

Finally, the result is rounded to the nearest thousand GPs, giving an estimate of 37,000. For comparison, at 31 March 2016, the GP headcount for England alone was 41,877. But many doctors were part-time, and the full-time equivalent was 34,914. This would scale up to about 43,000 for the whole UK.

So, the estimate of 37,000 is slightly low, but remarkably close, considering how many of the assumptions were no more than educated guesses.

Now try to work out a problem using the Fermi approach.

Activity 6 Solving a Fermi problem

Allow about 20 minutes

Estimate how many cats there are in the UK. (Remember: this is a rough estimate. You are not trying to get an exact count!)

You will need to consider:

- How many people live in the UK.
- Roughly how many people live in an average household. This will need to be a guess.

From these figures, you can estimate how many households there are in the UK.

Interactive content is not available in this format.

Now:

- Guess what fraction of households have one or more cats.
- Households with cats often own more than one, so guess an average figure for the number of cats in a cat-owning household.

By combining these estimates

- how many households
- what fraction own one or more cats

- the average number of cats per cat-owning household

you should be able to arrive at a ballpark estimate of the UK cat population.

Discussion

We assumed:

- UK population 65 million
- 3 people per household
- 1 household in 8 owns cats
- the average number of cats in a cat-owning household is 1.5.

Here is our calculation, rounding to the nearest 100,000 cats!

```
>>> 65e6
65000000.0
>>> _/3
21666666.666666668
>>> _/8
2708333.3333333335
>>> _*1.5
4062500.0
>>> round(_, -5)
4100000.0
>>>
```

So, there are just over 4 million cats.

Of course, your estimates are probably slightly different, but your result for Activity 6 was probably not that different from ours. Your guesses might have been better than ours because, according to Statista (2018), the number of cats was 8 million.

The next section looks at a different method of estimation, in which there are a large number of people to estimate a quantity and then take the average of their individual estimates.

4 The wisdom of crowds

You have probably heard of the 'wisdom of crowds'. This is the observation that if you get a large number of people to estimate something, and then take the average of their estimates, the result is often close to the true value.

In his book *The Wisdom of Crowds*, James Surowiecki (2004) suggested that a variant of this idea could be applied to decision making. If a large number of people give independent answers, their individual differences may balance out, leading to the group as a whole reaching a good decision.



Figure 3 Jar of sweets

A similar idea lies behind the crowd-forecasting website Almanis (Figure 4). People can join for free and become forecasters, providing answers to a wide range of questions. Members can also raise their own questions. They can earn rewards, including cash, by contributing to accurate forecasts.



Figure 4 A page from Almanis

Almanis says, 'Combining many individuals' forecasts dramatically increases accuracy.' But do crowd-sourcing forecasts or estimates really result in improved accuracy? You can now take part in a simple experiment created for this course. It won't provide conclusive evidence either way about the wisdom of crowds, but it is an interesting example to try.

Activity 7 Join the crowd

Allow about 20 minutes

Figure 5 is a computer-generated graphic of random circles. Have a go at estimating how many there are. Your estimate should not be a simple wild guess but an estimate. You aren't going to count all of the circles because it would take too long. Instead, you could count the number in a small area and then mentally scale up, for example. Visit this [poll](#) and place your guess in the field provided. You will then see a running average of all the estimates entered to date.

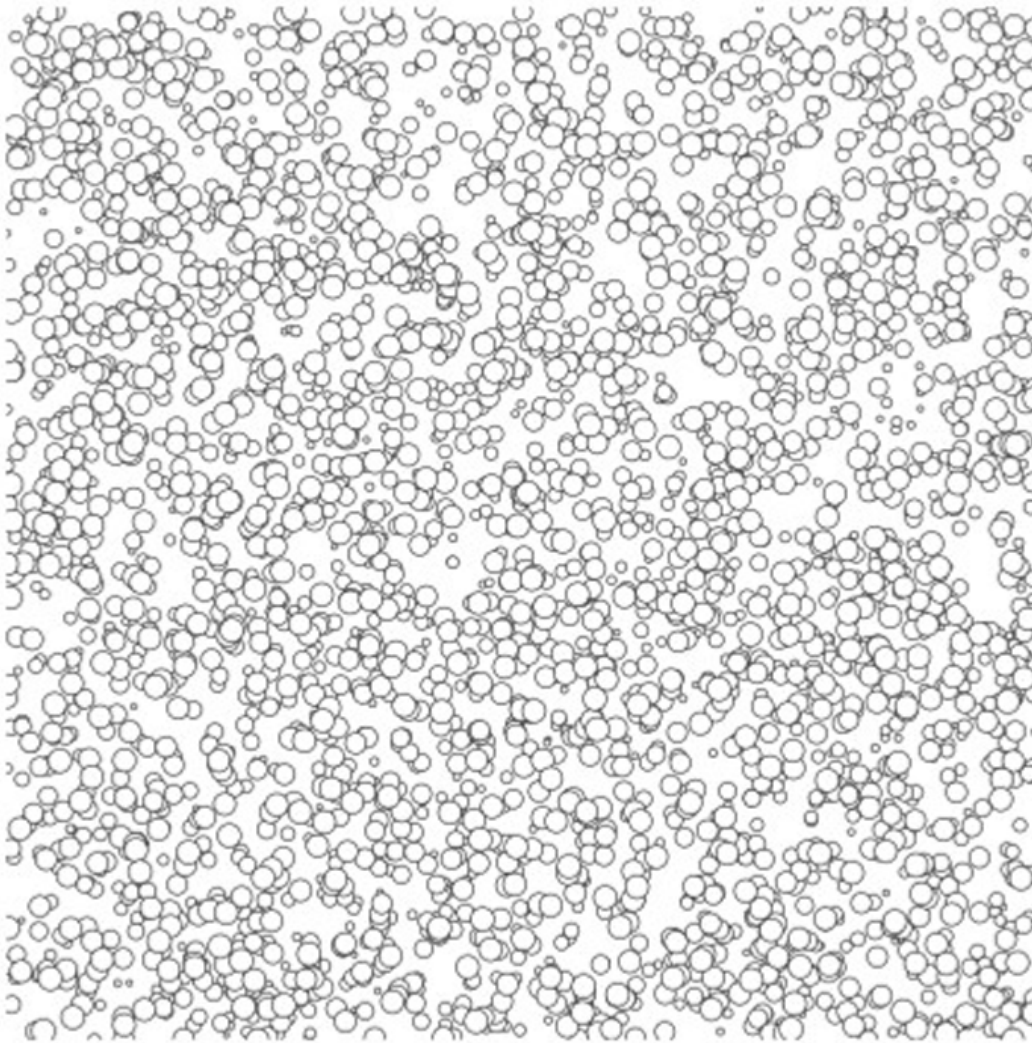


Figure 5 How many circles are there?

Discussion

The wisdom of crowds predicts that the more people who submit their estimates to the running poll, the closer the running average will be to the actual number.

The exact number of circles is: **3307**.

The next section explores how accurate you can be when making estimates about the society you live in.

5 What do you know?

It is implicit in the idea of crowd-sourcing prediction that the crowd members are making guesses that are not just random stabs in the dark but are informed by some knowledge about the situation. For example, if you were guessing how many sweets are in the jars in Figure 3, you would have at least a rough idea of what would be a likely number.

There is also evidence that some people are consistently able to make guesses that are much better than the average. Phillip Tetlock's team at the US government-funded Intelligence Advanced Research Project (Iarpa) claims to have identified 'super-forecasters'. Their unusual talents make them highly successful at predicting world events, and able to perform better than established experts. Almanis presumably hope that their system of identifying and rewarding accurate prediction will enable super-forecasters to emerge, whose abilities can then be put to use.

However, even if super-forecasters manage to be highly successful without being experts they probably still have a reasonable level of knowledge about the field where they are making predictions.

Studies have consistently shown that most people are surprisingly inaccurate at estimating facts about the society they live in.

You can explore this in the next activity.

Activity 8 How many senior citizens?

Allow about 1 minute

What proportion of the population of the UK are 65 or more years old?

Interactive content is not available in this format.

Discussion

Surveys show that most people believe the proportion is about 37%.

With your Fermi problem-solving skills, you can easily do much better!

Assume that the average length of life is 80 years. That can't be far out for people in the UK.

Assume that the proportion in all age groups is the same. That can't be far out either, but if anything is likely to overestimate, rather than underestimate, the proportion of older people.

The span from 65 to 80 is 15 years, so a Fermi-style estimate would be $15/80$.

In the Python console, do the following calculation (multiplying by 100 is to convert to a percentage).

```
>>> 15/80
0.1875
>>> round(_*100)
```

The result is 19%, a little over a half of what people tend to believe.

The actual figure in 2014 was 17.4%. Even though the proportion of the population who are 65 or over is steadily increasing, by 2024 it is still only forecast to be 19.9%.

The next section looks at what psychological research suggests are possible reasons why our estimates are often very inaccurate.

6 Thinking fast and slow

In his book *Thinking, Fast and Slow*, Daniel Kahneman (2011) argues the case for two types of thinking.

'System 1' is fast, instinctive, often unconscious, and requires comparatively little effort. However, it tends to take shortcuts. System 1 is a necessary survival mechanism because staying alive requires making a continuous series of rapid decisions. But, at the same time, it is illogical and risks reaching conclusions that are mistaken.

'System 2', on the other hand, is slower and more considered, reasons much more logically, involves conscious thought, and generally takes a lot more effort.

As an example of fast and slow thinking, consider the following question.

Which weighs the most: a kilogram of lead or a kilogram of feathers?

At first, most people hear System 1 screaming, 'Lead's heavy, lead's heavy!'

But then System 2 gets to work, pointing out that they are being fooled. A kilogram of anything weighs just that: a kilogram.

This example demonstrates a crucial fact about System 1 versus System 2 thinking. Often a question that requires System 2 thought ('What does *weigh a kilogram* mean?') gets replaced by a System 1 question ('What's *heavy* – *lead or feathers*?') because the latter takes less effort to process.

Kahneman (2011) calls the question you are asked the **target question** (p. 97) and the simpler question it is replaced by the **heuristic question** (p. 129). The word *heuristic* originally meant a way of discovering things but is used by Kahneman to mean something like 'quick and instinctive'.

One kind of heuristic question is *availability*. When people are asked to estimate how common something is, they substitute a simpler question: how readily do examples of it spring to mind? But this availability is very influenced by a range of factors other than the actual frequency. For example, something will have higher availability if it :

1. is dramatic or frightening
2. has recently been in the news
3. is frequently reported in the news
4. is familiar to you from personal experience.

The reason why the proportion of the population who are 65 or over is overestimated is probably a combination of factors 3 and 4.

The Fermi problem approach, on the other hand, is clearly in System 2 territory. Even though data sometimes has to be guessed, the overall process steers us towards more considered judgements.

Recalling the 'super-forecasters', these are people probably using System 2 thinking to make their predictions, rather than relying on hunches or intuition.

In Session 5 you will meet other examples of System 1 heuristics and the biases they introduce, and learn how thinking tools may equip you to avoid these dangers.

7 This session's quiz

Check what you've learned in Session 3 by taking the end-of-session quiz.

[Session 3 practice quiz](#)

Open the quiz in a new tab or window and come back here when you are done.

8 Session 3 Summary

In Session 3 you learned to use the Python interactive console as a sort of 'big calculator'. You used it to find answers to a range of intriguing problems. You also:

- learned about 'Fermi problems'. These are problems for which you can generate a useful 'ballpark' estimate even though you have very little information to go on. This led to the 'wisdom of crowds' – the idea that if a large number of people estimate something, the average estimate is likely to converge on the true value.
- saw that individuals as a rule are not very good at estimating facts about society. This is sometimes because they follow instinctive shortcuts, rather than applying the more systematic approach used for Fermi problems.
- met the concepts of fast and slow thinking: intuitive shortcuts contrasted with a more deliberate and analytical approach.

Session 4 is about putting together an argument. Have you ever sat in front of a blank page, desperately trying to pull your ideas together as a deadline hurtles towards you? If so, argument maps may be just what you need!

You can now go to [Session 4](#).

Session 4: Reasoning with argument maps

Introduction



Figure 1 Writing a reasoned conclusion can be challenging when you don't know how to start

In Sessions 1 to 3, you learned about tools for finding sources of information and checking those sources. Finding and validating information is one thing. There are many situations where you will need to go one step further. For instance, you may need to communicate the conclusions that you have drawn on the basis of the information. This involves convincing other people.

Have you ever been asked to prepare a (short) report, email or slide show? Often such communications have at least two parts: you need to discuss a topic and then come up with a reasoned conclusion. Here are just a few examples:

- a parking ticket appeal
- a school leave application
- an objection to a planning application to a council meeting
- a work email in which you argue for a business decision
- an essay or a report written at school or university.

But where do you begin? Do you recognise that sinking feeling of sitting in front of an empty computer screen or piece of paper, racking your brains to find that first sentence? There is no magic bullet but there are ways to help you prepare yourself before you write that first sentence.

Compare this problem with going on a journey. When you plan your travels, you don't immediately worry about where to put your foot next (which direction, how big a step, etc.). First, you need a plan or map, even it's just in your mind, about where to go, how you will go there, where to change mode of transport (get off the train, get into the plane), etc. In short, you first need to see the big picture, before you can fill in the details.

When writing a text that has argumentation (another way to say that it has a reasoned conclusion), there are techniques and tools to figure out the big picture first. A key tool that

you can use is that of an *argument map*. This is a map or plan that you create before you do any writing.

By the end of this session, you will be able to:

- describe the key ingredients of a basic argument map
- evaluate whether an argument has a solid base
- starting from a basic argument map, write some argumentative text based on it.

Throughout this course, argument maps are presented as figures. However, to support the accessibility of this course, all figures have long figure descriptions. The long figure descriptions for argument maps use a text-only shorthand notation to identify the elements of argument maps.

1 What is an argument?

What does it mean for a text to have argumentation or a reasoned conclusion? In the following activity, you will explore this question and encounter two distinct senses of the word 'argument'. Next you will learn how to represent a basic argument with an argument map.

Two perspectives on argumentation

Activity 1 Monty Python's Argument Clinic

Allow about 15 minutes

Watch the comedy sketch from [Monty Python's Flying Circus](#) (01.27 – 03.06). It vividly illustrates two different perspectives on the question 'What is an argument?'

Listen carefully and note down some of the key statements that the two main characters make about arguments.

Then describe in your own words each of the two perspectives.

Discussion

You might have noted down some of the following statements.

- 'If I argue with you I must take up a contrary position.'
- 'An argument is not the same as contradiction.'
- 'Contradiction is just automatic gainsaying (i.e. denying or contradicting) of everything the other person says.'
- 'Arguing is an intellectual process.'
- 'An argument can be the same as contradiction.'
- 'An argument is a connected series of statements to establish a definite proposition'.

One of the characters views an argument as two people having a verbal fight, contradicting each other, as in:

A: I've told you once.

B: No, you haven't

A: Yes, I have.

B: When?

A: Just now.

B: No, you didn't.

(...)

In stark contrast with that, the other character thinks about an argument as an intellectual process. More specifically, he thinks of it as a series of statements leading to a claim ('a definite proposition').

1.1 Claims and carrots

You have seen two different perspectives on the question 'What is an argument?' In this session, both will play a role. But it starts with the idea of an argument as a connected series of statements to establish a definite proposition. First, this idea needs to be translated into plain English.

Rather than speak about statements and propositions, this will speak about claims. At the heart of any argument sits a **main claim**. A claim expresses that something is the case or should be the case.

Assume that you have been asked to discuss the claim 'Eating carrots improves your eyesight'. That's going to be the main claim, the claim you will be investigating. The ultimate goal is to arrive at a discussion of this claim that ends with a reasoned conclusion.

As a first step, you could try to find support for this claim. After some investigations, you may have found out that:

- carrots are a source of vitamin A.
- taking vitamin A can reduce the risk of poor vision in individuals with a vitamin deficiency.

That gives you the material for a first very basic argument. Your argument consists of a main claim, and the two claims (shown above) that support this main claim. The supporting claims provide your audience (and you) with reasons for accepting the main claim. These reasons may themselves require further support, and will be discussed again later.

In summary, a main claim on its own is not yet an argument. A basic argument requires at least one further claim that supports or opposes the main claim.

1.2 A first argument map

As you investigate your main claim, you can keep track of the argument so far using an argument map. This is a diagram that displays the claims you have collected so far and the relationships between them. Figure 2 shows an argument map for the main claim and the supporting claims you have collected so far.

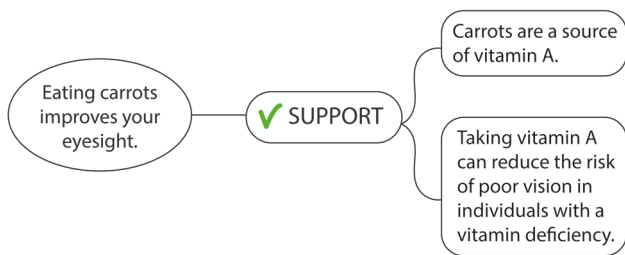


Figure 2 A basic argument map with one main claim and two supporting claims

In Figure 2, the main claim is enclosed in a circle. The supporting claims, enclosed by a box, are connected to the main claim via a box labelled 'SUPPORT'. There is also a green tick inside this box.

In this section you were introduced to main and supporting claims. The next section introduces a third kind of claim: opposing claims.

2 Opposing claims and evidence

The suggestion is that, as a first step, you look for supporting claims. You looked at an example and you may have found further supporting claims.

Now assume that you have exhausted your search. Before writing up your argument, you may want to pause. For any claim, it is usually possible to find some supporting claims. But what if there are also claims out there that contradict your main claim? Before you can make a judgement, you need to collect both supporting and, what we will call, opposing claims.

2.1 Opposing claims

Returning to the benefits of carrot for our eyesight, here is an example of an opposing claim: 'Beta carotene supplements will not strengthen eyesight or slow decline in healthy people.'

You can add this to your argument map by adding two further items. Apart from the item above, you need to also state explicitly that 'Carrots are a source of beta carotene'. In this case, the two claims are connected to the main claim by an OPPOSE, rather than a SUPPORT box, in Figure 3.

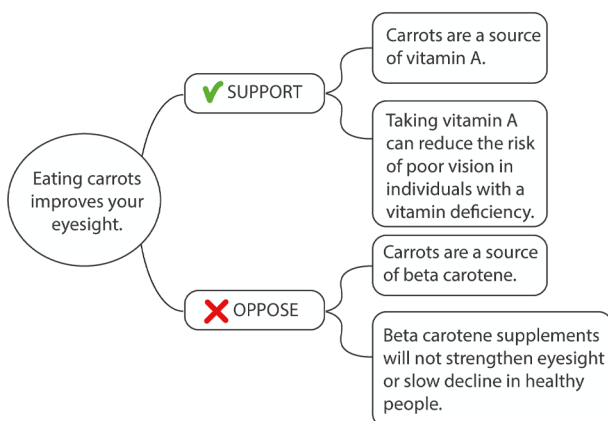


Figure 3 A basic argument with a main claim and both supporting and opposing claims

2.2 The importance of a good base

You can think of an argument map as a tipped-over pyramid (see Figure 4). At its pinnacle sits the main claim. The map records both supporting and opposing claims for that main claim. At its base are the claims for which no further support or opposition is provided.



Figure 4 A schematic representation of a tipped-over argument map

For your argument to be effective, the base must be solid. It carries your argument. If the base is dubious, your audience is unlikely to accept the argument. For that reason, the base needs to consist of claims that the audience will readily accept.

One way to do this is to have a base that consists of claims that

- a. you believe
- b. your audience also believes.

In other words, the claim needs to be accepted already by you and your audience. You cannot make a case based on a claim that you disagree on with your audience.

For example, you may choose a claim for your base because it is uncontroversial. This means that not only do you and your audience believe it, but also the wider community you belong to. Such information is referred to as **facts** or **common knowledge**. For instance, in your map, the claim that 'Carrots are a source of vitamin A' falls into this category.

Another way to make a solid base is to provide the audience with claims that express trustworthy evidence. For instance, evidence from a reputable scientific study. Such evidence may not be (and often isn't) common knowledge, but your audience may still accept the claim. They may accept it based on the reputation of the source. An example of a reputable source is a paper that has been published in an academic journal that uses peer review. A journal with peer-reviewed or refereed papers only publishes a study if other scientists, different from the authors, have checked the research and approved it for publication.

Activity 2 Building a base

Allow about 10 minutes

The argument map you have constructed so far (Figure 3) has a rather weak base. Can you strengthen the base by selecting the correct supporting claims, choosing between:

- (a) A paper published in 2003 by researchers at Brigham and Women's Hospital, Harvard University and several other institutions reported a study in which a large

group of healthy US male physicians were given beta carotene pills for 12 years. The researchers found that they had the same rate of age-related cataracts as those given a placebo (Christen et al., 2003).

(b) In 1998, researchers at Johns Hopkins and Nepal Eye Hospital Complex reported a study with 30,000 women in South Asia at high risk of vitamin deficiencies. They found that a group received vitamin A supplements had a lower risk of night blindness than a group that received a placebo (Christian et al., 1998).

In the map below, delete the incorrect option (a) or (b).

Eating carrots improves your eyesight				
SUPPORT			OPPOSE	
Carrots are a source of vitamin A.	Taking vitamin A can reduce the risk of poor vision in individuals with a vitamin deficiency.	Carrots are a source of beta carotene.	Beta carotene supplements will not strengthen eyesight or slow decline in healthy people.	
	SUPPORT			SUPPORT
	(a) A paper published in 2003 by researchers (...) (b) In 1998, researchers at Johns Hopkins (...)		(a) A paper published in 2003 by researchers (...) (b) In 1998, researchers at Johns Hopkins (...)	

Node (a) reference: Christen, W. G., Manson, J. E., Glynn, R. J., Gaziano, J. M., Sperduto, R. D., Buring, J. E., Hennekens, C. H. (2003) 'A randomized trial of beta carotene and age-related cataract in US physicians', *Arch Ophthalmol*, 121(3), pp. 372–378.

Node (b) reference: Christian, P., West Jr., K. P., Khatry, S. K., Katz, J., LeClerq, S., Pradhan, E. K., Shrestha, S.R. (1998) 'Vitamin A or β -carotene supplementation reduces but does not eliminate maternal night blindness in Nepal', *The Journal of Nutrition J. Nutr.*, 128(9), pp. 1458–1463.

For each of the claims 'Taking vitamin A can reduce the risk of poor vision (...)' and 'Beta carotene supplements will not strengthen eyesight (...)' try out a dialogue. Start with the claim 'Taking vitamin A (...). Ask 'What's the evidence for that?' and try out both continuation (a) and (b):

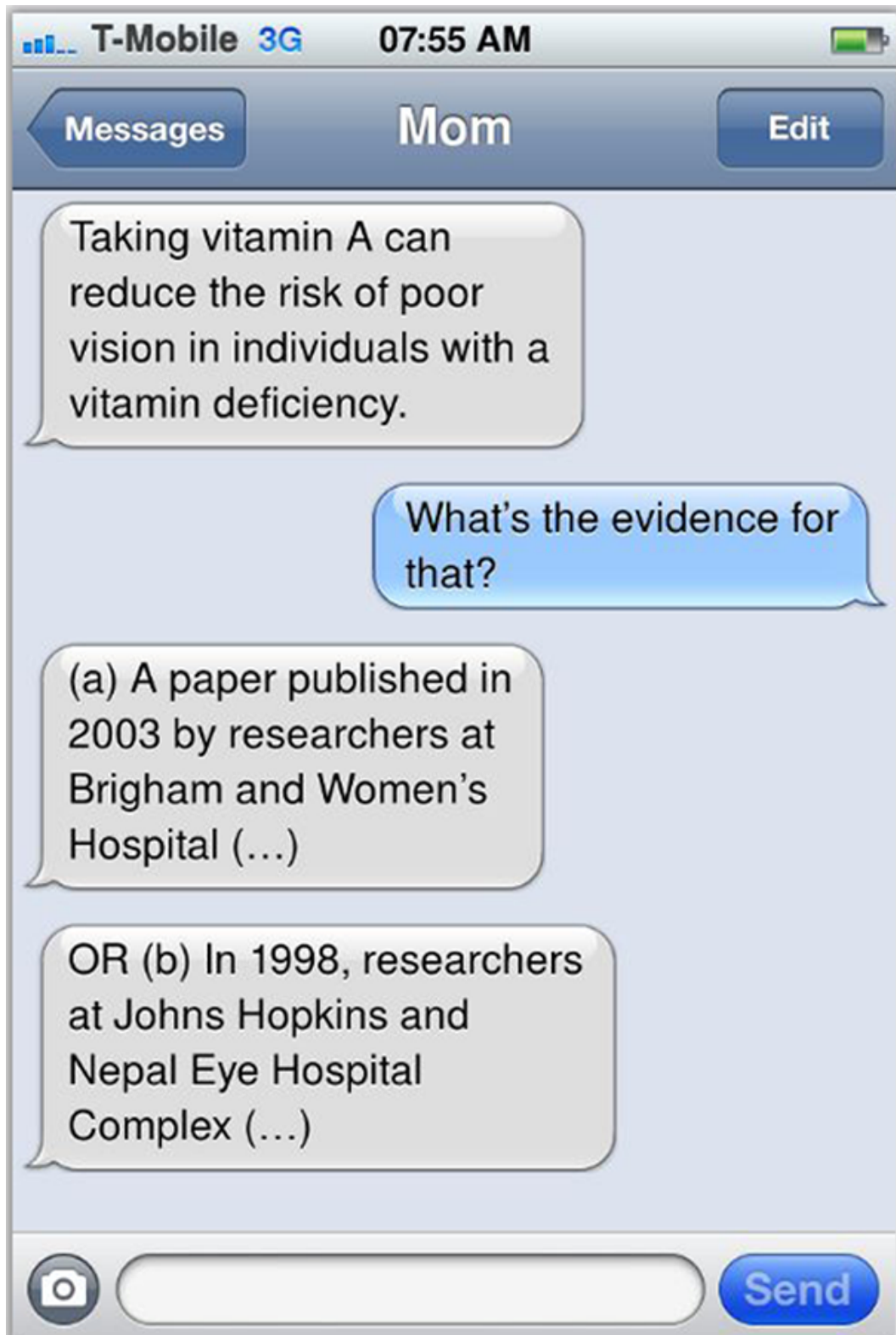
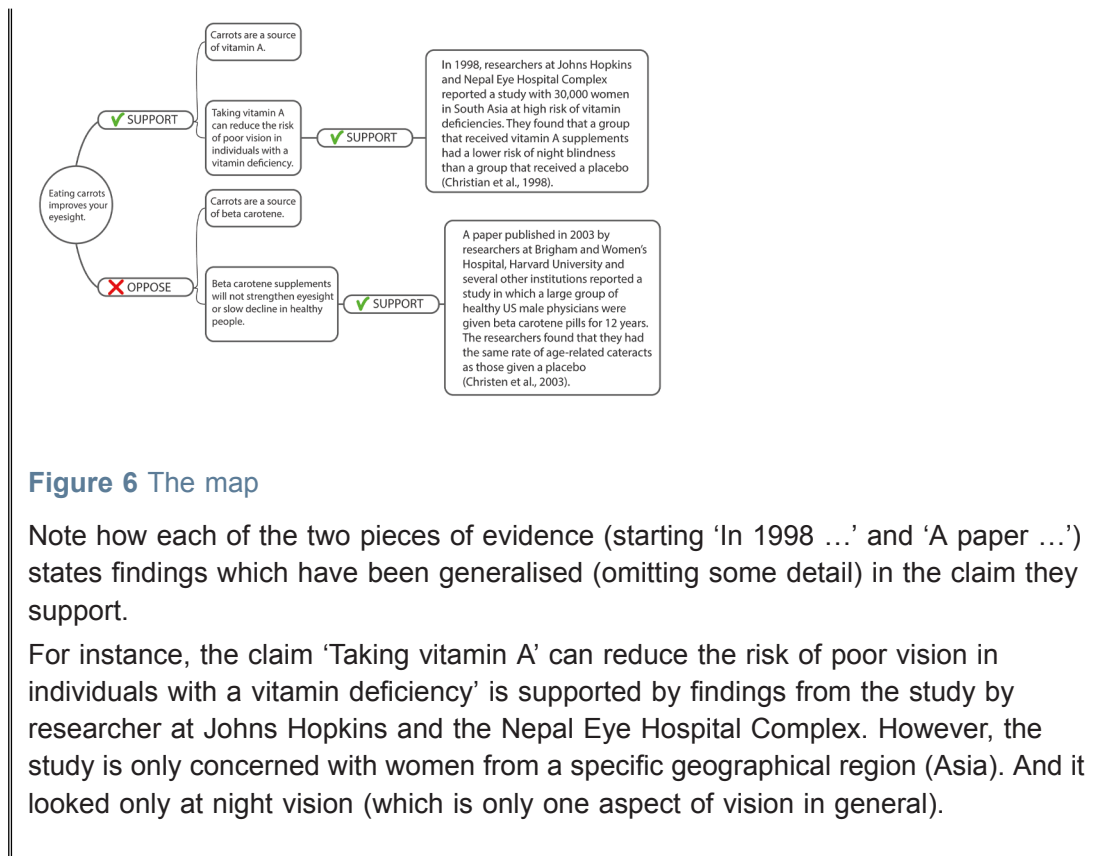


Figure 5 The argument 'Taking vitamin A can reduce the risk of poor vision (...)'

Discussion

Your map should now look like this.



3 The anatomy of argument maps

In Activity 2 you saw that a claim can itself be supported or opposed by a further claim. And that claim can, in turn, be supported or opposed by other claims. In summary, an argument map can have three types of claim: a main claim, supporting claims and opposing claims. Whereas there is only one main claim, there can be any number of supporting and opposing claims.

You can think of the claims in an argument map as living on different levels. The main claim lives on Level 0. Claims that support or oppose it are on Level 1. On Level 2, you find claims that, in turn, support the claims at Level 1. And so on. An argument map can have any number of levels. This idea is illustrated in Figure 7.

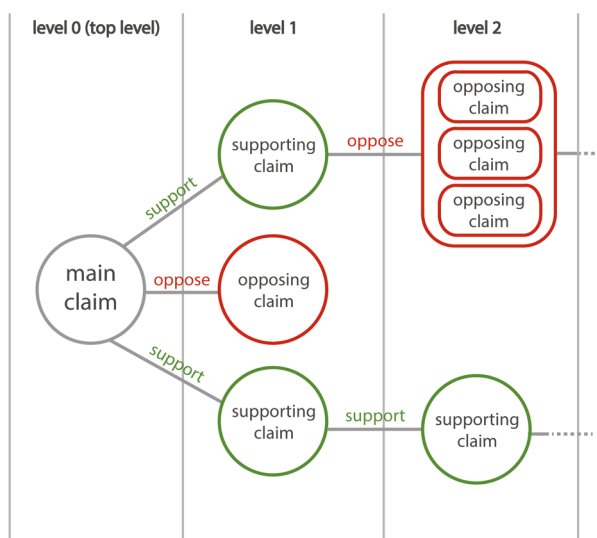


Figure 7 An argument map arranged in levels, with the main claim at the top (left-hand) level

4 From maps to words

In Section 2, you reached the point where your argument map is sufficiently developed to make the next step: writing a discussion on the main claim that ends with a reasoned conclusion.

Here is a recipe that can help you with this step.

Recipe: from maps to words

How to turn an argument map into a discussion with a reasoned conclusion.

1 Start your text by describing the main claim. You may want to add a sentence explaining why you are examining this claim. For instance, the claim that 'Eating carrots is good for your eyesight' is a common one, but is it true?

2 Next look at the supporting claims. Describe these in a paragraph or so. Conclude with the concrete evidence for these claims. You may want to start the paragraph by stating explicitly what you're going to do in this paragraph. For instance, 'Let's start by examining the evidence in favour of this claim.'

3 Then look at the opposing claims. Again, describe the claims and conclude with the concrete evidence. To indicate that you are now switching from supporting to opposing claims, you may want to use a connecting phrase, such as 'However', 'But', 'Though', etc.

4 Finally, you need to weigh up the opposing and supporting claims and draw a general conclusion. You may again want to use a connecting phrase (e.g. 'In conclusion, ...') to signpost what you are doing. Return to the main claim. Is it true or false? Or perhaps it is partly true and partly false. Summarise in which ways it is true and in which ways it is false according to the evidence.

5 If you have used references, conclude with a reference section. You can find advice on the use of references and in-text citations on the OU Library site.

Activity 3 Writing up the argument

Allow 20 minutes

Given the argument map that you have constructed, write a few paragraphs discussing the claim that 'Eating carrots improves your eyesight'. Try to follow the recipe above.

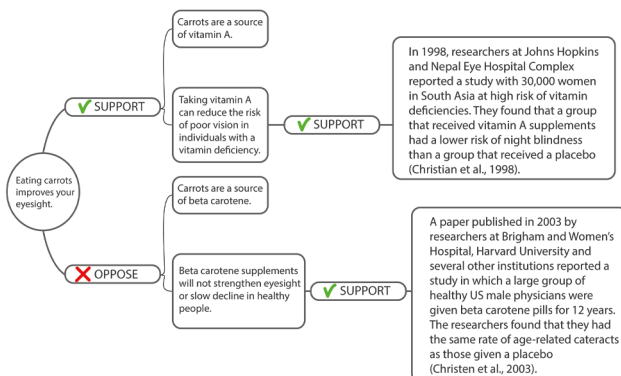


Figure 8 Complete map for the main claim 'Eating carrots improves your eyesight'

Discussion

Here is our attempt. Next to our text are the steps of the recipe, so you can see exactly what has been done in each paragraph. Also any connecting phrases and sentences that signpost what is being done in the discussion are underlined.

You may remember being told as a child that eating carrots is good for your eyesight, but is it?

Let's start by examining the evidence in favour of this claim. Carrots are a source of vitamin A. Vitamin A has indeed been shown to reduce the risk of poor vision in individuals who are likely to have a vitamin deficiency. More specifically, researchers at Johns Hopkins and Nepal Eye Hospital Complex found that vitamin A supplements can reduce the risk of night blindness in Asian women at high risk of vitamin deficiencies (Christian *et al.*, 1998).

However, the study looked only at people who had a high risk of vitamin deficiencies. What about healthy individuals? Researchers at Brigham and Women's Hospital, Harvard University and other institutions found that male participants (from the US) had the same rate of cataracts, regardless of whether they were given beta carotene or a placebo (Christen *et al.*, 2003).

In conclusion, eating carrots can be good for you, if you are likely to have a vitamin deficiency. However, if you are on a healthy diet already, eating extra carrots is not going to make a difference.

References

Christen, W. G., Manson, J. E., Glynn, R. J., Gaziano, J. M., Sperduto, R. D., Buring, J. E., Hennekens, C. H. (2003) 'A Randomized Trial of Beta Carotene and Age-Related Cataract in US Physicians', *Arch Ophthalmol.*, 121(3), pp. 372–378.

Christian, P., West Jr., K. P., Khattri, S. K., Katz, J., LeClerq, S., Pradhan, E. K., Shrestha, S. R. (1998) 'Vitamin A or β -Carotene Supplementation Reduces but Does Not Eliminate Maternal Night Blindness in Nepal', *J. Nutr.*, 128(9), pp. 1458–1463.

1. Start your text by describing the main claim. You may want to add a sentence explaining why you are examining this claim.

2. Next look at the supporting claims. Describe these in a paragraph or so. Conclude with the concrete evidence for these claims. You may want to start the paragraph by stating explicitly what you are going to do in this paragraph, for instance: 'Let's start by examining the evidence in favour of this claim.'

3. Then look at the opposing claims. Again, describe the claims and conclude with the concrete evidence. To indicate that you are now switching from supporting to opposing claims, you may want to use a connecting phrase, such as 'However', 'But', 'Though', etc.

4. Finally, you need to weigh up the opposing and supporting claims and draw a general conclusion. You may again want to use a connecting phrase (e.g. 'In conclusion, ...') to signpost what you are doing. Return to the main claim. Is true or false. Or perhaps it is partly true and partly false. Summarise in what ways it is true and in what ways it false according to the evidence.

5. If you have used references, conclude with a reference section.

Undoubtedly there will be differences between the wording of your and our discussion. However, if you followed the recipe, the overall structure of your discussion should be similar to ours.

The text in Activity 3 is certainly not an example of high literature. It may even feel a bit stilted. However, it will do the job in an academic context (for example, in answer to an assessment question). It will also work in professional contexts.

Of course, the recipe provided shows only one possible way to go from an argument map to a text. For comparison, here is a text by a reporter for the *New York Times*, Anahad O'Connor (2005). It covers mostly the same ground as our text, but the content has been organised a little differently. In the right-hand margin are some comments which relate the text to our argument map. Also, as before, connecting phrases and sentences have been highlighted which signpost the structure of the article and the argument.

THE CLAIM – Eating carrots improves your eyesight.

The main claim is set out at the beginning, as in our text.

THE FACTS – Your mother probably told you that carrots are good for your eyes – and you probably dismissed it as just an old wives' tale. But the claim is not baseless.

This is followed by a sentence that tells us why the claim is of interest.

Carrots are high in beta-carotene, a component of vitamin A, which is critical to normal vision. It's no coincidence that in countries where rice is a dietary staple but carrots and other sources of the vitamin are scarce, poor vision is rampant.

The context is set. The relationship between carrots and beta-carotene is introduced. The rest of this paragraph is not covered by our argument map.

So should you forget about glasses and just eat carrots? Probably not. Studies show that while taking vitamin A can reverse poor vision caused by a deficiency, it will not strengthen eyesight or slow decline in people who are healthy.

Interestingly, the author introduces the opposing and supporting claims in one single sentence. They are contrasted using the connecting word 'while'.

A study by researchers at Johns Hopkins in 1998, for example, looked at 30,000 women in South Asia at high risk of vitamin deficiencies. It found that a group that received vitamin A tablets had 67 per cent fewer cases of night blindness than a group that received a placebo.

Next, the author reveals evidence for the supporting claim.

But in 2003, researchers at Brigham and Women's Hospital in Boston found that a group of thousands of healthy men who took beta carotene pills for 12 years had the same rate of age-related cataracts as those given a placebo.

In this paragraph, the evidence for the opposing claim is dealt with.

THE BOTTOM LINE – Eating carrots helps maintain normal vision.

The conclusion has no explicit justification – it is left to the reader to make the connection with the claims and evidence from the preceding paragraphs.

Hopefully this illustrates that, although the recipe this author used is different in detail from ours, the strategy is on the whole very similar. The author deals systematically with the

claims and evidence and uses connecting phrases to signal to the reader what they are doing.

5 This session's quiz

Now it's time to complete the Session 4 badge quiz. It is similar to previous quizzes, but this time instead of answering five questions there will be fifteen.

[Session 4 compulsory badge quiz](#)

Remember, this quiz counts towards your badge. If you're not successful the first time, you can attempt the quiz again in 24 hours.

Open the quiz in a new tab or window (by holding down Ctrl [or Cmd on a Mac] when you click the link) then come back here when you've finished.

6 Summary of Session 4

This session, you learned about a first argument map. You saw how an argument map can help you get ready to write a reasoned conclusion. Building an argument suggests a way to get started:

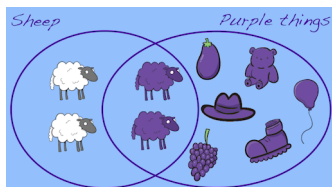
- First identify a main claim.
- Then look for supporting and opposing claims.
- The supporting and opposing claims may themselves require further opposing or supporting claims.
- Make sure that your argument map has a solid base. For any claims at the base, ask yourself whether your audience is likely to accept it.
- Finally, examine your argument map carefully, turning it step-by-step into a reasoned conclusion. A recipe was provided that can help you with this.

Of course, the recipe is not set in stone. It provides you with some guidance on how to write your own reasoned conclusions. As you get more confident at doing so, you may want to explore your own variations on this recipe.

7 Looking forward

You are now halfway through the course. The next video gives you a preview of the remainder of the course.

Video content is not available in this format.



Video 1

The Open University would really appreciate your feedback and suggestions for future improvement in our optional [end-of-course survey](#), which you will also have an opportunity to complete at the end of Session 8. Participation will be completely confidential and we will not pass on your details to others.

You can now go to [Session 5](#).

Session 5: Reasoning with sets

Introduction

In Session 3 you read about the book *Thinking, Fast and Slow*. The author Daniel Kahneman argues that we often replace questions by simpler ones that can be answered with less effort. The book draws on research that Kahneman and his collaborator Amos Tversky carried out over several decades.

One of their most famous experiments involved giving subjects the following scenario.

Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

The subjects were then asked:

Which is more probable?

1. Linda is a bank teller.
2. Linda is a bank teller and is active in the feminist movement.

Most people choose option 2 as the correct answer. You can probably see why. Intuitively, you can hear an inner voice shouting that option 2 fits the description of Linda better. However, the question asks which option is *most likely*, and the correct answer is 1.

Bank tellers (clerks) who are also active in the feminist movement are a *subgroup* of bank tellers as a whole. There are fewer people in this subgroup than there are bank tellers altogether. So the probability of being a bank teller who is active in the feminist movement must be less than the probability of being a bank teller, whether they are active in the feminist movement or not.

In this session you will learn about a way of visualising the situation in the form of an **Euler diagram**. These diagrams are powerful aids to understanding many problems involving **sets** – collections of objects or people that share some property.

An Euler diagram represents sets as ovals. Relationships between are shown as relationships between the corresponding ovals.

For example Figure 1 (a) shows two sets A and B which have some objects in common, so the ovals are shown overlapping. This is the idea of **intersection**.

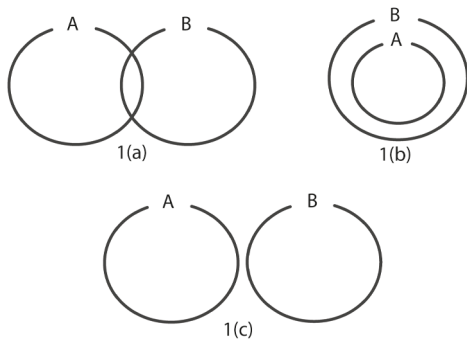


Figure 1 Euler diagrams

In Figure 1 (b) set A is in set B, so every object that belongs to set A is also in set B, and this is shown by the oval that represents A being inside the one representing B. This is the idea of **inclusion**.

In Figure 1 (c) sets A and B have no objects in common, and in this case the two ovals are shown with no overlap.

Euler diagrams bear some resemblance to Venn diagrams, another common way of showing sets graphically, but there is a crucial difference between the two. Any region in a Euler diagram corresponds to a set that actually contains objects, whereas a Venn diagram shows all potential combinations, irrespective of whether or not they are empty.

So in Figure 2 the same two sets C and D first as a Venn diagram, and then as an Euler diagram. The Venn diagram shows an overlap, but because there are no objects common to C and D the intersection is empty. In the Euler diagram the fact there are no common elements is represented directly by the two ovals not overlapping.

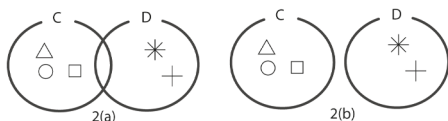


Figure 2 Venn and Euler diagrams

In this session you will also learn about sets in Python, and then go on to explore some more ways in which System 1 heuristic thinking can lead to mistaken conclusions. This will involve thinking about the size of different sets. Python will be used to do some simple experiments that simulate random events.

By the end of this session, you will be able to:

- use Euler diagrams as a tool for reasoning about sets
- understand operations on sets
- carry out simple set operations using Python
- use Euler diagrams to reason about the size of sets and calculate simple probabilities
- see how Euler diagrams can help to understand the counterintuitive answers to some well-known questions, such as Linda the bank teller, the law of small numbers, and the false positive paradox.

1 Lewis Carroll, the master puzzler

Lewis Carroll (1832–1898), the British author of *Alice in Wonderland* and *Alice through the Looking Glass*, also published many logic puzzles. Here is one of them.

Suppose you are given the following starting points (called **premises**).

1. All babies are illogical.
2. Illogical persons are despised.
3. Nobody is despised who can manage a crocodile.

What deduction can you make that uses all three of these premises?

One way to tackle this is by using Euler diagrams. The name comes from the Swiss mathematician Leonhard Euler (1707–1783), who had used them earlier than Venn.

The idea is that a set of things are represented by an oval. For example, this could be the set of babies. At this point you aren't concerned with individual babies, just with babies as a class.

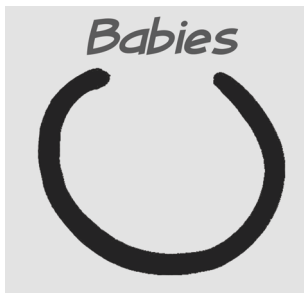


Figure 3 An oval labelled 'babies'

You can also consider the set of illogical persons. Premise 1, All babies are illogical, means the set of babies must be entirely contained in the set of illogical persons. You can represent the relationship like this.

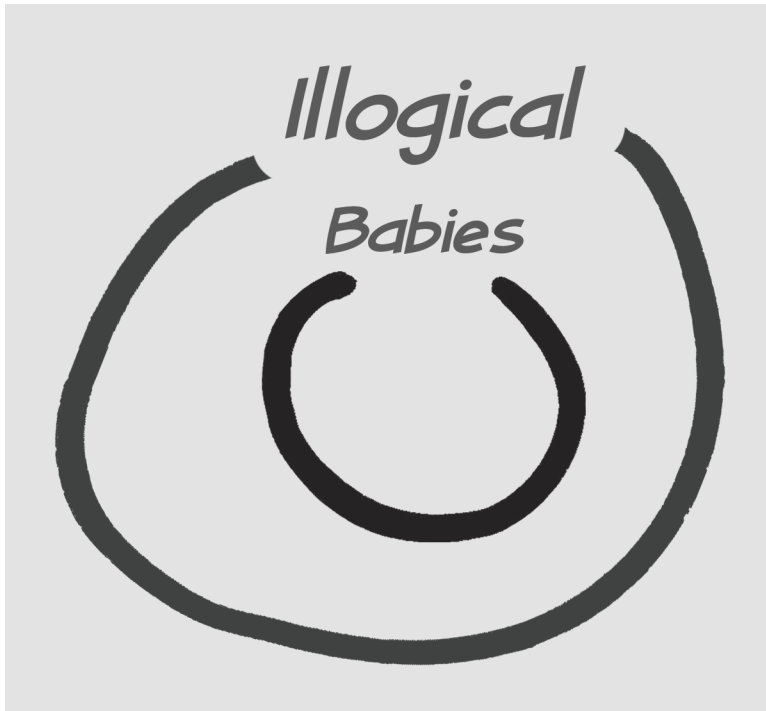


Figure 4 An oval labelled 'illogical' encloses the oval labelled 'babies'

From Premise 2, Illogical persons are despised, you can deduce that the set of illogical persons is entirely contained in the set of despised persons.

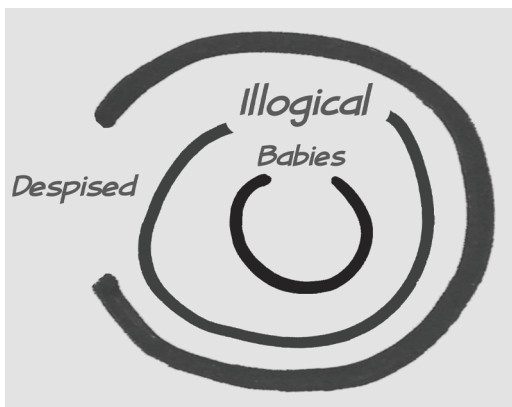


Figure 5 An oval labelled 'despised' encloses the oval labelled 'illogical' which in turn encloses the oval labelled 'babies'

Finally, Premise 3, Nobody is despised who can manage a crocodile, implies that no crocodile managers are despised. This is represented in the Euler diagram by showing the set of crocodile managers as having no overlap with the set of despised people.

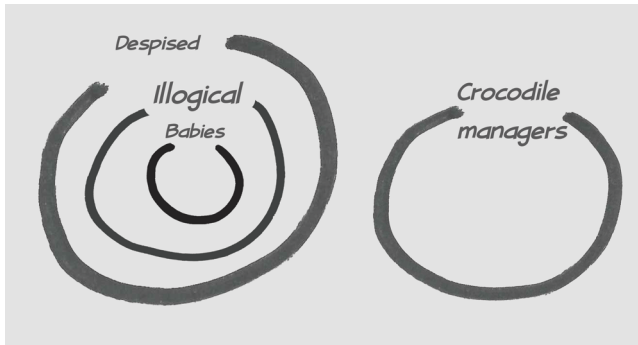


Figure 6 Premise 3

From this, you can see that the set of babies cannot have any overlap with the set of crocodile managers, and you reach the conclusion that

No babies can manage crocodiles.

You can try this using another logic puzzle in the following activity.

Activity 1 'No ducks waltz'

Allow about 10 minutes

Consider the second Lewis Carroll logic puzzle below. What conclusion can you reach using all three of the premises given?

You could draw Euler diagrams, using pen and paper, but you may be able to solve the puzzle in some other way. If so, that's fine. To solve it by Euler diagrams, you only need to use the two ideas you saw in the first example: sets enclosing one another and non-overlapping sets.

1. No ducks waltz.
2. No officers ever decline to waltz.
3. All of Sue's poultry are ducks.

Discussion

From Premise 1 you can draw this diagram.

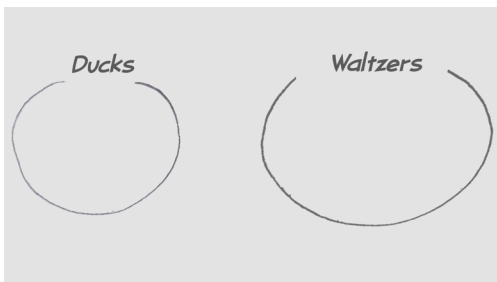


Figure 7 Diagram from Premise 1

From Premise 2 you can see that all officers waltz.

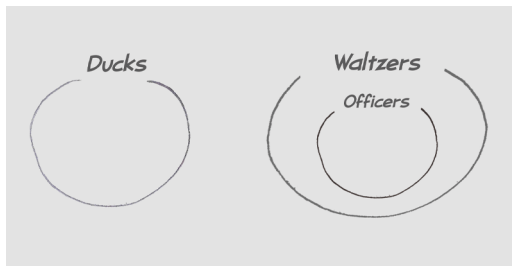


Figure 8 Premise 2 shows that all officers waltz

Premise 3 says that Sue's poultry are a subset of ducks

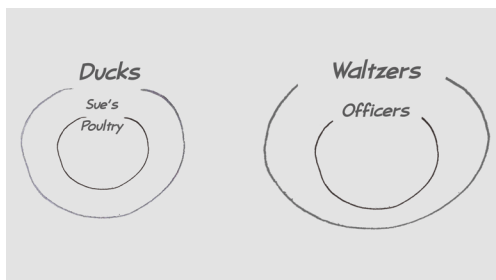


Figure 9 None of Sue's poultry are officers

So, there is no overlap between Sue's poultry and officers, and you reach the conclusion that **none of Sue's poultry are officers**.

In the next section you will learn about some operations you can do with sets.

2 Combining sets



Figure 10 Some purple sheep

The Euler diagrams you saw in Section 1 showed sets containing other sets, and sets that did not overlap other sets. But, of course, it is common for two sets to share some members. Consider the example of purple sheep (Figure 10).

Figure 11 shows two sets: the set of sheep, and the set of things that are purple. The overlapping area represents the set of purple sheep. This is called the **intersection** of the sets.

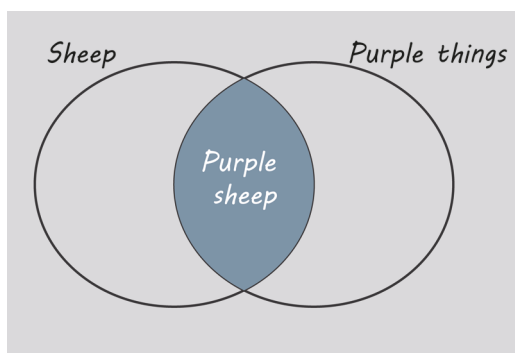


Figure 11 The intersection of Sheep and Purple things is Purple sheep

Another way to combine two sets is to join them together and take all the objects that are in the first set, the second set, or both. This is called the **union** (Figure 12).

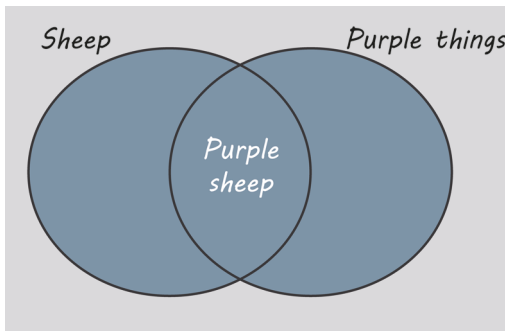


Figure 12 The union of Sheep and Purple things is things that are Sheep, or Purple, or both.

A common way to list the members of a set is between 'curly brackets', also called braces. You could write:

sheep = {'agnes', 'wilhemina', 'rusty', 'billy', 'leaper'}

purple_things = {'rusty', 'aubergine', 'amethyst', 'leaper'}

The intersection of 'sheep' and 'purple_things' would be
{'rusty', 'leaper'}

and the union would be

{'agnes', 'wilhemina', 'rusty', 'billy', 'leaper', 'aubergine', 'amethyst'}

These are not sets of real objects but of words. However, sets of real objects have intersections and unions in the same way as these examples.

There are two important points to note about sets.

- No member of a set can appear more than once.
- The order in which the members of a set are listed is irrelevant. It is still the same set whatever the order.

Python has sets and can calculate intersections and unions. In the interactive shell below execute the following lines.

Interactive content is not available in this format.

```
>>> sheep = {'agnes', 'wilhemina', 'rusty', 'billy', 'leaper'}
```

```
>>> purple_things = {'rusty', 'aubergine', 'amethyst', 'leaper'}
```

Now enter

```
>>> sheep
```

and

```
>>> purple_things
```

and you will see that Python has remembered the sets.

To calculate the intersection, you use the & symbol. Enter

```
>>> sheep & purple_things
```

and you will see the expected set

```
{'rusty', 'leaper'}
```

For the union, you use the **!Warning! Consolas not supported** | symbol. Enter

```
>>> sheep | purple_things
```

and you will see the expected result

{'agnes', 'wilhemina', 'rusty', 'billy', 'leaper', 'aubergine', 'amethyst'}.

Activity 2 Do it yourself

Allow about 5 minutes

You are given the following sets:

$a = \{1, 2, 3, 5, 8, 13, 21\}$

$b = \{3, 6, 9, 12, 15, 18, 21\}$

First, work out their intersection and union in your head. Then enter the sets into the Python console above and check that `&` and `|` give the expected results.

Discussion

You should get these results.

```
>>> a = {1, 2, 3, 5, 8, 13, 21}
```

```
>>> b = {3, 6, 9, 12, 15, 18, 21}
```

```
>>> a & b
```

```
{3, 21}
```

```
>>> a | b
```

```
{1, 2, 3, 5, 6, 8, 9, 12, 13, 15, 18, 21}
```

The next section explains how to find the size of a set.

3 The size of a set

Every set has a **size**: how many members it contains. If a set has been stored in Python, you can find its size using `len`. For example, here is a set of numbers:

```
nums = {6, 3, 5, 1, 7, 9, 11, 4}
```

If you enter this into the Python shell below and then execute

```
>>> len(nums)
```

you should get 8.

Interactive content is not available in this format.

Euler diagrams are useful for reasoning about the size of sets. For example, consider the set of 52 playing cards in a standard pack (also called a deck). Figure 11 shows two smaller sets – picture cards and hearts – are contained in the overall set of size 52.

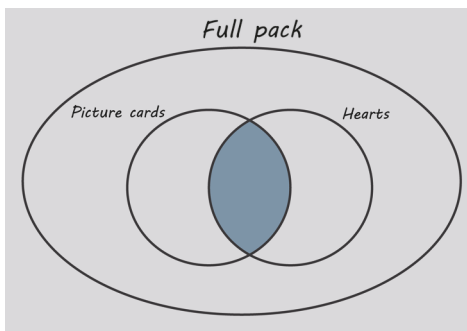


Figure 13 Picture cards and Hearts are sets contained within overall pack

Picture cards are jacks, queens and kings, and there are 12 of these altogether, 3 per suit. There are 13 cards in each suit.

The shaded intersection in Figure 14 represents the picture cards that are also hearts. There are 3 of these.

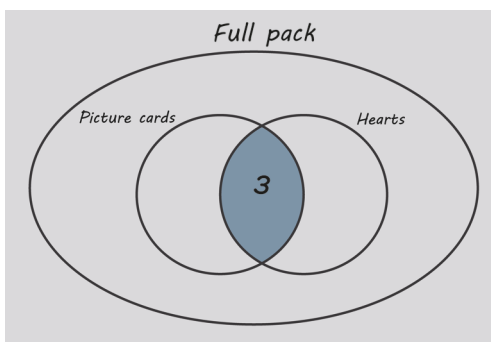


Figure 14 Picture cards and Hearts are sets contained within overall pack. There are 3.

You can continue to explore this in the next activity.

Activity 3 Figure it out

Allow about 5 minutes

The shaded areas in the diagrams below represent, respectively:

- picture cards that are not hearts
- hearts that are not picture cards
- cards that are neither hearts nor picture cards.

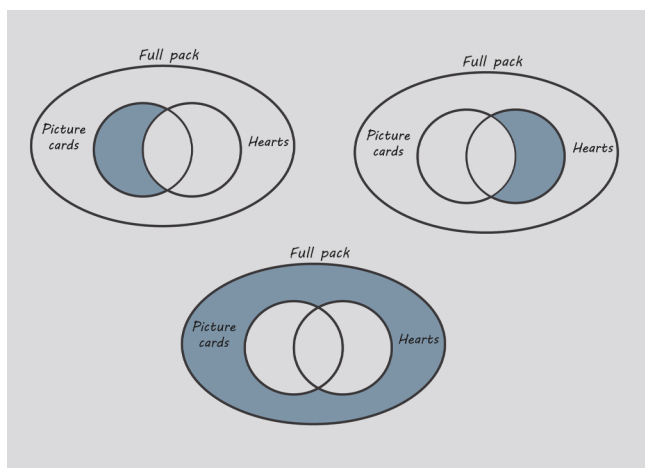


Figure 15 Solution to activity

Using a pen and paper, copy the original Euler diagram and fill in the numbers for each of these regions.

Discussion

Your Euler diagram with the numbers should look like this.

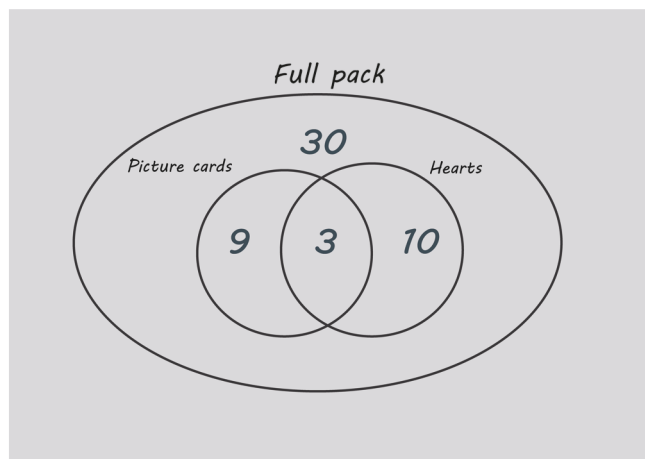


Figure 16 The intersection of Picture cards and Hearts contains 3 cards.

3.1 Taking a chance

Calculating the sizes of sets lets you reason about chances. For example, if a card is picked at random from the pack (that is, any card is as likely to be picked as any other), what are the chances that it will be a picture card that is not a heart?

There are 9 picture cards that are not hearts, and 52 cards altogether. Therefore, the chances are $9/52$.

For comparing different probabilities with one another, it is very useful to express them as percentages. Here is how to express $9/52$ as a percentage using the Python shell.

First, work out $9/52$.

Then multiply it by 100, to make it into a percentage.

Finally, round it. One decimal place seems sensible.

```
>>> 9/52
0.17307692307692307
>>> _*100
17.307692307692307
>>> round(_, 1)
17.3
```

So, the chances are 17.3%.

Now try this for yourself in the next activity.

Activity 4 Quick on the draw

Allow about 10 minutes

A playing card is drawn at random from a full pack. Use the Python console to work out the chances that it will be:

- A heart, but not a picture card.
- Neither a heart nor a picture card.
- Not a picture card.

Interactive content is not available in this format.

Discussion

A heart, but not a picture card: $(13 - 3)/52 = 10/52 = 19.2\%$.

Neither a heart nor a picture card: $(52 - 22)/52 = 30/52 = 57.7\%$.

Not a picture card: $(52 - 12)/52 = 40/52 = 76.9\%$.

3.2 Back to Linda

Thinking with Euler diagrams also helps to clarify why it has to be more likely that Linda is a bank teller than a bank teller *and* active in the women's movement (Figure 15).

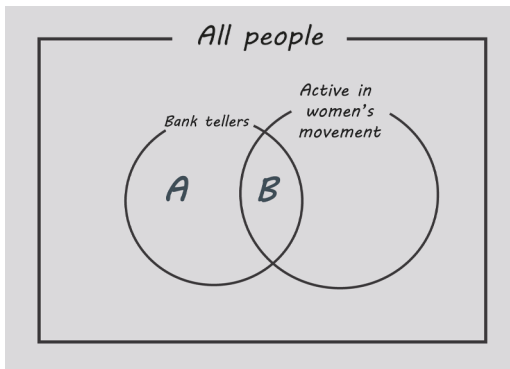


Figure 17 Sets in the Linda problem.

Here the outermost set is shown as a rectangle, which is the conventional way to show the set that represents 'everything' for the purposes of a problem under discussion.

Suppose the number of bank tellers not active in the women's movement is A and the number of bank tellers who *are* active is B . Altogether there are $(A+B)$ bank tellers.

Suppose that after counting all the people the result is 1,000,000. (Of course, this is not intended as any kind of real estimate. It is just an illustrative number, and any other would have done as well.)

Then the chance of Linda being a bank teller is $(A+B)/1,000,000$.

The chance of her being a bank teller *and* active in the women's movement is $B/1,000,000$.

Because B is less than $(A+B)$, the second probability is certain to be smaller.

Another bias in our thinking can come from our tendency to believe that small samples provide reliable information about the population as a whole.

4 The law of small numbers

This concept is again from the book by Kahneman (2001, p. 109). It can be illustrated by the following example.

Suppose there is a medical syndrome X, which is relatively rare and affects 1 person in every 1000 on average (that is, the rate is 0.1%). In the imaginary country of Ruritania, scientists have done a survey to see if the rate of this condition varies from one part of the country to another.

The map in Figure 18 shows the regions of Ruritania. For each region, the map gives the population of the region, and the percentage of the population with the condition X.

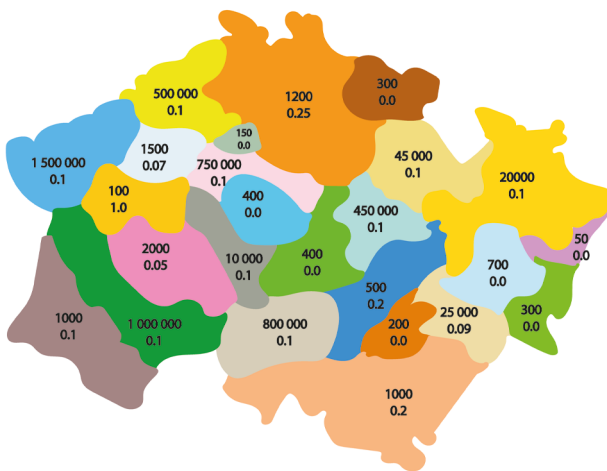


Figure 18 The regions of Ruritania

In some regions, the rate of condition X is unusually low, bearing in mind the average rate of 0.1%. These regions are shaded in Figure 17.

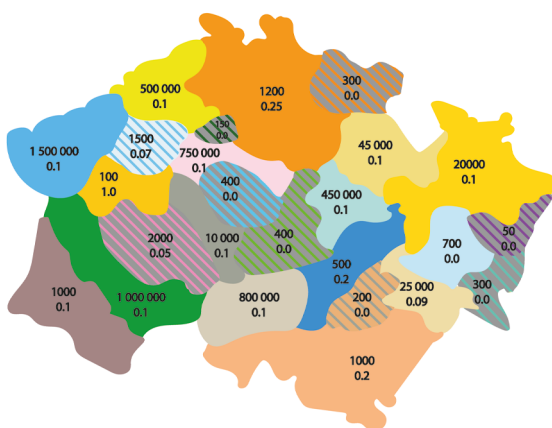


Figure 19 Regions with an unusually low incidence are shaded.

Looking more closely, you will see a clear pattern. All of the relatively X-free regions have small populations.

- What is the connection?

- Do people in the low-population regions live in smaller communities, leading to more personalised medical care and a reduced risk of the condition?
- Could the condition be caused by the stress of urban living, which is reduced in smaller communities where people lead more relaxed lives?

At this point you might try to confirm your theories, by looking at the regions where the rate of X is abnormally high. These are shaded in Figure 20.

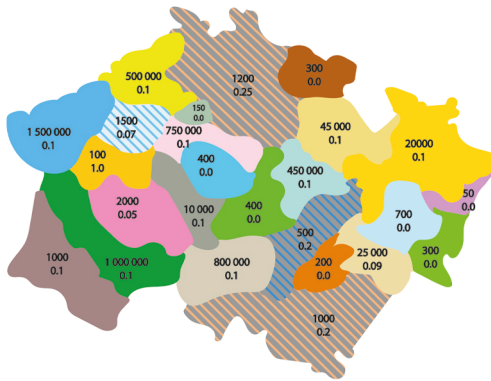


Figure 20 Regions with an unusually high incidence are shaded.

But these regions are *also* ones with low populations! What is going on? How does a low population lead to both a lower *and* a higher rate of the condition?

The answer is, it doesn't! The numbers have been generated by a computer simulation. In every region the average rate used for the simulation was exactly the same, 0.1%. However, in small populations random fluctuations are bound to make a much bigger difference to the rate. Imagine a region has only 100 people in it. If a single person had the condition X, the rate would be a massive 1%, which is 10 times the average. If no one has the condition, the rate will plummet to 0%.

So, the smaller regions are certain to include many with below average rates, and many with above average rates, and there is no cause and effect involved.

You might feel that this is an artificial example but it is not. Studies in the USA found that small schools were more common than might be expected among schools with high average test results. As a result, many charities provided small schools with financial support, for example US\$1.7 billion from the Bill & Melinda Gates Foundation.

However, in an analysis of the scores of Pennsylvania schools, Howard Wainer and Harris Zwerling **Warning! Calibri not supported** (2006) showed that schools with the *worst* average scores were even more likely to be among the smaller ones. So the apparent superiority of small schools is almost surely an illusion. In the same way, our simulation of syndrome X made it seem at first that people in small regions were less inclined to have the condition.

Activity 5 Try it yourself

Allow about 20 minutes.

You can do similar simulations for yourself in the Python shell.

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You need to start by loading a part of the Python system that is only available on request. You do that by entering

```
>>> from random import sample
```

Next, you need to say what options the samples will be taken from, and what frequency each option should occur with.

```
>>> choices = ['no']*999 + ['yes']
```

This says you want to choose from a list having 999 occurrences of **!Warning! Consolas not supported**'no' **!Warning! Consolas not supported** and 1 occurrence of **!Warning! Consolas not supported**'yes'. On *average*, **!Warning! Consolas not supported**'yes' will get picked 1 time in 1000, but it is a random process, so **!Warning! Consolas not supported**'yes' might get picked more or less often than that.

Now you are ready to take a random sample. The following expression will sample one item from the `choices` list 100 times in a row.

```
>>> samples = [sample(choices,1) for s in range(100)]
```

This will give a list containing 100 samples each containing one item but one sample containing 100 items is what is actually needed. We can get that as follows

```
>>> results = [item for s in samples for item in s]
```

If you now enter `results` you will get something like this

```
>>> results
['no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no', 'no',
'no', 'no']
```

This is what you would expect, given the frequencies you have assigned to each option: 999 for 'no' versus 1 for 'yes'. The actual rate at which 'yes' should appear is 1 in 1000, which is 0.1%.

But if you repeat the experiment a few times, a **!Warning! Consolas not supported**'yes' pops up now and again. This is like the example you saw earlier in which there was

only a 0.1% chance of having the imaginary syndrome X, but among 100 people, cases occurred occasionally.

You can get Python to count how many times 'yes' came up, as follows

```
>>> results.count('yes')
```

Usually this will be 0, which corresponds to no one having syndrome X, which is a rate of 0%. But if you keep repeating the steps of the simulation

```
>>> samples = [sample(choices,1) for s in range(100)]
```

```
>>> results = [item for s in samples for item in s]
```

```
>>> results.count('yes')
```

then from time to time you will get 1, which corresponds to a rate of 1%, 10 times the average. So in these small samples of 100 rates are either 0%, or else 10 (or more) times the average rate, purely from random effects, exactly as discussed earlier.

If you now try a sample of a million, things will be very different. Try executing the following steps (warning: do *not* try to look at the actual content of `results`; displaying a million items is too much for the console!)

```
>>> samples = [sample(choices,1) for s in range(1000000)]
```

```
>>> results = [item for s in samples for item in s]
```

```
>>> results.count('yes')
```

Running the calculations will take a few seconds. If you see a message saying a web page is slowing your browser down, simply ignore it.

To get the rate, divide the output from the count by 1000000.

```
>>> _/1000000
```

```
0.000969
```

(This is the result we got; yours will be slightly different, of course.)

0.000969 is about 1 in a thousand, close to the known average. While the rate fluctuates a lot for a small number of samples (100), with a large number of samples (1000000), the rate is much more predictable.

The next section looks at how the conclusion people draw from a positive test result can often be wrong.

5 Testing, testing

Suppose that one person in every thousand is known to have a fatal infection. (This is called the **base rate**.) Scientists have developed a test for the disease and experiments have shown that the test is 99% accurate.

By 99% accurate we mean that, on average, 99 out of every 100 people who test positive will have the disease, and 99 out of every 100 who test negative will not have the disease.

As part of a routine health check, you are found to test positive.

Activity 6 Take a guess

Allow 1 minute.

Given the information above, you want to know what the chances are that you have the disease. Which of the following is the best answer?

- A. 99%
- B. 90%
- C. About 9%
- D. 1 %

Discussion

The correct answer is C, about 9%. There is a greater than 90% chance that you don't have the disease!

Most people overestimate the chances, because it is natural to focus on the fact that the test is 99% accurate. In a study reported in 2008 (Gigerenzer *et al.*), the majority of a group of 160 doctors who were asked a similar question gave the wrong answer.

To see why the answer to Activity 6 is 9%, it helps to do a thought experiment with a concrete number of people. A good choice is 100000, because everything works in whole numbers.

Figure 19 shows a whole population of 100000 split into two groups: those who have the disease (D) and those who do not (ND). Because 1 per thousand has the disease, on average 100 have the disease and the other 99 900 don't.

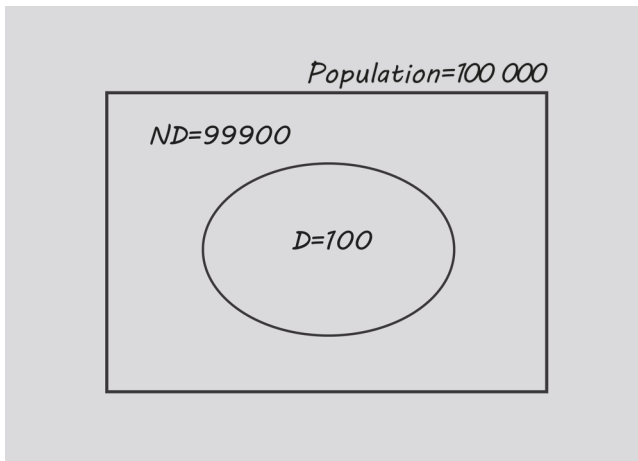


Figure 21 Population split into D and ND

First, consider set D. The accuracy is 99%, meaning that 99 of the 100 with the disease will test positive (D+) and 1 will test negative (D-), as shown in Figure 20.

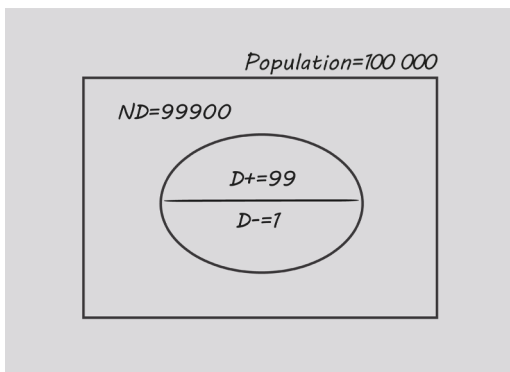


Figure 22 D is split into D+ and D-

Next, consider set ND.

Because the accuracy is 99%, that means 99% of the 99900 who don't have the disease will test negative. This comes to 98901 people. The remaining 1% of ND (999 people) will test positive. These numbers are shown in Figure 21.

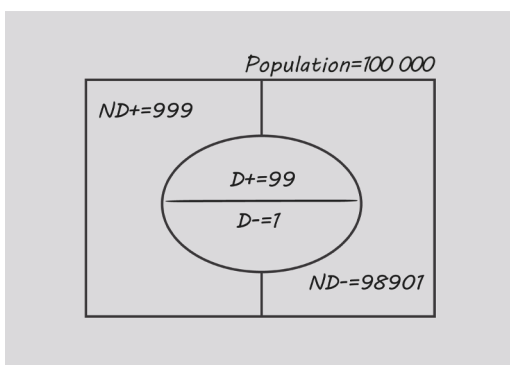


Figure 23 ND is split into ND+ and ND-

You tested positive, so focus on the positives (Figure 22).

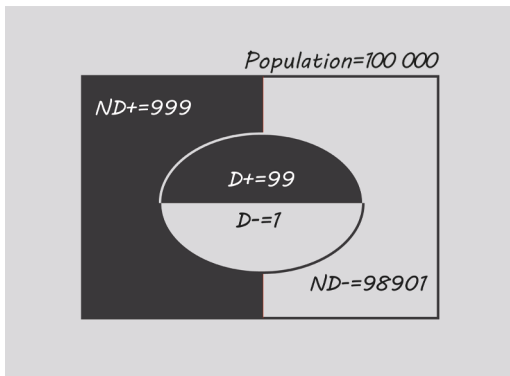


Figure 24 Of 999 + 99 positives, only 99 have the disease

There are $999 + 99 = 1098$ testing positive altogether, but only 99 of these actually have the disease. So the probability that someone testing positive is actually infected is $99/1098 = 9.0\%$ to one decimal place.

The probability that they are *not* infected is thus $100\% - 9\% = 91\%$. Your chances are good!

Hopefully this explanation has convinced you of the correct answer and, if you were given a different base rate (or a different test accuracy), you could follow a parallel set of calculations and find the new probability of a person testing positive being infected.

However, it's possible to capture the details of the calculation in a single formula. This doesn't involve the size of the population, which was just a number chosen for convenience. If a different one, 1 000 000 say, had been used instead, the final answer would have ended up the same.

Using *brt* for the base rate of the disease, and *acc* for the accuracy, expressed as decimal fractions, e.g. 0.001 and 0.99, the formula for the probability, when written in Python is $\text{brt} * \text{acc} / (\text{brt} * \text{acc} + (1 - \text{brt}) * (1 - \text{acc}))$

In this formula

!Warning! Consolas not supported $\text{brt} * \text{acc}$ represents $D+$, the proportion of the population who have the disease and test positive

$(1 - \text{brt}) * (1 - \text{acc})$ represents $ND+$, the proportion of the population who *do not* have the disease and test positive, and therefore

$(\text{brt} * \text{acc} + (1 - \text{brt}) * (1 - \text{acc}))$

represents the total proportion testing positive, and the division is working out

That is, the chances that a person who tests positive is actually infected.

You can try this for yourself in the next activity.

Activity 7 Playing in the sandpit

Allow 5 minutes

The following shows how the example you saw worked out with sets could be done in the Python shell, using the formula.

```
>>> brt = 0.001
>>> acc = 0.99
>>> brt*acc / (brt*acc + (1 - brt)*(1 - acc))
0.09016393442622944
```

You do not need to type in the expression

```
brt*acc / (brt*acc + (1 - brt)*(1 - acc))
```

You can copy it from here and paste it in at the prompt `>>>`.

Interactive content is not available in this format.

To get the result as a tidy percentage, use

```
>>> round(_*100, 1)
9.0
```

1. Try this in the Python shell now and check that you get the correct answer, 9.0.
2. Now repeat the calculation but begin by leaving the accuracy the same but setting the base rate to
 - 0.01 (i.e. 1 in 100)
 - 0.1 (i.e. 1 in 10)

Observe the effect on the probability of being infected.

Discussion

The probabilities are now 50.0% and 91.7%, respectively. As the base rate gets bigger, the probability becomes more like the figure intuitively expected.

The effect you have been exploring is often called the **false positive paradox**. It arises whenever the base rate is small compared with the rate of false positives, so the number of actual cases is swamped by the number of false positives. However, people don't tend to take the base rate into account. The figure that stands out is the accuracy of 99%.

Consequently, when the base rate is low, as is usually the case, people grossly overestimate the likelihood that a positive test result is conclusive.

6 This session's quiz

Check what you've learned this Session by taking the end-of-session quiz.

[Session 5 practice quiz](#)

Open the quiz in a new tab or window then come back here when you've finished.

7 Summary of Session 5

In this session you learned how Euler diagrams are used as a tool for reasoning, and you saw them applied to logic problems and to representing sets of things. You also learned:

- about the two important operations that can be applied to sets – union and intersection.
- how to define sets in Python, and how to use Python to find the intersection and union of sets.
- how Euler diagrams can be used to reason about the numbers of objects in sets, and how this can help assess the probability of something happening. This led on to the law of small numbers, whereby random fluctuations produce bigger variation among small populations than among large ones.
- about the false positive paradox. You saw an example worked out first using Euler diagrams, and then by calculations in Python.

Session 6 returns to the theme of argument maps and explores some of the benefits of argument mapping. You will be introduced to FreeMind, a digital thinking tool which is useful for constructing argument maps. You will also learn a recipe for creating argument maps from arguments expressed in text.

You can now go to [Session 6](#).

Session 6: Digital argument mapping

Introduction

In Session 4, you learned about argument maps. An argument map, such as Figure 1, allows you to expose the structure of an argument: the patterns that are implicit in that argument. Claims are depicted as boxes with text, and these boxes are connected by lines that represent support and oppose relations.

When preparing to write a reasoned argument, an argument map can help you to organise your thoughts.

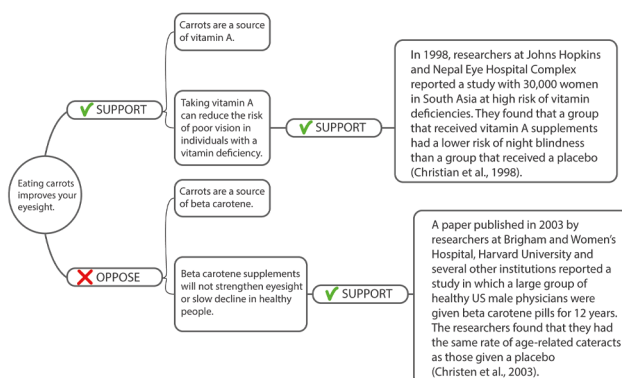


Figure 1 An argument map about the claim that 'Eating carrots improves your eyesight'

The map at the centre of Session 4, shown in Figure 1, was created with FreeMind, a digital tool. This session introduces FreeMind. You will learn how to use it to map arguments that *other people* have put forward.

Mapping not only helps you organise your own thoughts, it can also help you with understanding arguments put forward by other people. This may, in turn, allow you to better appreciate both the strengths and the weaknesses of their arguments.

By the end of this Session, you will be able to:

- create an argument map using a digital tool
- explain how digital argument mapping extends our natural capabilities
- distinguish between grouped and independent claims.

1 Why map other people's arguments?

This session you are going to explore the use of the FreeMind tool. You will learn how to map an argument that was put forward by someone else. The argument may be in the form of a piece of text, or perhaps as part of an answer to a question in an interview. Before diving into digital argument mapping, it's important to briefly explore why it is useful at all to learn to map other people's arguments (in addition to our own).

To appreciate the benefits of mapping other people's arguments, we will compare your ability to understand stories with your ability to digest an argumentative text.

People learn to understand stories and answer questions about them at an early age. As adults, most people are skilled at reading a story and processing the information in that story. We can answer questions about when things happened according to the story and why. According to Schema theory (e.g. Mandler, 1984), when reading stories, we make sense of the connections between individual events in the story by recognising underlying patterns in the story. These include succession in time (when things happen), cause and effect (why things happen), and so on.

We don't seem to have the same ability to recognise the underlying patterns in argumentative texts. There is little explicit or implicit training at an early age that helps us to effortlessly see the patterns that are implicit in an argumentative text. However, Harrell (2011) proposes that argument mapping can help us develop this ability.

And it seems to work. There are several studies that report that argument mapping can help students improve their critical thinking skills. Both van Gelder *et al.* (2004) and Twardy (2004) found that teaching argument mapping can help students do significantly better on standardised tests for critical thinking. Also, a study that compared the traditional teaching of critical thinking with the use of argument mapping found that students who learned argument mapping did significantly better than their counterparts. In particular, they were better at tasks such as spotting the premises and conclusion in an argument and explaining and evaluating the connections between them (Harrell, 2007).

2 Going digital

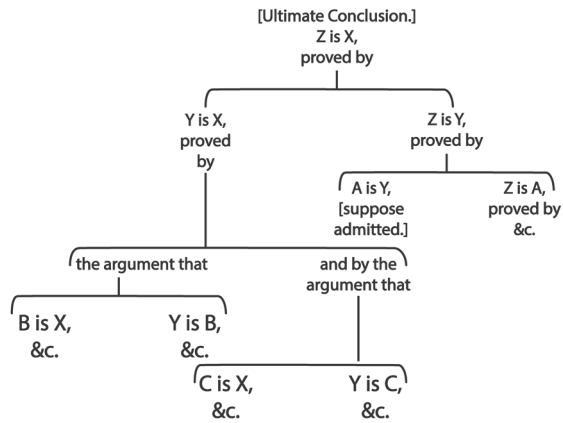


Figure 2 An argument map from the logic textbook *Elements of Logic* (on page 467 of the 1852 edition) by Richard Whately, professor of political economy at Oxford and Anglican archbishop of Dublin

Argument mapping goes back at least as far as the mid-19th century (see Figure 2). At that time electronic digital computers hadn't been invented. As soon as the first electronic computers were built, it was only a matter of time before argument mapping went digital.



Figure 3 Vannevar Bush with an electromechanical device for helping solve complex differential equations

As early as 1945, Vannevar Bush (the electrical engineer and director of the US Office of Scientific Research and Development during the Second World War; Figure 3), mused that:

Then, on beyond the strict logic of the mathematician, lies the application of logic in everyday affairs. We may some day click off arguments on a machine with the same assurance that we now enter sales on a cash register.

(Bush, 1945, p. 5)

Today, there is a wide variety of digital tools for mapping arguments. Some of these tools have been designed specifically for argument mapping. Whereas some of these tools can also be used for other purposes.

Activity 1 Search activity

Allow about 10 minutes

Search online for argument-mapping tools with your favourite web browser. Make some notes on the differences between the available software. For instance, which operating system (Windows, MAC OS, or Linux) is required?

Discussion

Google search claims to have found no less than 19 million pages for the keywords *argument*, *mapping* and *tools*. In second place is the 'Argument map' Wikipedia page. This page includes a section with external links to argument-mapping software.

Some of the software is cross-platform (which means you can use it on Windows, Linux and Mac OS machines). Other software requires a particular platform (e.g. Windows), whereas other software is web-based. This means that you can run it in your web browser. That is great because you can run a web browser on almost any computer (including mobile devices). However, on the flipside, this does mean that you can only edit your maps when you are online.

You may have found it perfectly doable to create argument maps with pen and paper. So why go digital? In Session 1 you saw that digital-thinking tools can help extend our natural capabilities in several ways, as shown in Figure 4.

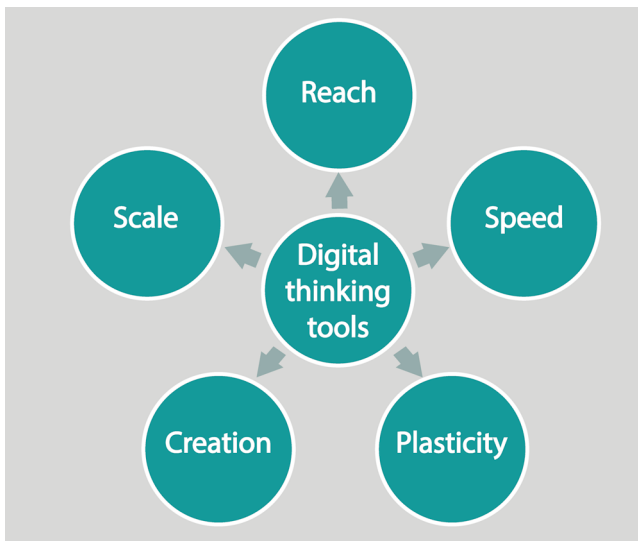


Figure 4 Five ways in which digital thinking tools can extend our natural capabilities

Activity 2 Extending our natural capabilities

Allow about 10 minutes

Consider each of the five dimensions in Figure 4 in which natural capabilities can be extended. For each dimension, write down how digital argument mapping may extend our natural capabilities.

Before you start, you may want to revisit the argument-mapping tools that you found in Activity 1 and read some of the descriptions of these tools.

Discussion

- **Creation** refers to the fact that digital tools allow us to create data in many formats. Most digital tools for argument mapping allow us to store the maps in a variety of formats, including structured text, images and web pages.
- **Plasticity** refers to the fact that information in digital form is easy to reform and reorganise. Digital argument mapping tools allow us to reorganise the relations and nodes in an argument map, copy and paste text into nodes, and so on. Any changes are made with little effort and can be undone with the click of a button.
- **Reach** refers to the fact that digital technology allows us to share data easily with potentially millions of other people. Once a map is digital, it is easy to send to the other side of the world with a single click. There are also tools that allow for

collaboration on maps with others. Two people can be working many thousands of miles apart and yet edit the same map.

- **Speed** refers to the rate at which information can be processed. Once a map or collection of maps has been created, you can, for example, search the maps for key words or claims. The result is available within milliseconds. In contrast, searching a pile of pen-and-paper maps could take hours, days or even months.
- **Scale** refers to the fact that digital tools let us gather, access, store and analyse gigantic amounts of data. This one is intimately connected to speed. Being able to search a bunch of maps at speed allows us to deal with many more maps than would be feasible if working with pen and paper maps.

3 Using FreeMind

In the remainder of this session, you will explore a specific tool for mapping arguments: FreeMind.



Figure 5 The FreeMind logo – an orange butterfly

As you have already seen, there are many tools that allow you to map arguments. FreeMind has been chosen to illustrate the key ideas behind using such digital tools. By all means, do feel free to explore other tools. To us, FreeMind seemed particularly suitable in the context of the current course for the following reasons:

- It is cross-platform: it is available for Windows, Linux and Mac OS computers.
- It is available at no cost.
- It has a large community of users and is open source. This means that volunteers continually develop it further.
- It was developed for a more generic purpose: mind mapping.

The last point requires some explanation. Although, as you will see, you can use FreeMind for argument mapping, it was originally developed for **mind mapping**, a technique for organising thoughts and ideas (rather than arguments). There is a list of

uses of FreeMind on the [FreeMind wiki page](#). The fact that you can use FreeMind for multiple purposes means that you are more likely to find the tool useful beyond this course.

3.1 Mind and argument maps

FreeMind was originally designed for the creation of mind maps. A mind map, just like an argument map, is a diagram that consists of nodes and connections between these nodes.

In argument maps (see Figure 6, which you will recognise from Session 4), there is a hierarchy of nodes: It starts at level 0 with a central, top or root node, which represents the main claim. This node is connected to nodes at level 1, which in turn are connected to nodes at level 2, and so on.

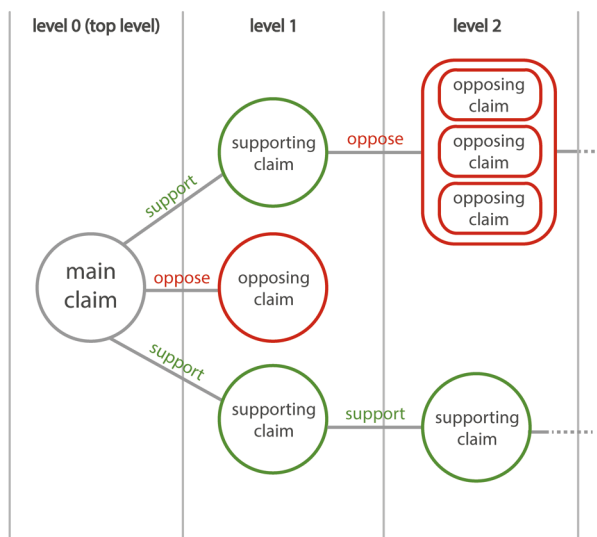


Figure 6 An argument map arranged in levels, with the main claim at the top (left-hand) level

Mind maps have the same hierarchy of levels. As a result, FreeMind can also be used for argument mapping.

Although mind and arguments maps have similar structures, there are differences in how these structures are used. In an argument map, the nodes represent claims and the connections represent support and oppose relations. In mind maps, nodes stand for concepts. A connection between two nodes communicates that the concepts are associated. For an example of a mind map, see Figure 7. This map shows the Google operators from Session 2.

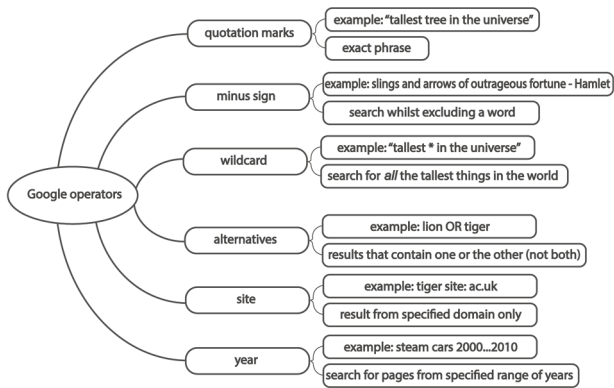


Figure 7 A FreeMind mind map for the Google search operators

Activity 3 Argument versus mind maps

Allow about 5 minutes

Complete the table by typing each item below into the correct cell below.

support and oppose relations, association, claims, and concepts

	Mind maps	Argument maps
Nodes	<i>Provide your answer...</i>	<i>Provide your answer...</i>
Relations	<i>Provide your answer...</i>	<i>Provide your answer...</i>

Answer

	Mind maps	Argument maps
Nodes	concepts	claims
Relations	association	support and oppose relations

Discussion

Mind maps and argument maps have a similar structure: both consist of nodes and relations. But whereas in a mind map the nodes are concepts, in an argument map the nodes are claims. And the relations in a mind map are associative, whereas in an argument map the relations are argumentative (either oppose or support).

3.2 Installing FreeMind

Before you can start creating your own FreeMind argument maps, you will need to install the FreeMind software.

Activity 4 Installing FreeMind

Allow about 10 minutes

On the official [FreeMind website](#) you will find a link to the download page. This page has installations for MS Windows, Mac OS X and Linux.

Select the appropriate download for the operating system on your computer and install FreeMind.

If you have problems in getting FreeMind to run, please see the [‘Asked questions’ page](#) on the FreeMind website.

3.3 FreeMind for argument mapping

In the next activity, you will learn how to use FreeMind. You will watch a video in which an argument map is created for the following short piece of text:

Technology has really brought changes to human life. The world has become a global village. We see things happening all over the world within just seconds of their occurrence. We speak to people far away from our areas.

This text is based on a contribution from Stanley (from Oloitokitok in Kenya) to a discussion on a global phone-in programme called *Have Your Say* (BBC, 2004; BBC World Service, 2007). The programme was originally broadcast on the BBC World Service.

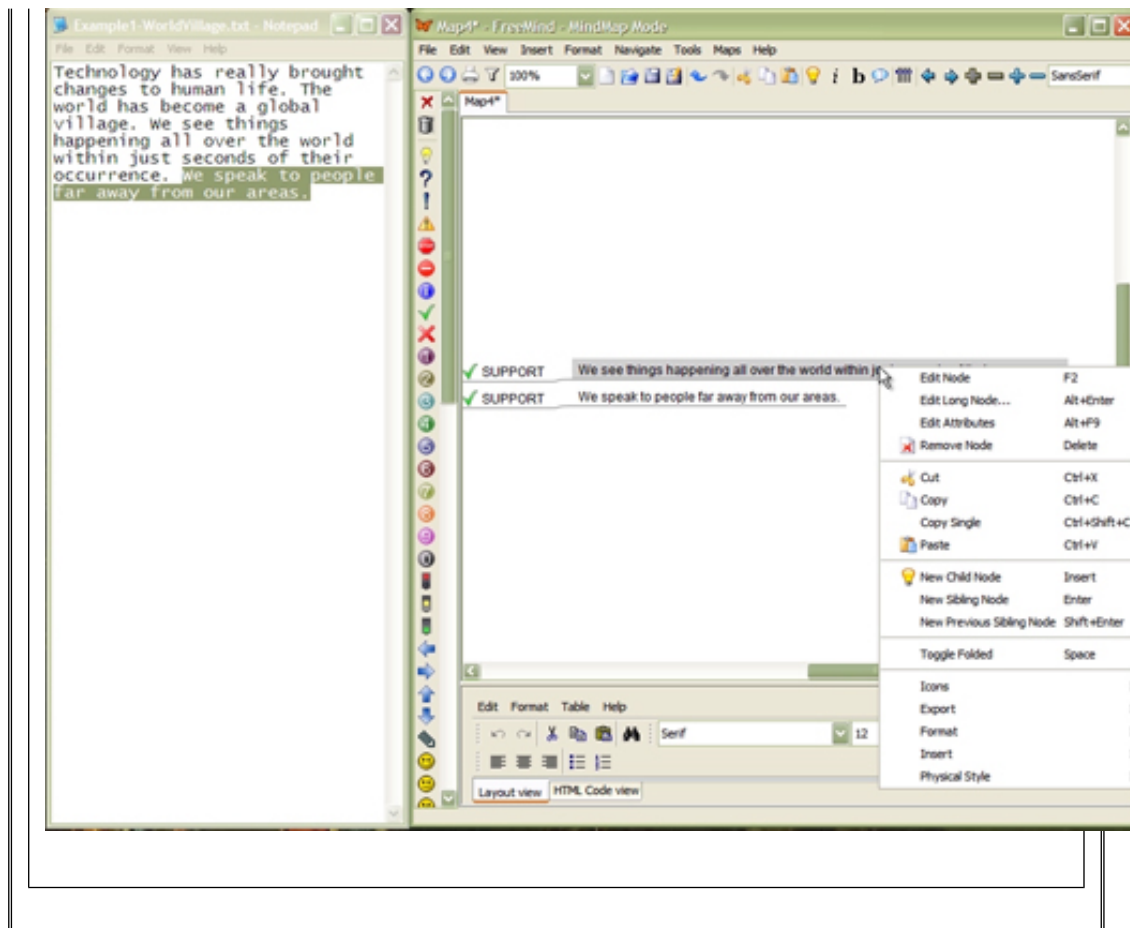
Activity 5 FreeMind argument-mapping video

Allow about 15 minutes

Watch the video which explains how to create an argument map with FreeMind.

Video content is not available in this format.

[Video 1](#)



Move onto the next activity where you will try FreeMind for argument maps.

Activity 6 Trying FreeMind for yourself

Allow about 10 minutes

Now that you have watched the video, try FreeMind for yourself. Without looking at the video, try to map Stanley's argument:

Technology has really brought changes to human life. The world has become a global village. We see things happening all over the world within just seconds of their occurrence. We speak to people far away from our areas.

When you have completed your map, compare it with the map that was created in the video in Activity 5.

Discussion

The final map from Activity 5 is shown in Figure 8.

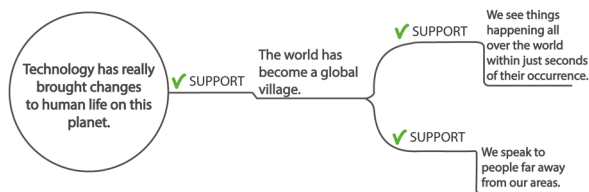


Figure 8 The argument map from Activity 5

Your map may differ in various minor ways from the one in Figure 8. There are many settings that influence the appearance of a map. For example, Figure 9 shows the same map, but now with the main claim in **bold**, bubbles around all the nodes and a green background for the supporting claims.

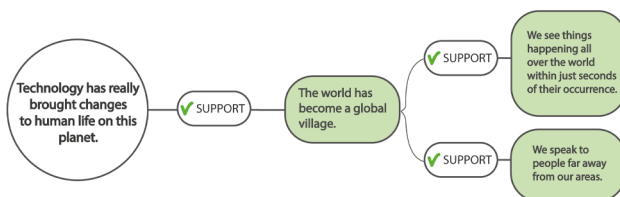


Figure 9 The argument map for Activity 5 with minor variations in how it is realised

You may also have discovered that there are various ways to introduce new nodes to your map. For instance, you can introduce a child node with the New Child Node option, but also by choosing New Sibling Node on another child node.

Using the New Sibling Node option means that all child nodes are placed to the right of their parent node. In contrast, using New Child Node causes additional nodes to be put towards the left and right of the parent node. This gives the map a different appearance.

For instance, the map in Figure 1, which was created using New Sibling Node for the nodes at level 1, looks different when New Child Node is used instead. Now, the level 1 nodes appear to both the left and right of the main claim, as shown in [Figure 10](#) (larger version of map).

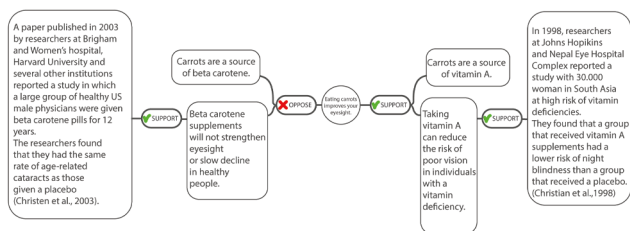


Figure 10 The map of Figure 1 but now with the level 1 nodes created using New Child Node, rather than New Sibling Node

4 Another recipe: from words to maps

In Session 4, a recipe for going from argument maps to words was introduced. Starting from the argument map with the claim that 'Eating carrots improves your eyesight', you constructed a short piece of text to express the argument. Now, you will go in the other direction: from words to maps.

The aim is to take a text and build an argument map that makes the argumentation in that text explicit. The recipe for this exploits the hierarchical structure of argument maps (as depicted in Figure 6 and repeated here as Figure 11). The recipe is applied to the text one step at a time. At each step, you add further levels to the argument map.

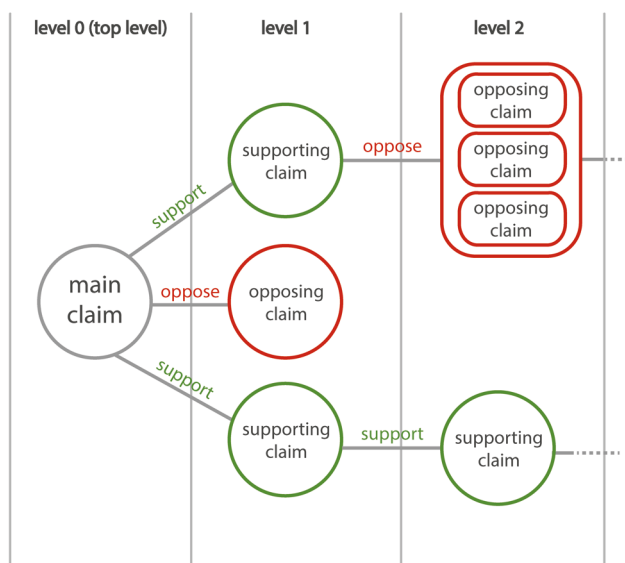


Figure 11 Argument map arranged in levels, with the main claim at the top (left-hand) level

4.1 The recipe: first and second step

The recipe starts at level 0 where you find the main claim.

First step: Identify the main claim. First, try to find the main claim. The main claim is the overall point or conclusion that the author of the text is making. The text presents information that directly or indirectly supports or opposes the main claim. The main claim can be explicit or implicit:

- If the main claim is explicit, one or more of the statements in the text put this claim forward.
- If it is implicit, you will need to infer the main claim that the author is trying to get across. Once you have inferred the implicit claim, state it in your own words.

Once you have identified the statement(s) that make the main claim, or you've stated the implicit main claim in your own words, you can start the argument map. Place the main claim in the top level oval, as shown in Figure 12.

The main claim goes here.

Figure 12 The main claim at level 0 (the top level)

Now, proceed to the next level. Since you started at level 0, the next level is level 1.

Second step: Find text supporting and/or opposing the claim(s) found at the previous level. Now, you need to find parts of the text that directly oppose or support the claim at the previous level. Read the text from the beginning to the end. For each statement, ask yourself the question ‘Does it support or oppose the claim at the previous level?’ Add these claims to your map and connect them, using the oppose or support relationship, to a claim at the previous level.

4.2 Identifying relationships in text

To determine whether a support or oppose relation holds between two or more statements, look out for connecting words or phrases. These are not always present. However, if they are, they can provide helpful clues. Table 1 lists a few examples of connecting words and phrases and the most likely relation that they communicate.

Table 1 Connecting words and phrases and the likely relationships they convey

Text	Connecting word/phrase	Likely relationship
A because B.	because	B supports A
A therefore B.	therefore	A supports B
A for example, B.	for example	B supports A
A. First, B. Second, C. Finally, D.	first, second, finally	B, C and D support A
A but nevertheless B.	but nevertheless	A opposes B
A. However B.	however	B opposes A

4.3 Grouped versus independent claims

If you find several statements that support (or oppose) the claim at the previous level, you will need to decide whether these claims provide support independently of each other, or only when taken together as a group. You will then need to update your argument map accordingly. For instance, Figure 13 shows a map with a group of opposing claims and another group of supporting claims.

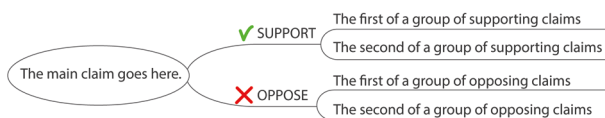


Figure 13 A map with a group of supporting claims and another group of opposing claims

Now look at a concrete example. Consider the claim that Socrates had a beard. You could support this claim using the following two further claims:

- Socrates was an adult Greek male in 4th-century Athens.
- In 4th-century Athens, shaving was uncommon and most adult Greek males wore a beard.

These claims need to be grouped, as in Figure 14.



Figure 14 Two grouped claims supporting that Socrates had a beard

The two claims support the main claim that Socrates had a beard, only when taken together as a group. If either of the supporting claims turns out to be false, the main claim is no longer supported.

For instance, suppose it is true that in *4th-century Athens, shaving was uncommon and most adult Greek males wore a beard*. Also assume that it is false that *Socrates was an adult Greek male in 4th-century Athens*. In that case, the claim that *Socrates had a beard*

is no longer supported. For this claim to be supported, *both* supporting claims need to be true.

In contrast, independent claims stand on their own. Their force is not dependent on other claims. Figure 15 shows several independent opposing and supporting claims for a main claim.

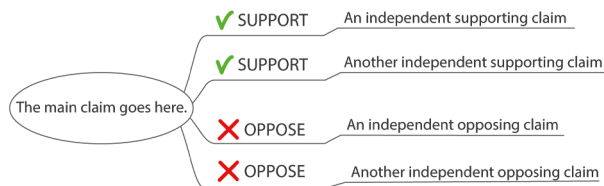


Figure 15 A map with independent opposing and supporting claims at level 1

Returning to Socrates, further evidence that he had facial hair could be that busts of Socrates show him with a beard (Figure 16). Unlike the two grouped claims, this supporting claim stands on its own.

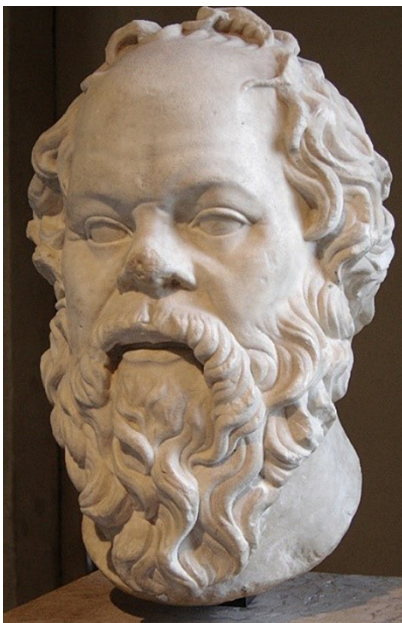


Figure 16 A bust of Socrates (c. 470–399 BC)

You can add this further supporting claim to obtain the argument map in Figure 17.

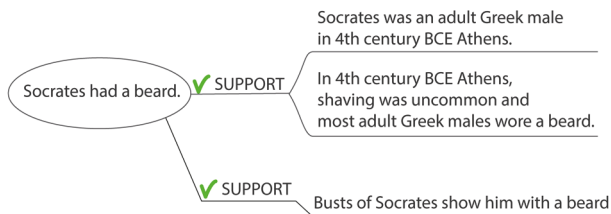


Figure 17 Two grouped and one independent claim supporting the claim that Socrates had a beard

You have ended up with map containing a mixture of an independent and two grouped claims, all of which support the main claim that *Socrates had a beard*.

4.4 The recipe's third step

Coming back to the recipe, you are now going to look at the third step.

Repeat: Proceed with the next level. Now, repeat the procedure in the second step for the next level by searching for statements that oppose or support the statements you identified at the previous level. Keep adding further levels until you hit a level at which you can no longer find supporting or opposing claims for the previous level.

This completes the recipe's three steps:

1. Identify the main claim
2. Find supporting and opposing claims (for the claims at the previous level)
3. Repeat step (2) until all claims in the text have been covered.

You will be putting the recipe for going from words to maps into practice in the next session. For your convenience, the entire recipe has been included at the beginning of Session 7.

5 This session's quiz

Check what you've learned this session by taking the end-of-session quiz.

[Session 6 practice quiz](#)

Open the quiz in a new tab or window then come back here when you've finished.

6 Summary of Session 6

In this session you learned about:

- some of the benefits of argument mapping in general and digital argument mapping in particular.
- FreeMind, a digital-thinking tool that can be used for argument and mind mapping
- a recipe for going from words to argument maps and how connecting words and phrases ('because', 'however', etc.) can signal which relationship holds between two claims.
- the difference between independent and grouped claims.

In Session 7 you will apply the recipe for going from words to maps to several examples.

You can now go to [Session 7](#).

Session 7: Argument mapping in action

Introduction

This session, you will put the argument-mapping recipe from Session 6 into practice. You will also examine several arguments around digital technologies, such as the internet, social media platforms and encryption.

The session concludes with a discussion of tools for sharing maps and the role of implicit assumptions in argument mapping.

By the end of this session, you will be able to:

- create an argument map that captures the content of a short text that makes an argument
- contribute to a shared argument map
- explain the role of assumptions in argument mapping.

1 Recap of the argument-mapping recipe in action

Before applying the recipe for argument mapping, for your convenience, it is repeated here in its entirety.

Recipe: from words to maps

How to create an argument map based on the argument in a short piece of text

First step: Identify the main claim. First, try to find the main claim. The main claim is the overall point or conclusion that the author of the text is making. The text presents information that directly or indirectly supports or opposes the main claim. The main claim can be explicit or implicit:

- If the main claim is explicit, one or more of the statements in the text put this claim forward.
- If it is implicit, you will need to infer the main claim that the author is trying to get across. Once you have inferred the implicit claim, state it in your own words.

Once you have identified the statement(s) that make the main claim, or you've stated the implicit main claim in your own words, you can start the argument map. Place the main claim in the top-level oval, as shown in Figure 1.



Figure 1 The main claim at level 0 (the top level)

Second step: Find text supporting and/or opposing the claim(s) found at the previous level. Now, you need to find parts of the text that directly oppose or support the claim at the previous level. Read the text from the beginning to the end. For each statement, ask yourself the question 'Does it support or oppose the claim at the previous level?' Add these claims to your map and connect them, using the oppose or support relationship, to a claim at the previous level.

Repeat: Proceed with the next level. Now, repeat the procedure in the second step for the next level by searching for statements that oppose or support the statements you identified at the previous level. Keep adding further levels until you hit a level at which you can no longer find supporting or opposing claims for the previous level.

The final 'repeat' step of the recipe asks you to continue until no more opposing or supporting claims can be found in the text. Sometimes, a text will include statements that are not part of the argument that is put forward. For instance, some statements may summarise, describe or explain something. Such statements should not be included in your argument map, if they are not meant to oppose or support a claim. As result, not all of the information in a text will necessarily be included in your argument map.

In the next three sections, you will make argument maps for short arguments. You will build your maps step-by-step. At each point, you will be able to check your work against the solutions that are provided. But do try each step yourself first, before looking at the solution! Think of each of these mapping activities as a puzzle. Hopefully, after some practice, you will get the hang of it and enjoy the challenge of dissecting an argument.

Don't worry if your maps don't always exactly match the ones provided. Sometimes, there are different, equally valid, ways of mapping the same text. That is fine as long as you can defend the reasoning behind your own map. And of course, ideally, you should also be able to understand the reasoning behind our maps, once you see them.

2 Keen on the internet

You start by looking at a short argument by Andrew Keen, an author and former internet entrepreneur. Keen was one of the first to argue that the internet is not necessarily a force for good. Here he is with a characteristically combative contribution to the blog of the OU/ BBC Virtual Revolution series:

In China, Russia and Iran, the Internet has become a disturbingly effective set of technological tools for maintaining the power of the old elites. In Russia, for example, Putin's cronies just financed an online witch hunt against a single Georgian activist which was so effective that it brought down not only Twitter, but also Facebook. In Iran, the increasingly powerful regime now sponsors religious workshops in the holy city of Qom which offer courses for seminarians in how to blog about the Iranian revolution. In China, the regime pays 'distributed citizens' to 'engage in conversation' with dissidents on the Internet. Crowd-sourcing, hacking, blogging then, are all turned on their heads. Now they are chillingly effective tools to destroy political democracy, intellectual dissent and individual freedom.

(Keen, 2009)



Figure 2 Andrew Keen

The aim of the first activity is to analyse Keen's sceptical evaluation of the internet by constructing an argument map for it. You will be provided with guidance throughout the analysis. The guidance is based on the three steps of the recipe in Section 1.

Activity 1 In China, Russia and Iran ...

Allow about 15 minutes

According to the first step of the recipe, you should start by identifying the main claim. If you are looking at a paragraph of text, you can often find it at the beginning or the end (and sometimes in the heading or subheading).

A good indication that you have found the main claim is that the claim you have identified does not support any other claims in the paragraph. If a claim supports another claim, it can't itself be the main claim. Usually, but not always, there will also be clues such as the use of connecting words and phrases including 'therefore', 'in conclusion' and 'consequently'. The claim can consist of one or more sentences.

Now try to identify the sentences in Keen's argument that express its main claim.

Discussion

The main claim is 'Crowd-sourcing, hacking, blogging then, are all turned on their heads. Now they are chillingly effective tools to destroy political democracy, intellectual dissent and individual freedom.' Note the use of the word 'then' to signal that a conclusion is being drawn and how the second sentence explains what is meant by the first sentence. Place this main claim on your argument map (Figure 3).

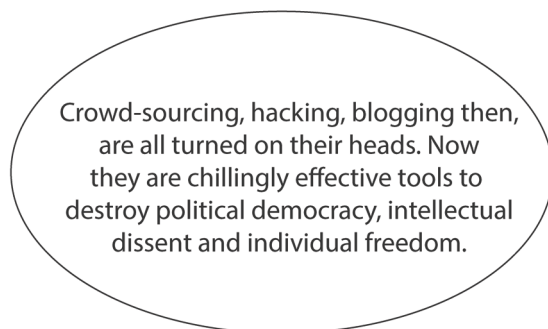


Figure 3 Main claim of argument map

Next, apply the repeat step of the recipe by proceeding to the next level. Identify any further claims and add them to the argument map using the appropriate relationship.

Now apply the second step of the recipe. Having identified the main claim, locate a statement which directly supports (or opposes) this main claim.

Discussion

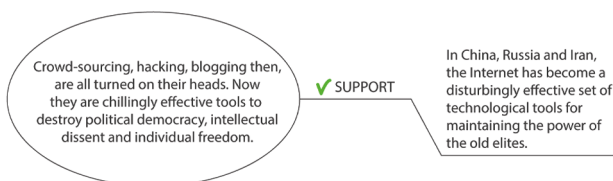


Figure 4 Argument map for levels 0 and 1 of Keen's argument

You can now update your map accordingly (Figure 4).

The statement in question is 'In China, Russia and Iran, the Internet has become a disturbingly effective set of technological tools for maintaining the power of the old elites.' This statement is more specific than the main claim. For that reason, this statement itself is not the main claim. The main claim makes a general claim about 'Crowd-sourcing, hacking, blogging', whereas this claim focuses on China, Russia and Iran.

There are three statements starting with 'In Russia', 'In Iran' and 'In China'. When taken together, do they support the claim at the previous level?

Discussion

For these three statements you need to decide whether they form a group or are independent of each other. In this case, they are grouped. Individually, they do not support the claim at the previous level that 'In China, Russia and Iran, the Internet has become a disturbingly effective set of technological tools for maintaining the power of the old elites.'

To signal that these three statements support the previous statement as a group, on the argument map, connect them to the previous statement with a single line labelled 'support' (Figure 4).

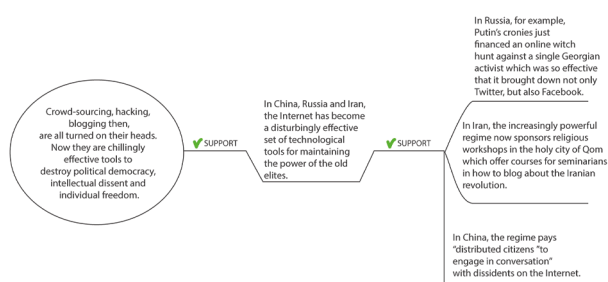


Figure 5 Argument map for levels 0, 1 and 2 of Keen's argument

This concludes your construction of the argument map for Keen's argument. Even though it dates from 2009, it still feels highly contemporary in 2019 (when this course was written). Discussion about the negative impact of social media on both democratic and authoritarian societies is still very much in the public eye.

3 The open exchange of information

Keen's view is very pessimistic. Others have argued for the benefits of social media and, especially, the free flow of information that is made possible by social networks such as Twitter. For example, Biz Stone, co-founder of Twitter, has expressed the argument for the free flow of information very succinctly.



Figure 6 The twitter logo, a silhouette of a bird symbolising the free exchange of information through tweets (that is short 280-character messages) on the Twitter network

Listen to Biz Stone make his argument in the following video.

Video content is not available in this format.

Video 1



Here is the text of Stone's argument:

[...] I realised that that became then something we were working towards which was this idea that the open exchange of information can have a positive global impact, the idea that when we say 'positive global impact' we can break that down and you can say if people are more informed then they become more

engaged, and if they are more engaged then they can become more empathetic. They are able to understand something that is happening halfway around the world in a uniquely different way; they are able to walk in that person's shoes. And when we are more empathetic, we realise we are global citizens and we have a sense of the world and what our place is in it and we want to essentially do good.

Although Stone's argument is succinct, it does hide a sophisticated structure. To map that structure, we can use an idea from Session 6 first. There you saw that connecting words and phrases (such as because, despite, and, but, so, due to, etc.) can give you important clues about how claims are connected. Before you attempt to map Stone's argument, it is helpful to first identify those connecting words and phrases.

Activity 2 Spotting the connecting words and phrases

Allow about 5 minutes

Identify the connecting words and phrases in Stone's argument. Copy the text of the argument to your favourite text editor or word processor and highlight the connecting words and phrases in **bold**.

Discussion

The connecting words and phrases are marked in bold below. There are five in total. I realised that that became then something we were working towards which was **this idea that** the open exchange of information can have a positive global impact, **the idea that when we say** 'positive global impact' **we can break that down and you can say if** people are more informed then they become more engaged, **and if** they are more engaged then they can become more empathetic. They are able to understand something that is happening halfway around the world in a uniquely different way; they are able to walk in that person's shoes. **And when** we are more empathetic, we realise we are global citizens and we have a sense of the world and what our place is in it and we want to essentially do good.

The second stage is to map Stone's argument, one level at a time.

Activity 3 Mapping Stone's argument

Allow about 10 minutes

Now, you can start applying the recipe, one level at a time. Apply the first step to obtain the argument map at level 0.

Discussion

Stone starts by putting forward the main claim. This claim is introduced by the phrase 'this idea that'. This gives you an initial argument map (Figure 7).



Figure 7 Level 0 of an argument map for Stone's argument

The remaining argument contains three connecting phrases: '**If**', '**and if**' and '**And when**'. These phrases signal three claims. Each of these claims takes the conclusion of the previous claim somewhat further.

Schematically speaking, you have:

- **If** more informed, **then** more engaged
- **If** more engaged, **then** more empathetic
- **If** more empathetic, **then** global citizens (= sense of the world, what our place is in it, and do good).

Together the three claims support the main claim that the open exchange of information can have a positive global impact in the sense that 'we realise we are global citizens and we have a sense of the world and what our place is in it and we want to essentially do good.'

Because these three if/then passages constitute a chain (of the form *If A, then B. If B, then C. If C, then D*), they are grouped under a single support relationship (Figure 8). On their own, these claims do not provide support for the main claim. Only when grouped together do they back the main claim

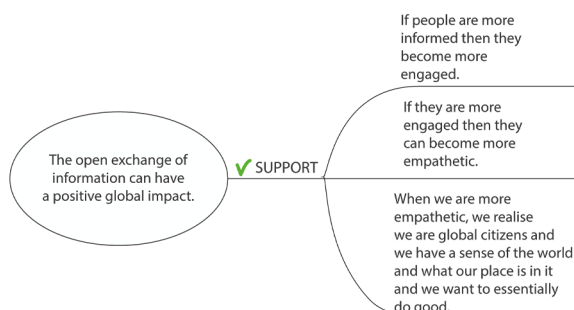


Figure 8 Levels 0 and 1 of an argument map for Stone's argument

The second supporting claim is followed by a bit of explanation. Immediately after the term 'empathetic' has been used, Stone explains that 'They are able to understand

something that is happening halfway around the world in a uniquely different way; they are able to walk in that person's shoes.'

We chose not to include the explanation on the argument map. The explanation does not introduce a new claim. Rather, it elaborates on the supporting claim that 'if they are more engaged then they can become more empathetic', by defining one of the terms that is used in that claim.

Biz Stone's argument came from his involvement with Twitter. In the next section, you will learn about another digital technology, the Tor network. The argument around Twitter focused on the benefits of the free flow of information. The argument around Tor that you will study focuses on the ability of the security services to monitor and track information flows.

4 The TOR network

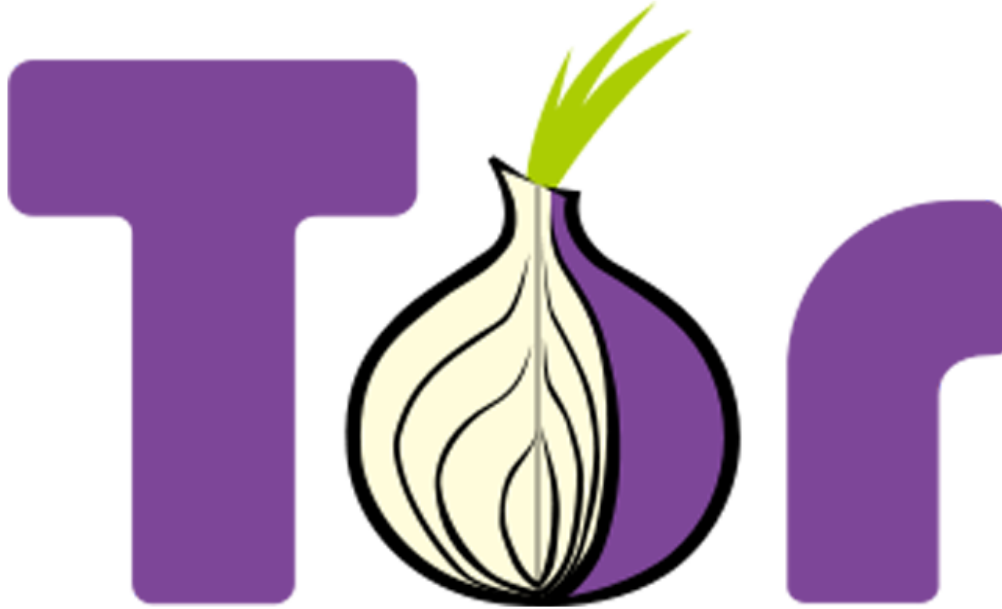


Figure 9 The Tor project logo contains a cartoon onion, which alludes to the sophisticated way in which messages that are sent over the Tor network are concealed by layers of encryption

The internet is a rich source of information for intelligence services around the world. Since the revelations by former US government contractor and CIA employee Edward Snowden, we know that the intelligence services of western countries such as the USA and UK collect and monitor data that is exchanged via the internet. However, the internet is incredibly versatile and, with clever algorithms and encryption techniques, networks can be created that allow for communications that evade monitoring, up to a point. The Tor network is a good example of this.

Criminals and terrorists use such networks but also, for example, news organisations that want to protect their sources (Figure 10).

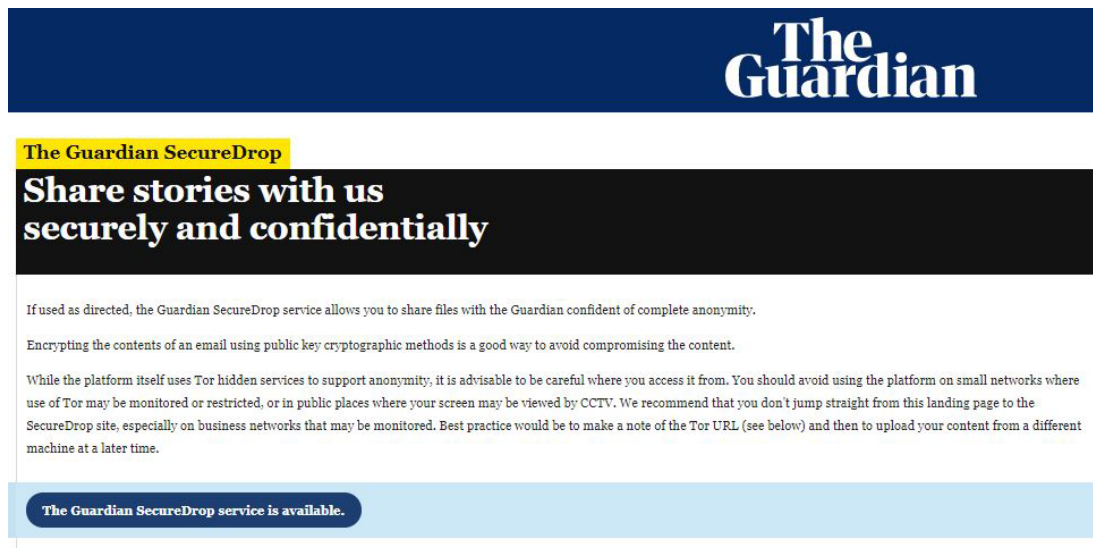


Figure 10 Front page of the Guardian portal for sharing files with 'complete anonymity'

Security services, such as the US National Security Agency (NSA), have debated and complained about Tor in internal briefings (Figure 11).

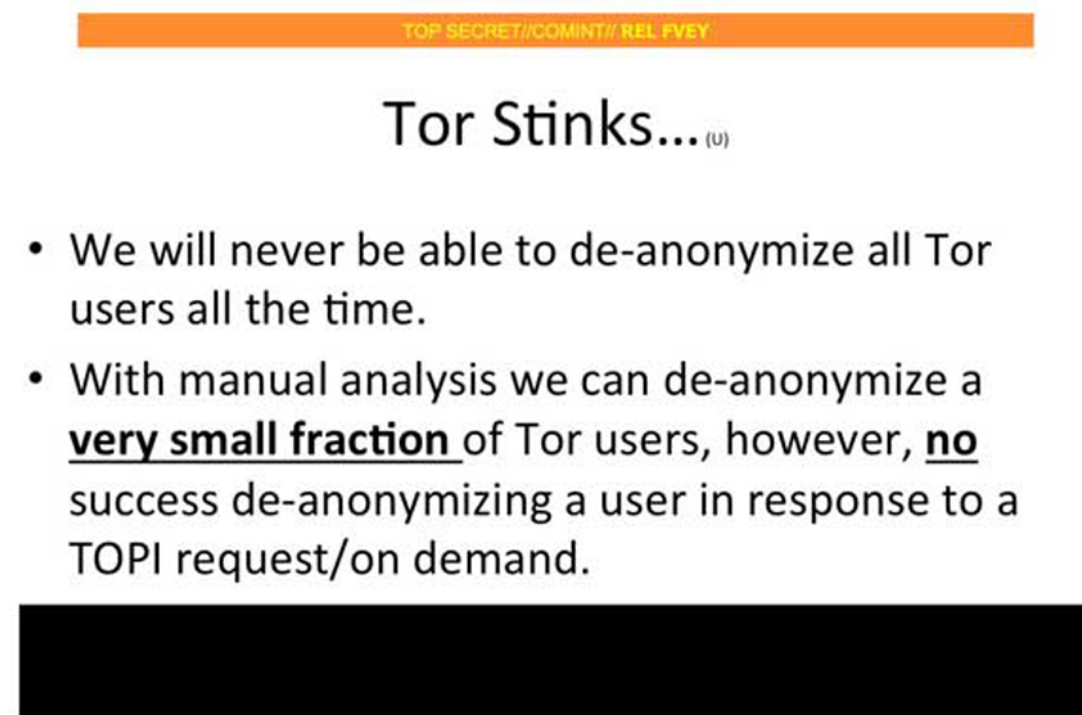


Figure 11 'Tor Stinks ...': a slide prepared for a top-secret NSA briefing that was leaked to the press in 2013

Even a simple slide, such as the one in Figure 11, can convey an argument. In the next activity, you will dissect this argument. For the purpose of the activity, don't worry about what 'de-anonymizing a user in response to a TOPI request/on demand' means. All you need to take away from that part of the slide is that there are certain communications on Tor that, so far, cannot be successfully de-anonymised. In other words, there are communications on TOR that hide the users' identities and no way has yet been found to work out those hidden identities.

Activity 4 Mapping 'Tor stinks'

Allow about 15 minutes

Start by identifying the main claim that is put forward on this slide (following the first step of the recipe in Section 1).

Discussion

In this case, the main claim is made by the slide's title: 'Tor stinks ...' (Figure 12). In other words, the title puts forward the claim that Tor is a problem for the NSA or intelligence community.

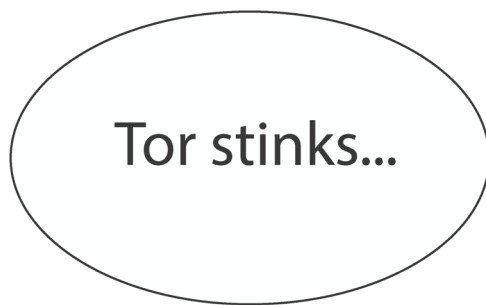


Figure 12 Level 0 of an argument map for the Tor slide

Next, apply the second step of the recipe. In this case, there are no connecting words or phrases to help you. In such a situation, you can test whether a statement, say *B*, is supporting claim *A* by reformulating it as a short dialogue of the form:

Speaker 1: *A*

Speaker 2: Why *A*?

Speaker 1: *B*

A similar strategy also allows you to test whether *B* opposes *A*. In that case, a dialogue of the following form should work:

Speaker 1: Not *A*

Speaker 2: Why not *A*?

Speaker 1: *B*

The first bullet item on the slide 'We will never be able to de-anonymize all Tor users all the time' passes the dialogue test for a support relationship.

Intelligence officer 1: Tor stinks!

Intelligence officer 2: Why does Tor stink?

Intelligence officer 1: We will never be able to de-anonymize all Tor users all the time.

Next, consider the second bullet:

With manual analysis we can de-anonymize a **very small fraction** of Tor users, however, **no** success de-anonymizing a user in response to a TOPI request/on demand.

The first part of this statement fits the dialogue test for an oppose relationship:

Intelligence officer 1: Tor doesn't stink!

Intelligence officer 2: Why not?

Intelligence officer 1: With manual analysis we can de-anonymise a very small fraction of Tor users.

'With manual analysis we can de-anonymize a very small fraction of Tor users' says that there is a way to track at least some Tor users – even if it is only a small fraction. This suggests that Tor may not be entirely bad (from the perspective of the intelligence community). What you have here is an opposing claim, even if it is a very weak one. You can add the supporting and opposing claims you found to your argument map (Figure 13).

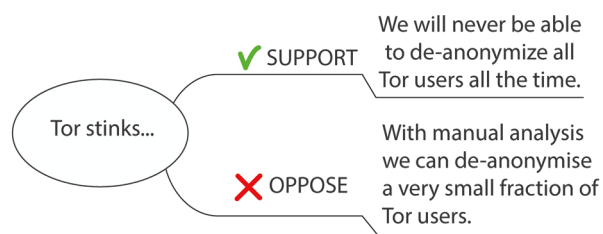


Figure 13 Levels 0 and 1 argument map for the Tor slide

Finally, apply the recipe's repeat step and add the second half of the second bullet on the slide:

however, **no** success de-anonymizing a user in response to a TOPI request/on demand.

Use the following reformulation (and don't worry about the meaning of TOPI request/on demand):

However, there are certain communications on Tor that, so far, cannot be successfully de-anonymised.

You can work out that the author is directing attention to the idea that, in certain circumstances, there is no way to de-anonymise users, not even a small fraction of

them. What you have here is an opposing claim that opposes the previous opposing claim! A visualisation with an argument map brings the idea across vividly (Figure 13).

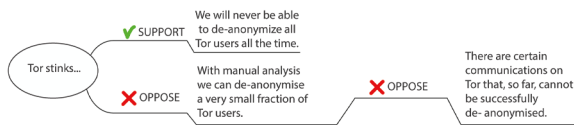


Figure 14 Levels 0, 1 and 2 argument map for the Tor slide

Note that in the argument map the word ‘however’ is omitted from the second opposing claim. This connecting word is not part of the claim itself. As you already explored earlier, such words give us clues about the role of the claim that they are attached to. In particular, ‘however’ signals that what follows is in some way at odds with what came before it.

That concludes the argument-mapping activities for this session. We hope you took our advice at the beginning and didn’t worry too much if your maps differed slightly from ours. The key points are:

1. You can defend the reasoning behind your maps
2. You can follow the reasoning behind our maps as well.

To illustrate this, consider the final map of Activity 4 (Figure 14). We decided that the two bullet items on the slide present claims that connect to the main claim. However, the second bullet item can also be thought of as opposing the first bullet item. In that case, we get a map with a different structure (Figure 15). Note that this map isn’t necessarily better or worse.



Figure 15 Levels 0, 1, 2 and 3 argument map for the Tor slide

5 Tread with care: the power of assumptions

This is the final section of Session 7. It starts by looking at online tools for sharing maps. Such tools open up new possibilities – for instance, they allow us to work with others and build argument maps together. Sharing and collaborating on maps is however not without its dangers. The makers and users of argument maps may have very different beliefs, which in turn may lead to very different argument maps.

5.1 Sharing maps

At the beginning of Session 6 you looked at the ways in which digital argument-mapping tools can enhance our natural capabilities. One dimension that we considered was ‘reach’. Once a map is digital, it is easy to send it to the other side of the world with a single click or to share it on Google drive, One drive, Dropbox or other cloud services. In addition, there are web-based versions of FreeMind, for instance, on [rollApp](#). Other tools allow you to view and contribute to maps that are shared on the web, for example:

- [AGORA-net](#)
- [bCisive](#)
- [kialo](#)
- [TruthMapping](#)
- [Argdown](#)

For instance, on [kialo](#) you can find a discussion that relates nicely to the arguments in Sections 1 and 2 of this session (Figure 16). This discussion is about the main claim that ‘[Social media has led to bubbles of reinforcing information, leading to paralysis of debate and stifling of opposing opinions](#)’.

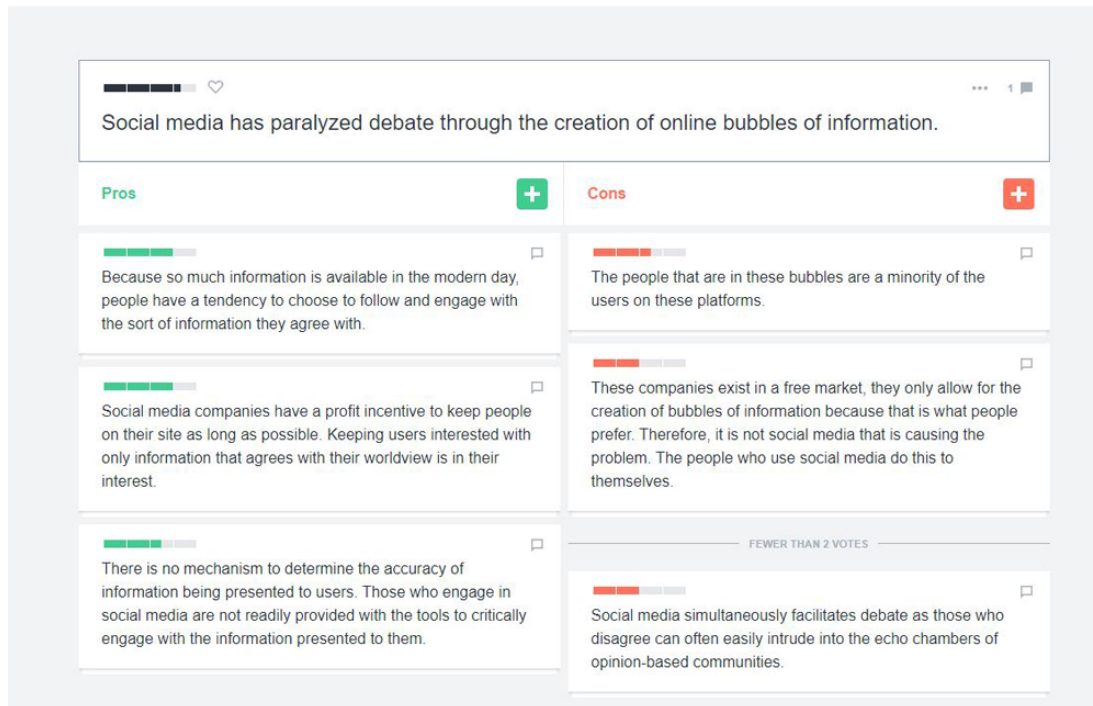


Figure 16 Screen capture of a kialo discussion, showing supporting claims on the left and opposing claims on the right

Kialo combines argument mapping with voting. The bars at the top left-hand side of each claim indicate how many people have voted for a claim. This is meant to reflect the strength of the claim. The more votes a claim attracts, the higher up it appears on the map.

It is also possible to zoom in on a claim and explore further claims that support or oppose it. For instance, Figure 17 shows how a claim from Figure 16 is opposed by a further claim.



Figure 17 Screen capture of a kialo discussion, showing an opposing claim to an opposing claim from the map in Figure 15

Kialo is a very neat tool for sharing and collaborating on maps. To conclude this session we will, however, sound a note of caution. To do so, we need to consider the role of assumptions in argument maps.

5.2 Assumptions and argument maps

Claims do not exist in a vacuum. When we come to judge how one claim relates to another claim, we rely on unspoken assumptions or beliefs. If these assumptions are shared by the claim maker and their audience, there is no need to state them explicitly and so they remain unspoken or implicit.

In Section 4, the author of the 'Tor stinks ...' slide and its intended audience are all members of an intelligence community. They are tasked with tracking people who may pose a threat to society. This audience will share the belief that anything that prevents them from doing so is a problem. This shared belief doesn't need to be stated explicitly – it is an unspoken assumption between members of the intelligence community. But the belief is crucial when we interpret *[the intelligence community] will never be able to de-anonymize all Tor users all the time* as supporting the claim that *Tor stinks*.

To see this, now consider an audience of hackers, journalists or human rights activists. They are unlikely to be persuaded by the argument that *Tor stinks ... because [the intelligence community] will never be able to de-anonymize all Tor users all the time*. On

the contrary, they may view the statement *[the intelligence community] will never be able to de-anonymize all Tor users all the time* as opposing the claim that *Tor stinks*.

Why bring this up in the context of sharing maps on the internet? When you read such maps, you need to be alert to the fact that the assumptions of the authors may be different from yours. As a result, you can't just uncritically take the content of such maps for granted.

6 This session's quiz

Check what you've learned this session by taking the end-of-session quiz.

[Session 7 practice quiz](#)

Open the quiz in a new tab or window then come back here when you've finished.

7 Summary of Session 7

This session continued where Session 6 left off. You:

- revisited the recipe for mapping arguments and applied it to several arguments: a short text, a video and a presentation slide.
- considered web-based collaborative argument mapping. You saw that some of these tools combine the power of argument mapping with social media tools such as voting.
- looked at the role of implicit assumptions or beliefs in arguments and how, to interpret an argument map correctly, you need to take such assumptions into account.

The next session examines the future of digital thinking tools. We ask whether, with the rise of artificial intelligence, digital thinking tools will become obsolete: Will machines do *all* our thinking for us? And, perhaps even more importantly, *should* we let machines do our thinking for us?

Session 8: From thinking tools to AI

Introduction

At the time this session was written (February 2019), artificial intelligence (AI) is a buzz word and speculation is rife about its benefits and dangers to humanity. Politicians and the public have started to take notice. In the UK, the House of Lords Select Committee on Artificial Intelligence released its report 'AI in the UK: ready, willing and able?' and the news is populated with headlines such as:

- Crime prediction software 'adopted by 14 UK police forces' (Kelion, 2019)
- Artificial intelligence learns 'deep thoughts' by playing Pictionary (Cuthbertson, 2019)
- Women are being pushed out of workforce by AI and job automation (Young, 2018)
- A robot pretended to be a politician for the day, and she had just the right amount of artificial intelligence (Peck, 2018; see Figure 1).
- The AI program that can tell whether you may go blind (Thiagarajan, 2019).



Figure 1 Pepper, the robot, 'gives evidence in Parliament'

In this course you have learned about several digital thinking tools. The emphasis is on *tools*: 'something necessary or useful for doing one's job' (Longman, 1987). But will such tools be needed in the future? Will the rise of AI mean that our thinking will be outsourced wholesale to artificially intelligent agents? And will that also make us, humans, redundant?

In this session, you'll examine these questions critically. We'll go back in time, to look at some of the historical roots behind the dream of a thinking machine. We will also look at the successes and failures of recent AI technologies.

Activity 1 Mapping this session

This session is an opportunity to apply the thinking tools that you encountered in this course. As you study this session, create your own argument map for the main claim that *AI eliminates the need for digital thinking tools*. At the end of this session you will be invited to share your map (as a .jpg or bmp file) and view the maps that other learners have created in Activity 2 Sharing your argument map.

By the end of this session, you will be able to:

- discuss some of the historical precedents for the current fascination with thinking machines
- describe some of the enablers of the current AI success stories
- describe some of the limitations of current AI technologies
- discuss your own analysis of the claim that AI eliminates the need for digital thinking tools.

1 Mechanising thought

The human craving for certain knowledge goes back a long way. There are records, from as far back as ancient Greece, of the thirst for knowledge that provides a fixed anchor for our thinking and can't be unsettled by new information or doubt. Ever since the time of Euclid (300 BC), mathematical practice has been a role model for establishing such knowledge.

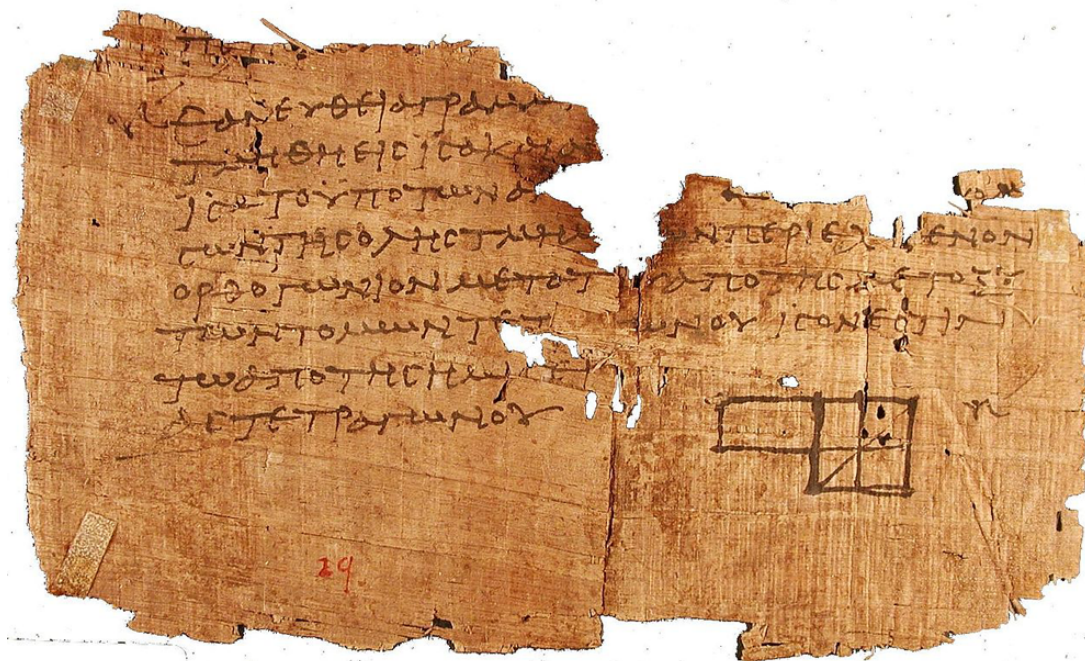


Figure 2 Oldest known fragment from Euclid's Elements (dated circa 100 AD)

In his *Elements*, a series of 13 books, Euclid put geometry on an apparently firm footing by showing how mathematical claims about figures (triangles, squares and so on) can be established beyond doubt (Figure 2). The idea is to give a **proof**.

A proof starts from several axioms, that is, simple claims that are beyond dispute. The proof shows how to arrive at new claims by combining the information from the axioms. Each step in a proof follows a recipe that is guaranteed to produce new true claims from already known true claims. In short, Euclid showed us a method for producing certain knowledge.

When one mathematician (A) wants to convince another (B) of a claim, this method guarantees success (at least in theory). A produces a proof which shows that the claim follows from the axioms. There is no scope for disagreement. If the steps in the proof lead from the axioms to the claim, the claim must be accepted by B.

1.1 Let us calculate!

Gottfried Wilhelm Leibniz (1646–1716) was a polymath and contemporary of the physicist Isaac Newton (1643–1727). About 2000 years after Euclid, Leibniz proposed that the ways of the mathematicians can be applied more widely:

The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: Let us calculate, without further ado, in order to see who is right.

(Leibniz, 1685, p. 51)



Quelle: Deutsche Fotothek

Figure 3 Frontispiece of the 1690 edition of Leibniz's extended version of his doctoral dissertation. It illustrates Leibniz's key idea that all concepts can be obtained from the combination of a relatively small number of simple concepts

Building on previous work by the philosophers Ramon Llull (1232–1315) and René Descartes (1596–1650), Leibniz produced an elaborate system (Figure 3) aimed at taking the passion out of any dispute (not just mathematical ones).

1.2 War and certainty

In *Cosmopolis: The Hidden Agenda of Modernity* (Toulmin, 1990), the philosopher Stephen Toulmin (1922–2009) argues that the work of Leibniz and Descartes shares a deeper common source. This was the 30-years war, a brutal war that ravaged much of Europe between 1618 and 1648 (Figure 4). Descartes experienced the consequences of the war in person, whereas Leibniz was born in its final two years and did his work during its aftermath.



Figure 4 Depiction of looting during the 30-years war by Sebastian Vrancx. Stephen Toulmin argued in Toulmin (1990) that the work of both Descartes and Leibniz should be understood in the context of the 30-year war and its atrocities.

In the war, theological disputes between Catholic and Protestant people were settled by force rather than reason and discussion. Descartes and Leibniz sought a method for yielding conclusions that were beyond doubt, in any dispute. Such a source of certainty would make it unnecessary to resort to violence. Any dispute could be settled by applying the method. During his life, Leibniz was actively involved in diplomacy and theological discussions aimed at bringing the sides together.

Interestingly, the work by Llull, another of Leibniz's inspirations, was also powered by the desire to settle theological disputes, although from a partisan angle. The story goes that Llull, born in Majorca, converted to Christianity between 1263 and 1265, abandoned family life and dedicated the rest of his life to converting Muslim and Jewish people. For instance, in 1293 he travelled to Tunis, seeking discussions with the city's intellectuals. This visit came to an end when he was imprisoned and subsequently expelled. However, the experience did not stop him from further similar undertakings, resulting in more prison visits, on occasion with Muslim scholars frequenting his cell in attempts to convert Llull. To aid him in these disputes, Llull had developed a paper machine of rotating discs marked with philosophical and theological axioms. It was said that any question about Christianity could be answered by appropriate manipulation of this machine.

1.3 Doubts still

The schemes of Llull and Leibniz were not universally applauded. *Gulliver's Travels*, a satirical travelogue by Jonathan Swift (1667–1745), makes fun of the whole idea. Swift, who was 21 years Leibniz's junior, describes Gulliver's visit to the 'Grand Academy of Lagado'. One of its resident professors is involved in 'a project for improving speculative knowledge by practical and mechanical operations'. Swift's Gulliver is openly disdainful:

Everyone knew how laborious the usual method is of attaining to arts and sciences; whereas by [the professor's] contrivance the most ignorant person at a reasonable charge, and with a little bodily labour, may write books in philosophy, poetry, politics, law, mathematics, and theology, without the least assistance from genius or study.

(Swift, 1726, p. 200)

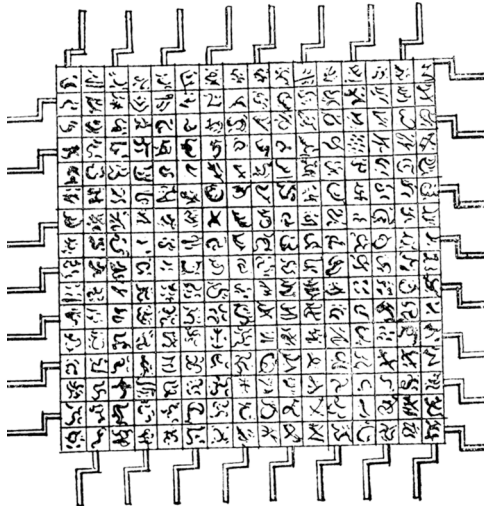


Figure 5 Drawing by Gulliver of the machine he saw at his visit to the Grand Academy of Lagado (Swift, 1726)

Gulliver goes on to describe how the machine – powered by the professor's pupils turning iron handles – rearranges words resulting in several large books 'of broken sentences, which [the professor] intended to piece together, and out of those rich materials to give the world a complete body of all arts and sciences'. *Gulliver's Travels* includes an illustration of the machine (see Figure 5), with the iron handles clearly identifiable. Swift's Gulliver concludes his description of meeting the professor in words that are unmistakably disdainful:

I made my humblest acknowledgement to this illustrious person for his great communicativeness, and promised, if ever I had the good fortune to return to my native country, that I would do him justice, as the sole inventor of this wonderful machine ... I told him, although it were the custom of our learned in Europe to steal inventions from each other, who had thereby at least this advantage, that it became controversy which was the right owner, yet I would take such caution, that he should have the honour entire without a rival.

(Swift, 1726, pp. 201–3)

This swipe at the professor might also be an allusion to a quarrel between Leibniz and Newton. Both Newton and Leibniz claimed to have invented calculus, a mathematical tool that plays a pivotal role in Newtonian physics.

The next section looks at how, from the 19th century the idea to mechanise thought was taken to the next level. It also looks at how this programme to mechanise thought had run into theoretical difficulties by the middle of the 20th century. And further practical obstacles led to a major change of approach – away from the foundations laid by Lull, Descartes and Leibniz – by the end of the 20th century.

2 The limits of computation

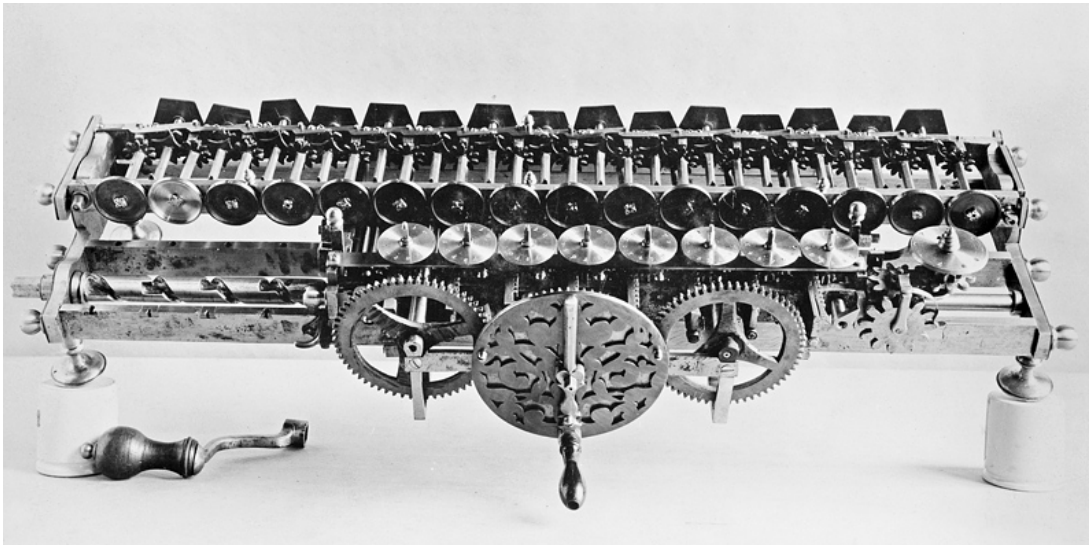


Figure 6 Leibniz's machine for multiplication

Leibniz went on to construct a mechanical device that automates multiplication (Figure 6). The development of a device that might deal with concepts and thoughts, rather than numbers, had to wait for another 150 years or so. Around 1840, the English polymath Charles Babbage (1791–1871) designed such a machine called the analytical engine (Figure 7).

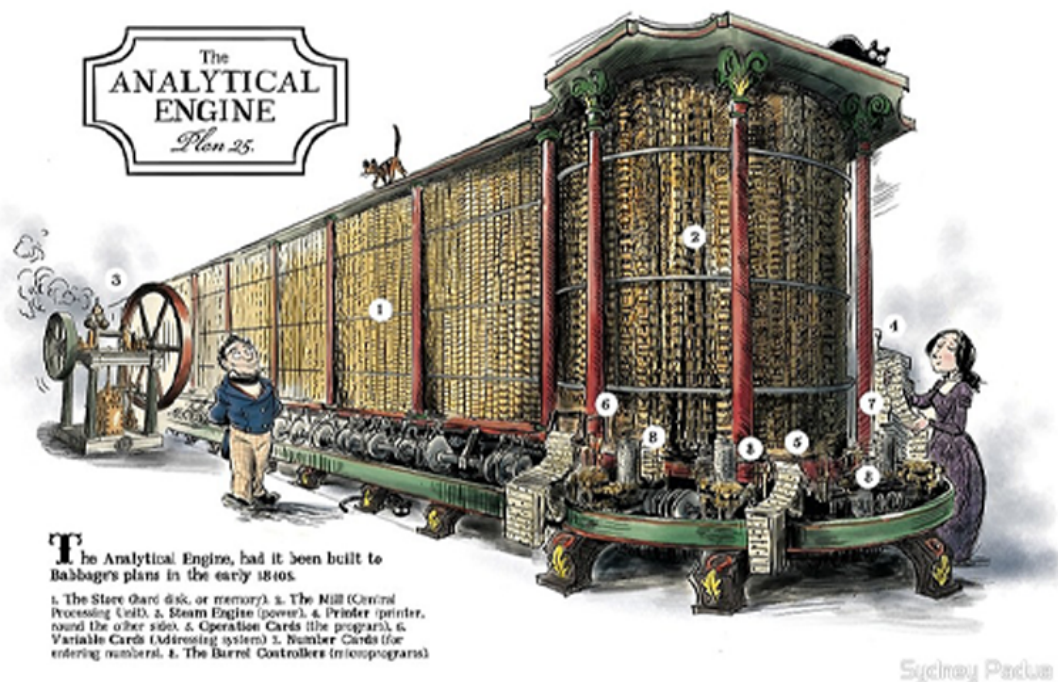


Figure 7 Artist's impression of Charles Babbage and Ada Lovelace with the Analytical Engine

The analytical engine was never built. But Babbage's fellow mathematician Augusta Ada King (1815–1852), the Countess of Lovelace (also known as Ada Lovelace), saw its potential for tasks beyond straightforward number crunching:

The operating mechanism can even be thrown into action independently of any object to operate upon (although of course no result could then be developed). Again, it might act upon other things besides number, were objects found whose mutual fundamental relations could be expressed by those of the abstract science of operations, and which should be also susceptible of adaptations to the action of the operating notation and mechanism of the engine. Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent.

(Countess of Lovelace, 1842)

It wasn't until the 20th century that general-purpose digital computers were built and started the information age.

2.1 Limits in theory

The first general-purpose digital computers were built from around 1940 onwards. With the actual construction of such machines, Leibniz's dream seemed to be very close to becoming reality. However, this first generation of computers was built with government funding for military and intelligence purposes (during the Second World War), rather than for Leibniz's original aim of settling disputes peacefully.

Even before these computers were built, mathematicians such as Kurt Gödel (1906–1978) and Alan Turing (1912–1954) discovered that there are definite limits to what they can do. This came about as follows.

The idea of a purely 'mechanical' way to prove or disprove a claim appealed greatly to mathematicians of the early 20th century interested in the foundations of mathematics. By then, mathematics itself had reached a stage where it was no longer the bastion of certain knowledge that it used to be. The mathematician and philosopher Bertrand Russell (1872–1970) had discovered a contradiction at the heart of mathematical language itself. There was a distinct fear that further, as yet, undiscovered contradictions might surface. Any resolution using a method that was guaranteed to yield certain knowledge was extremely welcome.

100's	10's	1's
2	9	3
1	4	6
3 +1	13	9
4	3	9

Figure 8 A mechanical procedure for column addition: carry out the addition following some simple rules: Start at the right-hand column. Add the numbers in that column. Write the total at the bottom of the column. If the total is greater than 9, cross out the 1 and add it to the total of the next column. Proceed with the next column (from right to left).

The question arose whether there is a mechanical procedure for determining whether a set of mathematical statements is true. What is a mechanical procedure? A mechanical procedure is a collection of rules that, once grasped, can be applied step-by-step without requiring any ingenuity. Such rules allow us to, for instance, perform a column addition. Once you have mastered column addition, you can carry it out without any creativity or flashes of insight. The rules can be applied in a 'mechanical' way (see Figure 8).

Gödel's and Turing's work demonstrated conclusively that there is no collection of rules for calculating whether any set of mathematical statements is true. Determining whether a set of mathematical statements is true can't be automated.

2.2 Computers as tools for mathematicians

Working mathematicians continued their labours and were relatively unfazed by Gödel's and Turing's findings. If anything, they were reassured that computers wouldn't put them out of a job anytime soon.

With the rise of computing technology, some forays were made into turning computers into the mathematician's assistant or tool. Whereas there is no general computer program for telling whether mathematical statements are true, there are relatively simple programs that can check whether a proof of a statement is correct. In other words, although computers can't come up with a proof for any arbitrary statement, they can tell us whether a proof, once found, has no missing or incorrect steps.

An early example is the Automath project by Dick de Bruijn (1918–2012) and his research group at Eindhoven University of Technology in the Netherlands. In the 1960s, the Automath team checked the proofs in a classic textbook on the foundations of *analysis* (*Landau's Grundlagen der Analysis*) – see Figure 9. Several years of labour went into translating the textbook content into precise statements that could be processed by a

computer. Along the way several mistakes and gaps in the original ‘proofs’ were discovered and corrected.

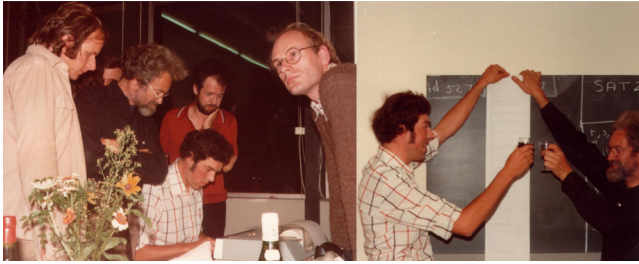


Figure 9 The Automath team using a computer to check the final proof of Landau's mathematics textbook, followed by celebrations with two team members holding a print-out of the final proof.

Automath pioneered the idea that computers can play a useful role in assisting, rather than replacing, mathematicians. The need for such tools has become increasingly pressing as some of the most influential mathematical proofs can take over a hundred pages of dense mathematical reasoning.

A dramatic example is the famous proof by Andrew Wiles (born 1953) of Fermat's last theorem. The initial proof of well over a hundred pages contained a mistake that was discovered only after Wiles had announced his proof in public. Wiles succeeded in correcting the proof and no further issues have been reported since.

Some mathematicians have warmed to using proof checkers to verify mathematical results, despite the enormous amount of work that is involved in translating a human-authored proof to computer input. For instance, after six years, in 2012, a team from Inria (the French national research institute for the digital sciences) and Microsoft Research completed checking a significant mathematical theorem, the Feit–Thompson theorem (Breton, 2012).

2.3 The rise and fall of classical artificial intelligence

Artificial intelligence (AI) emerged as a field during the 1950s. In the USA, it was initially funded through programmes aimed at automatic machine translation. At the time of the Cold War (roughly from 1946 until 1991), the US government was concerned about tracking the communications of its adversary, the then Soviet Union. These communications were in Russian and there were so many of them that it was well beyond what could be done by human Russian-to-English translators. Automatic machine translation was viewed as a possible solution.

In this new field of AI, Leibniz's dream was kept alive, despite the disappointing findings by mathematicians during the first half of the 20th century. The work of Doug Lenat (born 1950) illustrates how the field operated. Lenat initially made his name with a program that used rules of thumb to discover mathematical theorems. He believed that to arrive at a general artificial intelligence, most of human commonsense knowledge would have to be encoded. He began this enterprise – called the CYC project – in the 1980s. However, it ran into several obstacles.

The idea was that the machine would be fed lots of commonsense facts and some further statements. If it was then asked a question, it would be able to compute an answer based on commonsense knowledge and the statements (see Figure 10).

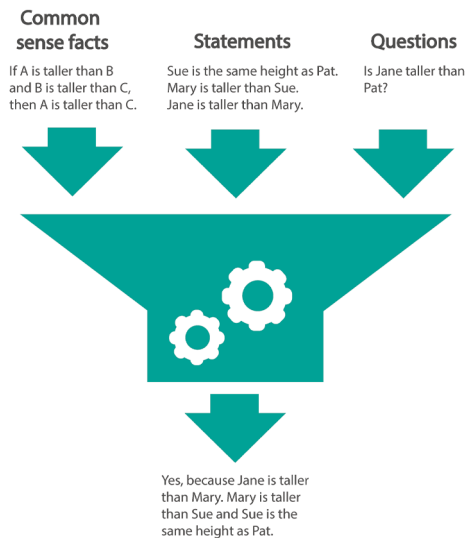


Figure 10 Example of a machine that takes commonsense facts, statements and a question and returns an answer to the question

You saw in Section 2.2 that even in mathematics, which deals with known axioms and relatively precisely stated proofs, it takes a large team many years to translate a human-authored proof into computer input. With commonsense knowledge, this problem is many times more challenging. This is because there are no neatly written-up lists of commonsense knowledge (unlike the axioms used by mathematicians). Of course, there are encyclopedias and other written sources, but much of our commonsense understanding of the world is rarely stated explicitly, if at all.

But forget that complication for a minute and suppose that commonsense knowledge can be translated into computer input. There are still the results of Gödel and Turing. Recall that they showed that there is no computer program that can tell whether a set of mathematical claims is true. Their results apply to claims in general (when stated with sufficient precision).

There is, however, a way out if we're willing to put a limit on the kind of claims that can be dealt with. Let us entertain this possibility for the sake of the argument. To escape from Gödel's and Turing's results, we need to restrict our attention to claims that are precise but also sufficiently simple – that is, claims that are written in what is referred to as **propositional logic** (a notation system that is suitable for processing by a computer). A computer program can safely reason with such claims and determine whether they are true.

However, even if we limit the computer input to propositional logic, we are not out of trouble. In the 1970s, computer scientists working in the field of computational complexity theory discovered some new results. These results showed that reasoning with propositional logic is most likely to take an unfeasible amount of time as the size of the computer input grows. In this case, the input is the number of commonsense facts (in propositional logic) that are used in the reasoning. Since it is difficult to know in advance which commonsense facts are needed for a problem, this number is likely to be very large. That, in turn, means that it takes a *very* long time for a computer to answer any questions that require commonsense knowledge.

3 Data, data, data

In Section 2 you saw that Leibniz's idea lost momentum towards the end of the 20th century. Two challenges appeared to be insurmountable. First, it turned out to be extremely laborious and difficult to formulate enough commonsense facts precisely. Second, the limits of computing machines meant that, even with enough knowledge, a computer program would struggle to produce conclusions in a reasonable amount of time, if at all.

However, the reverberations of Leibniz's heritage in the 20th century are only half of the picture. During the second half of that century, an alternative approach was bubbling beneath the surface. This approach, which can be traced back to Leibniz's and Descartes' contemporaries, emerged victoriously at the dawn of the 21st century.

3.1 The rationalists versus the empiricists

Leibniz and Descartes were rationalists. A rationalist values reasoning from first principles. To establish a claim, a rationalist tries to come up with a proof that shows how the claim follows from their axioms, that is those claims that are unquestionably certain. The adversaries of the rationalists were the empiricists, led by John Locke (1632–1704). An empiricist emphasises the importance of data, especially data as it comes in through the senses. To establish a claim, an empiricist tries to show that the claim fits with their observations, with the data.

The empiricist view bolstered an alternative approach to AI that was explored from the mid-20th century onwards. These AI researchers wrote computer programs that took lots of data and learned the patterns in this data for future use.

A typical problem is that of classifying images. The program is first 'trained' on numerous images and their correct labelling (Figure 11).

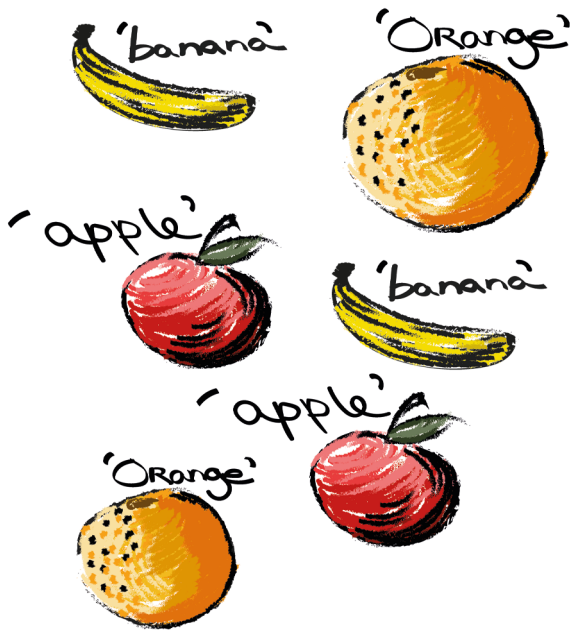


Figure 11 An example of training data: images of different fruits with the correct labels

After enough training has taken place, the program can be given an image that it hasn't seen before. It will predict the label. To do this successfully, the program needs to learn generalisations. For instance, each image of an individual banana will be slightly different from other images of that same or another banana. To predict the label correctly for an unseen banana image, it will have to ignore the differences from other bananas and notice the similarities. The empiricist approach proved extremely successful, especially when based on the use of artificial neural networks.

3.2 Rise of the empiricist AIs

The success of the empiricist approaches, and especially artificial neural networks, was grounded in techniques that had been known for many decades. However, in the early 21st century, the circumstances for deploying those techniques were favourable.

- The empiricist approach is built on data. As the internet came of age, many companies started tracking the behaviour of users. This produced lots of data. Users also generated data deliberately (e.g. on online photo sites such as Flickr which allow users to label images) and against payment (on platforms such as Amazon Mechanical Turk). Thus, a wealth of data became available to both businesses and researchers.
- Artificial neural networks require a lot of computing power to perform large numbers of simple but simultaneous calculations. Specialist computer circuits that were initially developed for computer games and other computer graphics applications turned out to be eminently suitable for that job (Figure 12).

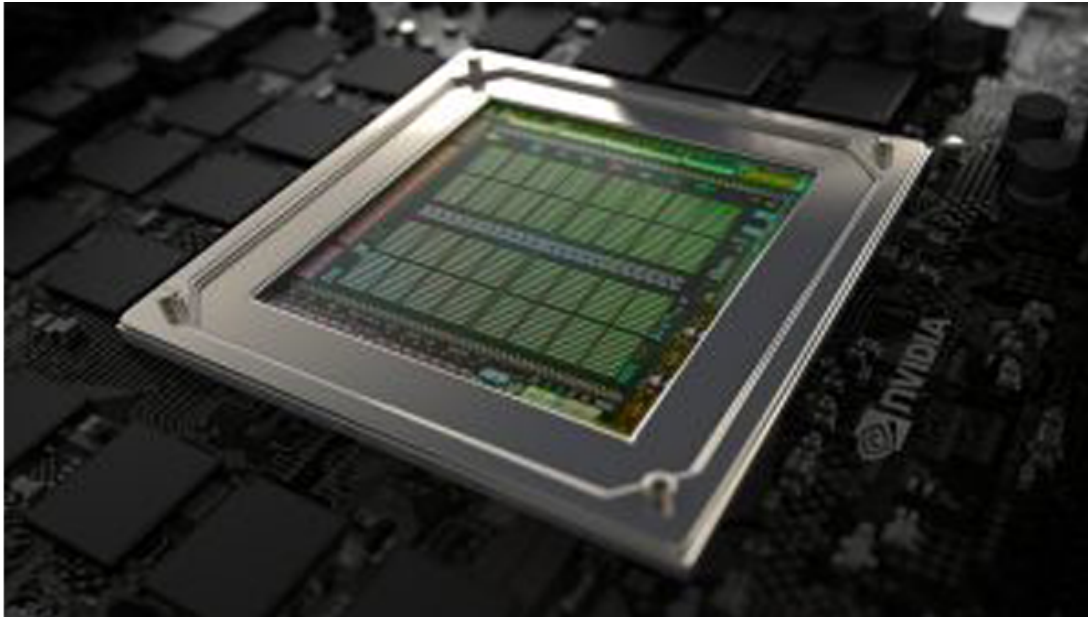


Figure 12 A graphics processing unit (GPU) speeds up image processing and artificial neural networks

3.3 Failures and limits of empiricist approaches

You have seen that the empiricist approach succeeded where the rationalist approach failed. The empiricist approach conquered the field with the availability of sufficient data and computing power. The rationalist approaches failed as a result of the difficulty of turning commonsense information into computer input and the inherent limitations of computers. However, there is no happy ending yet. The empiricist approach has its own limitations, which are becoming ever clearer.

In a rationalist approach, the idea is that the computer is provided with axioms, that is certain knowledge, from which further certain knowledge can be derived in a transparent and convincing way. In contrast, the empiricist approach relies on data, which doesn't necessarily need to represent true knowledge, and the conclusion is arrived at in ways that lack transparency. Each of these points can be illustrated, starting with data.

Bias in data

Data can represent not only useful information but also biases. A striking example of this problem was highlighted by Carole Cadwalladr, a journalist with the *The Observer* and winner of the 2018 journalism prize of the Orwell Foundation (Figure 13). In 2016, she wrote about the disconcerting results of some experiments with the Google 'auto-complete' feature:

I typed: "a-r-e". And then "j-e-w-s". Since 2008, Google has attempted to predict what question you might be asking and offers you a choice. And this is what it did. It offered me a choice of potential questions it thought I might want to ask: "are jews a race?", "are jews white?", "are jews christians?", and finally, "are jews evil?" ... Next I type: "a-r-e m-u-s-l-i-m-s". And Google suggests I should ask: "Are Muslims bad?" And here's what I find out: yes, they are. That's what

the top result says and six of the others. Without typing anything else, simply putting the cursor in the search box, Google offers me two new searches and I go for the first, “Islam is bad for society”. In the next list of suggestions, I’m offered: “Islam must be destroyed.”

(Cadwalladr, 2016)



Figure 13 Journalist Carole Cadwalladr

As explained on Google’s blog, the ‘predictions’ that autocomplete provides are based on ‘real searches that happen on Google and show common and trending ones relevant to the characters that are entered and also related to your location and previous searches’ (Sullivan, 2018). If there is a sufficiently large number of people who are preoccupied with a question, the rest of the Google searchers will receive it as a prediction (Figure 14). YouTube, which recommends videos, uses a similar algorithm, with an artificial neural network at its heart (Covington *et al.*, 2016).

Google appears to have manually adjusted its algorithms to avoid some of these results. (The autocomplete examples discovered by Cadwalladr no longer appear.) However, it is unlikely to ever succeed in eliminating all completions that are biased in one way or another. For instance, with most of the world’s population following a religion, it may surprise you that when we typed in ‘religion is’ (February, 2019), the completions offered

by Google were: 'poison, islam, bad, dying, the root of all evil, brainwashing, mass delusion, a disease, control'. Google relies on users of the service for reporting predictions that are 'inappropriate'.

Opacity of algorithms

You have seen that data can contain biases that are difficult to detect without human help. There is a second problem which concerns how neural networks process data. It turns out that, even when an algorithm produces plausible results on a data set, small changes to its input can lead to results that are entirely unexpected.

Rosenfeld *et al.* (2018) report on a wonderful study in which they pasted an object from one image into another image. For instance, they experimented with pasting an elephant into a living room. This resulted in the elephant not being detected at all, as well other objects changing their label. For example, an object that was previously labelled 'chair', switched its label to 'couch' with the elephant in the room (Figure 15).

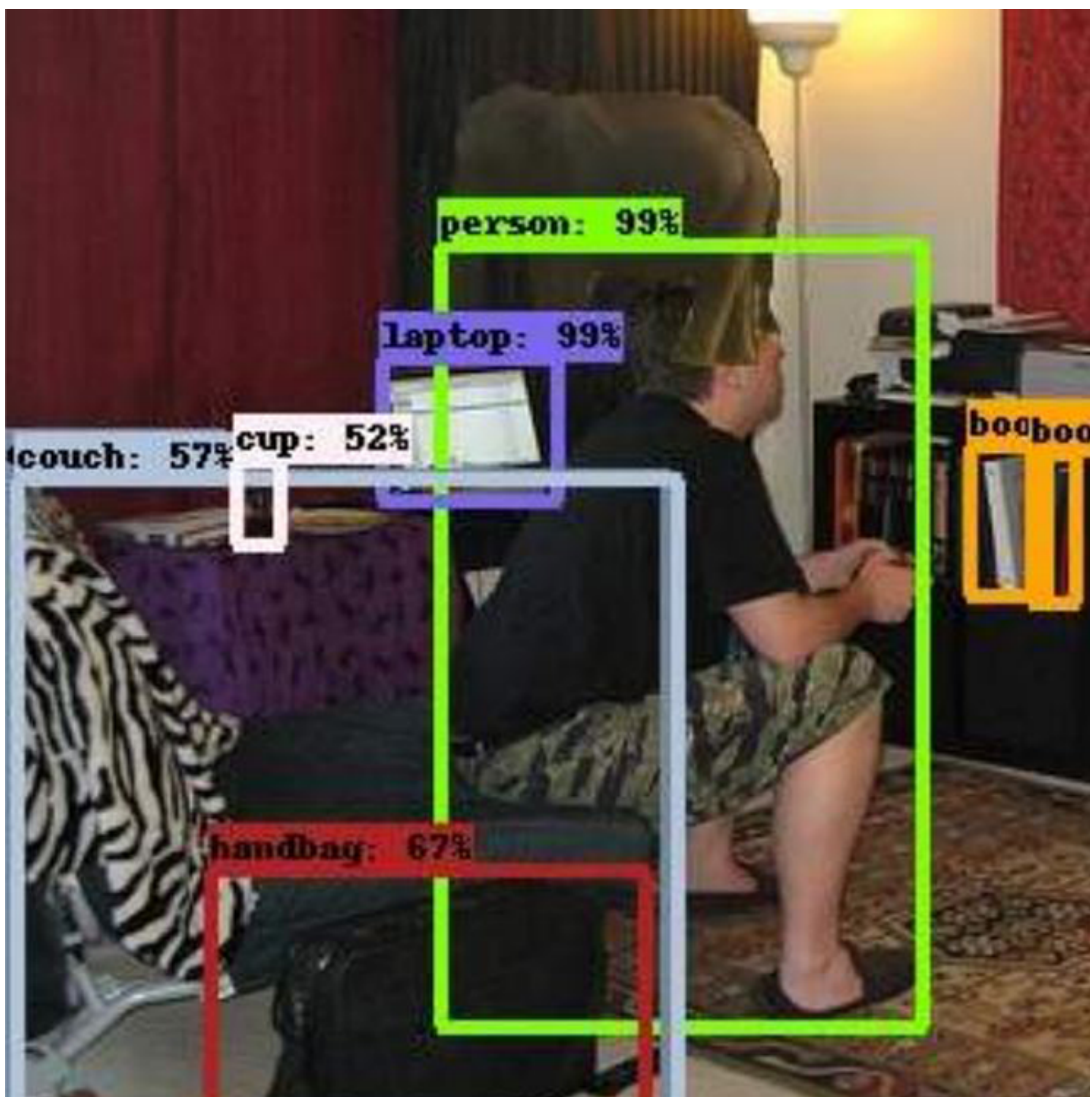


Figure 14 Object identification in a living room scene into which an elephant has been pasted. The elephant hasn't been detected at all and the object that was previously labelled as a chair is now labelled as a couch.

As you have seen, the quest for thinking machines or artificial intelligence has a long history, grounded in both rationalism and empiricism. You saw that both rationalistic and empiricist approaches have their shortcomings. This has, however, not stopped the current high expectations for artificial intelligence. The next section looks at the wider implications of the currently prevalent narrative of a future world filled with artificial intelligence.

4 Thinking outsourced?



Figure 15 Hannah Arendt, the American philosopher

If (...) the ability to tell right from wrong should turn out to have anything to do with the ability to think, then we must be able to 'demand' its exercise from every sane person, no matter how erudite or ignorant, intelligent or stupid, he may happen to be.

(Arendt, 1978, p. 13)

Now return to the beginning and revisit our initial questions:

- Does AI eliminate the need for thinking tools?
- Can or should we outsource our thinking and decision making to machines?

The quote above gives you some hint about our view. The American philosopher Hannah Arendt (1906–1975) wrote this backed up by the direct experience of a totalitarian state (Nazi Germany) in which many people did adopt a mindset that avoided thinking and taking responsibility. In this case, thinking was outsourced to the ‘Führer’ (English translation: leader) and his state, rather than machines. Yet, arguably, the same principle is at stake.

Our view on the matter is that thinking can’t be outsourced. Although machines can help people improve their thinking, in the end they should make the decisions and carry the responsibility for them. Without a doubt, our view will have influenced the selection of materials and arguments for this session. But that should not stop you from finding additional sources and evidence before determining your own stance!

Some people have argued that the eventual supremacy of AI over humanity is inevitable. They include Ray Kurzweil (born 1948), an inventor and director of research at Google. His book *The Age of Spiritual Machines* quotes the following, at first sight, quite persuasive argument.

As society and the problems that face it become more and more complex and as machines become more and more intelligent, people will let machines make more and more of their decisions for them, simply because machine-made decisions will bring better results than man-made ones. Eventually a stage may be reached at which the decisions necessary to keep the system running will be so complex that human beings will be incapable of making them intelligently. At that stage the machines will be in effective control. People won’t be able to just turn the machine off, because they will be so dependent on them that turning them off would amount to suicide. ... and because human work will no longer be necessary the masses will be superfluous, a useless burden on the system.

(Quote from Joy, 2000)

Bill Joy, a computer engineer and co-founder of Sun Systems (once a leading computer hardware and software company), points out that:

In [Kurzweil’s] book, you don’t discover until you turn the page that the author of this passage is Theodore Kaczynski – the Unabomber. ... Kaczynski’s actions were murderous and, in my view, criminally insane. He is clearly a Luddite, but simply saying this does not dismiss his argument; as difficult as it is for me to acknowledge, I saw some merit in the reasoning in this single passage’

(Joy, 2000)

4.1 Unpacking the argument

So, what is wrong with Kaczynski’s argument? After all, it seems to resonate with the current Zeitgeist, witness the success of Yuval Noah Harari’s book *Homo Deus* with both the general public and Silicon Valley (Bowles, 2018).

Harari makes a very similar prediction:

The most important question in the twenty-first century economics may well be what to do with all the superfluous people? What will conscious humans do once we have highly intelligent non-conscious algorithms that can do almost everything better?

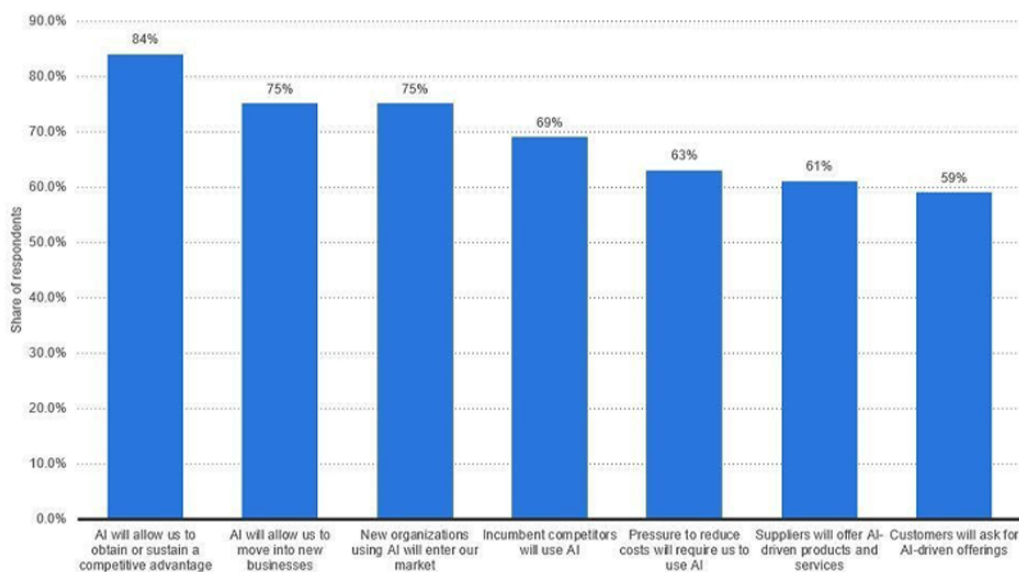
(Harari, 2016, p. 370)

But will machines do almost everything better? As you have seen, even with simple object recognition, there are significant gaps between human and machine capabilities. Given the long history of attempts to mechanise thought, the idea that we are now very close may prove illusory, again. The narrative of the inevitable rise of the infallible perfect machines may also hide from view more imminent threats.

For instance, you may want to ask whether businesses are adopting AI because it does things better. It turns out that this isn't at the top of the agenda of most businesses. They are focusing on other more practical reasons for adopting AI (Figure 16).

Reasons for adopting AI worldwide 2017

Business organizations' reasons for adopting artificial intelligence (AI) worldwide, as of 2017



statista

Figure 16 Business reasons for adopting AI

Recently, many news stories have highlighted that the major search and social media companies are (surprisingly?) driven by business considerations. They generate revenue by selling advertising opportunities. It is in the interest of these companies to keep their users glued to their platforms, since this maximises the amount of advertising they can be exposed to. AI algorithms play an important role in this. They learn how to best keep users engaged, sometimes with disastrous side effects. (For example, teenagers with suicidal thoughts may be directed to videos or web pages that encourage and reinforce their suicidal tendencies.) After the initial rose-tinted idealist view of these companies, it now seems to be taking a generally sceptical outlook.

Apart from optimism about what machines can do, there is also a strand of thought that plays down human capabilities and unique attributes such as human consciousness. Harari (2016), in the footsteps of John Gray (e.g. Gray, 2002), claims that science has shown that consciousness and free will, which set humans apart from machines, are mere illusions. But also on this front the argument is hardly settled. Neuroscientists such as Raymond Tallis (Tallis, 2011) and Kenan Malik (Malik, 2000) have argued at length that such conclusions are unwarranted, given the current state of knowledge.

4.2 The argument continues ...

Most strikingly, some of the harbingers of the inevitable AI supremacy and critics of free will and consciousness appear to change their perspective when discussing the implications of their theories and predictions:

All the predictions that pepper this book are no more than an attempt to discuss present-day dilemmas, and an invitation to change the future.

(Harari, 2016, pp. 74–5)

To a reader of Harari's book, this recommendation may come as a surprise, as it presents a constant and quite one-sided critique of the concepts of consciousness and free will. If the author's arguments hold water and both consciousness and free will are illusions, surely inviting the reader to change the future is futile?

5 This session's quiz

Congratulations on almost reaching the end of the course.

Now it's time to complete the Session 8 badged quiz. It is similar to the quiz that you took at the end of Session 4, with 15 questions in total.

[Session 8 compulsory badge quiz](#)

Open the quiz in a new tab or window (by holding down Ctrl [or Cmd on a Mac] when you click the link) then come back here when you've finished.

6 Summary of Session 8

Hopefully this session has stoked your interest and whetted your appetite for further thinking about the relationship between digital thinking tools and AI.

Following up on Activity 1, you may want to share your argument map with other people and look at their work.

Activity 2 Sharing your argument map

Allow around 15 minutes

If you have created your map in FreeMind, you may like to share it at [Biggerplate](#)

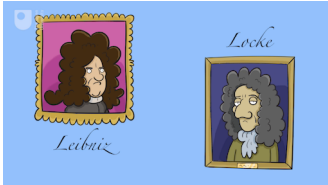
Make sure that your main claim is that *AI eliminates the need for digital thinking tools* and include this claim in the title of your map. This way, other people will be able to find your map and you can also search for maps with this claim in the title.

You have now almost reached the end of this course. But before you leave, have a look at the video in the next section.

7 Looking back

The following final video summarises Session 8.

Video content is not available in this format.



Video 1

You have now reached the end of this course. We hope that you have enjoyed the journey and will find some of the tools, techniques and ideas that you have encountered useful, whether it is for further study, your work life or beyond!

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Tell us what you think

Now you've come to the end of the course, we would appreciate a few minutes of your time to complete this short [end-of-course survey](#) (you may have already completed this survey at the end of Session 4).

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