7

Memory Overload

EVOLUTION DID NOT ENDOW HUMANS with the ability to play pick-up basketball. True, it produced legs for running, hands for dribbli shoulders for fouling, but all that this enables us to do is shoot hoops by ourselves. To get into a game with the strangers we nd in the sc on any given afternoon, we not only have to work in concert with four teammates we may never have met before—we also need to know we players on the opposing team are playing by the same rules. Other animals that engage strangers in ritualized aggression do so larg instinct—puppies throughout the world have the rules for rough-and-tumble play hard-wired into their genes. But American teenagers ha genes for pick-up basketball. They can nevertheless play the game with complete strangers because they have all learned an identical s about basketball. These ideas are entirely imaginary, but if everyone shares them, we can all play the game.

The same applies, on a larger scale, to kingdoms, churches, and trade networks, with one important difference. The rules of basketb relatively simple and concise, much like those necessary for cooperation in a forager band or small village. Each player can easily store brain and still have room for songs, images, and shopping lists. But large systems of cooperation that involve not ten but thousands or e of humans require the handling and storage of huge amounts of information, much more than any single human brain can contain and p

The large societies found in some other species, such as ants and bees, are stable and resilient because most of the information nee sustain them is encoded in the genome. A female honeybee larva can, for example, grow up to be either a queen or a worker, dependin food it is fed. Its DNA programmes the necessary behaviours for whatever role it will fill in life. Hives can be very complex social structures, containing many different kinds of workers, such as harvesters, nurses and cleaners. But so far researchers have failed to locate lawyer don't need lawyers, because there is no danger that they might forget or violate the hive constitution. The queen does not cheat the clea their food, and they never go on strike demanding higher wages.

But humans do such things all the time. Because the Sapiens social order is imagined, humans cannot preserve the critical informati running it simply by making copies of their DNA and passing these on to their progeny. A conscious effort has to be made to sustain law procedures and manners, otherwise the social order would quickly collapse. For example, King Hammurabi decreed that people are divi superiors, commoners and slaves. Unlike the beehive class system, this is not a natural division – there is no trace of it in the human ge Babylonians could not keep this 'truth' in mind, their society would have ceased to function. Similarly, when Hammurabi passed his DNA offspring, it did not encode his ruling that a superior man who killed a commoner woman must pay thirty silver shekels. Hammurabi delib had to instruct his sons in the laws of his empire, and his sons and grandsons had to do the same.

Empires generate huge amounts of information. Beyond laws, empires have to keep accounts of transactions and taxes, inventories o supplies and merchant vessels, and calendars of festivals and victories. For millions of years people stored information in a single place brains. Unfortunately, the human brain is not a good storage device for empire-sized databases, for three main reasons.

First, its capacity is limited. True, some people have astonishing memories, and in ancient times there were memory professionals wh store in their heads the topographies of whole provinces and the law codes of entire states. Nevertheless, there is a limit that even maste mnemonists cannot transcend. A lawyer might know by heart the entire law code of the Commonwealth of Massachusetts, but not the de every legal proceeding that took place in Massachusetts from the Salem witch trials onward.

Secondly, humans die, and their brains die with them. Any information stored in a brain will be erased in less than a century. It is, of c possible to pass memories from one brain to another, but after a few transmissions, the information tends to get garbled or lost.

Thirdly and most importantly, the human brain has been adapted to store and process only particular types of information. In order to ancient hunter-gatherers had to remember the shapes, qualities and behaviour patterns of thousands of plant and animal species. They remember that a wrinkled yellow mushroom growing in autumn under an elm tree is most probably poisonous, whereas a similar-looking mushroom growing in winter under an oak tree is a good stomach-ache remedy. Hunter-gatherers also had to bear in mind the opinions relations of several dozen band members. If Lucy needed a band member's help to get John to stop harassing her, it was important for h remember that John had fallen out last week with Mary, who would thus be a likely and enthusiastic ally. Consequently, evolutionary pre have adapted the human brain to store immense quantities of botanical, zoological, topographical and social information.

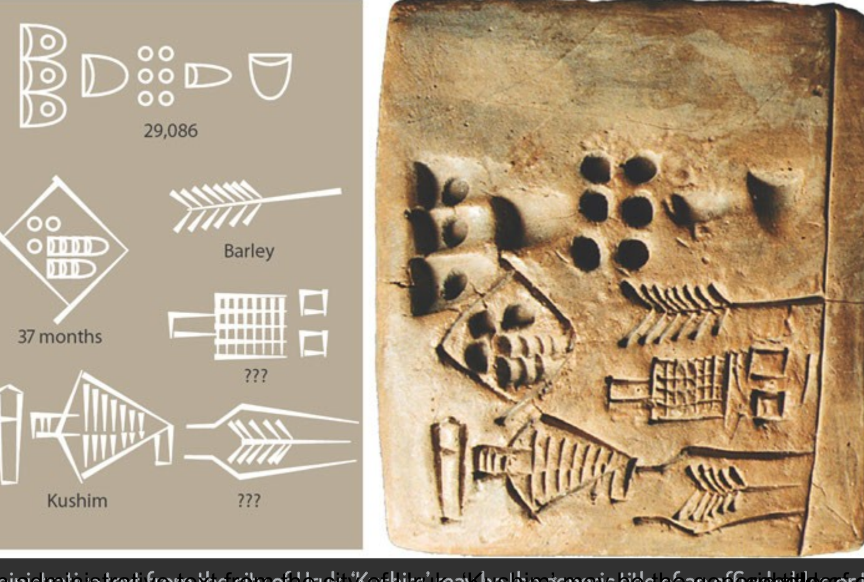
But when particularly complex societies began to appear in the wake of the Agricultural Revolution, a completely new type of informat became vital – numbers. Foragers were never obliged to handle large amounts of mathematical data. No forager needed to remember, say number of fruit on each tree in the forest. So human brains did not adapt to storing and processing numbers. Yet in order to maintain a la kingdom, mathematical data was vital. It was never enough to legislate laws and tell stories about guardian gods. One also had to collec order to tax hundreds of thousands of people, it was imperative to collect data about people's incomes and possessions; data about pay made; data about arrears, debts and nes; data about discounts and exemptions. This added up to millions of data bits, which had to be s processed. Without this capacity, the state would never know what resources it had and what further resources it could tap. When confro the need to memorise, recall and handle all these numbers, most human brains overdosed or fell asleep.

This mental limitation severely constrained the size and complexity of human collectives. When the amount of people and property in society crossed a critical threshold, it became necessary to store and process large amounts of mathematical data. Since the human bra do it, the system collapsed. For thousands of years after the Agricultural Revolution, human social networks remained relatively small an

The rst to overcome the problem were the ancient Sumerians, who lived in southern Mesopotamia. There, a scorching sun beating up muddy plains produced plentiful harvests and prosperous towns. As the number of inhabitants grew, so did the amount of information ne coordinate their affairs. Between the years 3500 BC and 3000 BC some unknown Sumerian geniuses invented a system for storing and pro information outside their brains, one that was custom-built to handle large amounts of mathematical data. The Sumerians thereby releas social order from the limitations of the human brain, opening the way for the appearance of cities, kingdoms and empires. The data-proc system invented by the Sumerians is called 'writing'.

Signed, Kushim

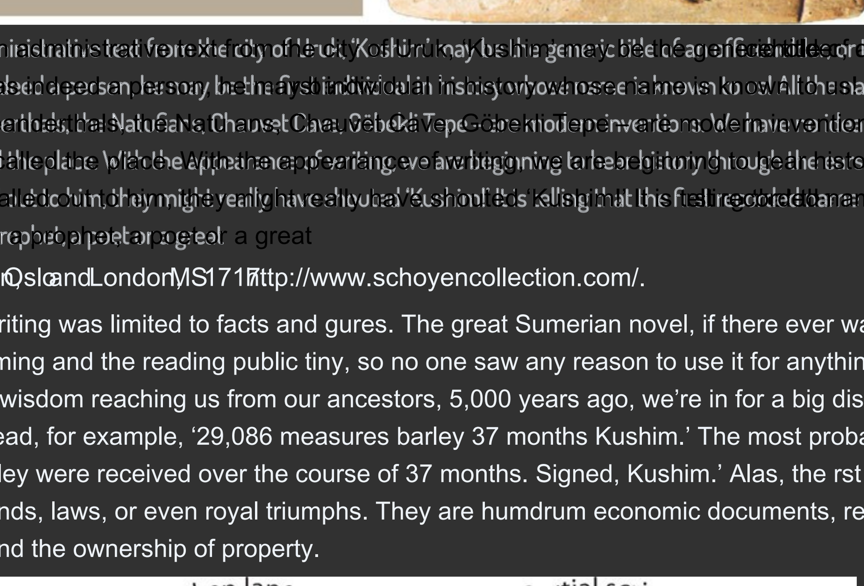
Writing is a method for storing information through material signs. The Sumerian writing system did so by combining two types of signs, pressed in clay tablets. One type of signs represented numbers. There were signs for 1, 10, 60, 600, 3,600 and 36,000. (The Sumerians combination of base-6 and base-10 numeral systems. Their base-6 system bestowed on us several important legacies, such as the divis day into twenty-four hours and of the circle into 360 degrees.) The other type of signs represented people, animals, merchandise, territo and so forth. By combining both types of signs the Sumerians were able to preserve far more data than any human brain could rememb DNA chain could encode.



34. A clay tablet with an administrative text from the city of Uruk, c. 3400–3000 BC. 'Kushim' may be a generic title of an office-holder, or the name of a particular individual. If Kushim was indeed a person, he may be the first individual in history whose name is known to us! All the names applied earlier in human history – the Neanderthals, the Natufians, Chauvet Cave, Göbekli Tepe – are modern inventions. We have no idea what the builders of Göbekli Tepe actually called the place. With the appearance of writing we are beginning to hear history through the ears of its protagonists. When Kushim's neighbours called out to him, they might really have shouted 'Kushim!' It is telling that the first recorded name in history belongs to an accountant, rather than a prophet, a poet or a great conqueror.

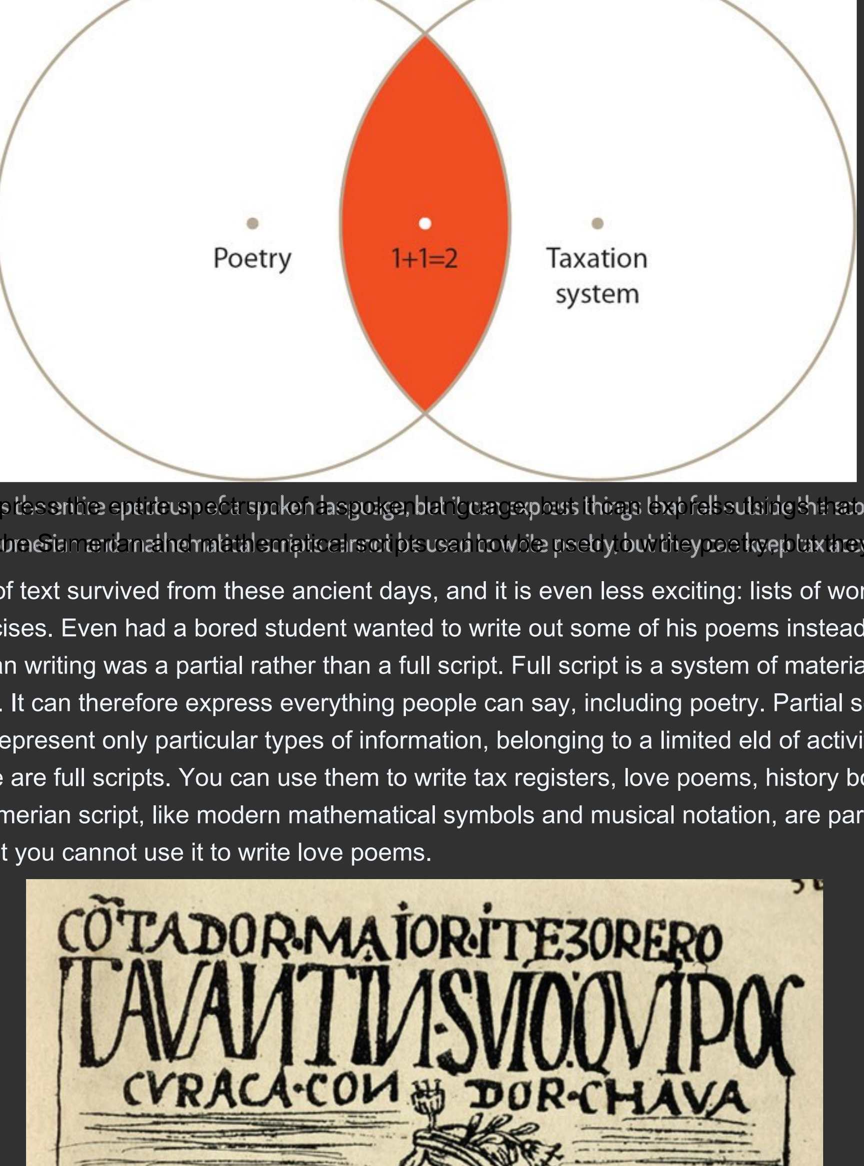
© TheSchøyenCollectionOslo and London, MS 1717. http://www.schoyencollection.com/.

At this early stage, writing was limited to facts and gures. The great Sumerian novel, if there ever was one, was never committed to c Writing was time-consuming and the reading public tiny, so no one saw any reason to use it for anything other than essential record-kee look for the rst words of wisdom reaching us from our ancestors, 5,000 years ago, we're in for a big disappointment. The earliest messag ancestors have left us read, for example, '29,086 measures barley 37 months Kushim.' The most probable reading of this sentence is: 'A 29,086 measures of barley were received over the course of 37 months. Signed, Kushim.' Alas, the rst texts of history contain no philoso insights, no poetry, legends, laws, or even royal triumphs. They are humdrum economic documents, recording the payment of taxes, the accumulation of debts and the ownership of property.



35. Full script is a system of material signs that can represent spoken language more or less completely. It can therefore express everything people can say, including poetry. Partial script, on the other hand, can represent only particular types of information, belonging to a limited field of activity. Latin script, ancient Egyptian hieroglyphics and Braille are full scripts.

Only one other type of text survived from these ancient days, and it is even less exciting: lists of words, copied over and over again by scribes as training exercises. Even had a bored student wanted to write out some of his poems instead of copy a bill of sale, he could no so. The earliest Sumerian writing was a partial rather than a full script. Full script is a system of material signs that can represent spoken more or less completely. It can therefore express everything people can say, including poetry. Partial script, on the other hand, is a syste material signs that can represent only particular types of information, belonging to a limited eld of activity. Latin script, ancient Egyptian hieroglyphics and Braille are full scripts. You can use them to write tax registers, love poems, history books, food recipes and business l contrast, the earliest Sumerian script, like modern mathematical symbols and musical notation, are partial scripts. You can use mathem to make calculations, but you cannot use it to write love poems.



36. A man holding a quipu, as depicted in a Spanish manuscript following the fall of the Inca Empire.

ManuscriptHistory of the Inca Kingdom by Guaman Poma de Ayala, Courtesy of the Royal Library, Copenhagen (GKS 2232 4to). Photo: The Art Archive/Archaeological Museum Lima/Gianni Dagli Orti (AA305957).

It didn't disturb the Sumerians that their script was ill-suited for writing poetry. They didn't invent it in order to copy spoken language, b to do things that spoken language failed at. There were some cultures, such as those of the pre-Columbian Andes, which used only parti throughout their entire histories, unfazed by their scripts' limitations and feeling no need for a full version. Andean script was very differe Sumerian counterpart. In fact, it was so different that many people would argue it wasn't a script at all. It was not written on clay tablets o paper. Rather, it was written by tying knots on colourful cords called quipus. Each quipu consisted of many cords of different colours, ma or cotton. On each cord, several knots were tied in different places. A single quipu could contain hundreds of cords and thousands of kno combining different knots on different cords with different colours, it was possible to record large amounts of mathematical data relating t example, tax collection and property.

For hundreds, perhaps thousands of years, quipus were essential to the business of cities, kingdoms and empires. They reached their full pote the Inca Empire, which ruled 10–12 million people and covered today's Peru, Ecuador and Bolivia, as well as chunks of Chile, Argentina Thanks to quipus, the Incas could save and process large amounts of data, without which they would not have been able to maintain the administrative machinery that an empire of that size requires.

In fact, quipus were so effective and accurate that in the early years following the Spanish conquest of South America, the Spaniards employed quipus in the work of administering their new empire. The problem was that the Spaniards did not themselves know how to re read quipus, making them dependent on local professionals. The continent's new rulers realised that this placed them in a tenuous positi native quipu experts could easily mislead and cheat their overlords. So once Spain's dominion was more firmly established, quipus were and the new empire's records were kept entirely in Latin script and numerals. Very few quipus survived the Spanish occupation, and mo remaining are undecipherable, since, unfortunately, the art of reading quipus has been lost.

The Wonders of Bureaucracy

The Mesopotamians eventually started to want to write down things other than monotonous mathematical data. Between 3000 BC and 2 more and more signs were added to the Sumerian system, gradually transforming it into a full script that we today call cuneiform. By 250 were using cuneiform to issue decrees, priests were using it to record oracles, and less exalted citizens were using it to write personal le roughly the same time, Egyptians developed another full script known as hieroglyphics. Other full scripts were developed in China aroun and in Central America around 1000–500

From these initial centres, full scripts spread far and wide, taking on various new forms and novel tasks. People began to write poetry books, romances, dramas, prophecies and cookbooks. Yet writing's most important task continued to be the storage of reams of mathem and that task remained the prerogative of partial script. The Hebrew Bible, the Greek the Hindu Mahabharata and the Buddhist Tripitaka oral works. For many generations they were transmitted orally and would have lived on even had writing never been invented. But tax re complex bureaucracies were born together with partial script, and the two remain inexorably linked to this day like Siamese twins – think cryptic entries in computerised data bases and spreadsheets.

As more and more things were written, and particularly as administrative archives grew to huge proportions, new problems appeared can easily retrieve information stored in their own minds. My brain stores billions of bits of data, yet I can quickly, almost instantaneously name of Italy's capital, immediately afterwards recollect what I did on 11 September 2001, and then reconstruct the route leading from m the Hebrew University in Jerusalem. Exactly how the brain does it remains a mystery, but we all know that the brain's retrieval system is ef cient, except when you are trying to remember where you put your car keys.

How, though, do you nd and retrieve information stored on quipu cords or clay tablets? If you have just ten tablets or a hundred table problem. But what if you have accumulated thousands of them, as did one of Hammurabi's contemporaries, King Zimrilim of Mari?

Imagine for a moment that it's 1776 Two Marians are quarrelling over possession of a wheat eld. Jacob insists that he bought the eld thirty years ago. Esau retorts that he in fact rented the eld to Jacob for a term of thirty years, and that now, the term being up, he intends reclaim it. They shout and wrangle and start pushing one another before they realise that they can resolve their dispute by going to the r archive, where are housed the decrees and bills of sale that apply to all the kingdom's real estate. Upon arriving at the archive they are shu one oficial to the other. They wait through several herbal tea breaks, are told to come back tomorrow, and eventually are taken by a grum clerk to look for the relevant clay tablet. The clerk opens a door and leads them into a huge room lined, oor to ceiling, with thousands of c tablets. No wonder the clerk is sour-faced. How is he supposed to locate the deed to the disputed wheat eld written thirty years ago? Eve nds it, how will he be able to cross-check to ensure that the one from thirty years ago is the latest document relating to the eld in questio can't nd it, does that prove that Esau never sold or rented out the eld? Or just that the document got lost, or turned to mush when some leaked into the archive?

Clearly, just imprinting a document in clay is not enough to guarantee accurate and convenient data processing. That requires methods of organisation like catalogues, methods of reproduction like photocopy machines, methods of rapid and accurate retrieval like computer algorithms, and pedantic (but hopefully cheerful) librarians who know how to use these tools.

Inventing such methods proved to be far more difficult than inventing writing. Many writing systems developed independently in cultures dista in time and place from each other. Every decade archaeologists discover another few forgotten scripts. Some of them might prove to be than the Sumerian scratches in clay. But most of them remain curiosities because those who invented them failed to invent efficient ways of cataloguing and retrieving data. What set apart Sumer, as well as pharaonic Egypt, ancient China and the Inca Empire, is that these cult developed good techniques of archiving, cataloguing and retrieving written records. They obviously had no computers or photocopying m but they did have catalogues, and far more importantly, they did create special schools in which professional scribes, clerks, librarians a accountants were rigorously trained in the secrets of data-processing.

A writing exercise from a school in ancient Mesopotamia discovered by modern archaeologists gives us a glimpse into the lives of the some 4,000 years ago:

I went in and sat down, and my teacher read my tablet. He said, 'There's something missing!'

And he caned me.

One of the people in charge said, 'Why did you open your mouth without my permission?'

And he caned me.

The one in charge of rules said, 'Why did you get up without my permission?'

And he caned me.

The gatekeeper said, 'Why are you going out without my permission?'

And he caned me.

The keeper of the beer jug said, 'Why did you get some without my permission?'

And he caned me.

The Sumerian teacher said, 'Why did you speak

And he caned me.

My teacher said, 'Your handwriting is no good!'

And he caned

Ancient scribes learned not merely to read and write, but also to use catalogues, dictionaries, calendars, forms and tables. They studied internalised techniques of cataloguing, retrieving and processing information very different from those used by the brain. In the brain, all freely associated. When I go with my spouse to sign on a mortgage for our new home, I am reminded of the rst place we lived together, reminds me of our honeymoon in New Orleans, which reminds me of alligators, which remind me of dragons, which remind me of The Ring of the and suddenly, before I know it, there I am humming the Siegfried leitmotif to a puzzled bank clerk. In bureaucracy, things must be kept a is one drawer for home mortgages, another for marriage certificates, a third for tax registers, and a fourth for lawsuits. Otherwise, how can you nd anything? Things that belong in more than one drawer, like Wagnerian music dramas (do I le them under 'music', 'theatre', or perhaps in category altogether?), are a terrible headache. So one is forever adding, deleting and rearranging drawers.

In order to function, the people who operate such a system of drawers must be reprogrammed to stop thinking as humans and to star as clerks and accountants. As everyone from ancient times till today knows, clerks and accountants think in a non-human fashion. They ling cabinets. This is not their fault. If they don't think that way their drawers will all get mixed up and they won't be able to provide the s their government, company or organisation requires. The most important impact of script on human history is precisely this: it has gradua changed the way humans think and view the world. Free association and holistic thought have given way to compartmentalisation and b

The Language of Numbers

As the centuries passed, bureaucratic methods of data processing grew ever more different from the way humans naturally think – and e important. A critical step was made sometime before the ninth century when a new partial script was invented, one that could store and p mathematical data with unprecedented efficiency. This partial script was composed of ten signs, representing the numbers from to 9. Confusin these signs are known as Arabic numerals even though they were rst invented by the Hindus (even more confusingly, modern Arabs use digits that look quite different from Western ones). But the Arabs get the credit because when they invaded India they encountered the s understood its usefulness, re ned it, and spread it through the Middle East and then to Europe. When several other signs were later adde Arab numerals (such as the signs for addition, subtraction and multiplication), the basis of modern mathematical notation came into bein

Although this system of writing remains a partial script, it has become the world's dominant language. Almost all states, companies, o and institutions – whether they speak Arabic, Hindi, English or Norwegian – use mathematical script to record and process data. Every p information that can be translated into mathematical script is stored, spread and processed with mind-boggling speed and efficiency.

$$\ddot{\mathbf{r}}_i = \sum_{j\neq i} \frac{\mu_j(\mathbf{r}_j-\mathbf{r}_i)}{r_{ij}^3}\left\{1-\frac{2(\beta-\gamma)}{c^2}\sum_{l\neq i}\frac{\mu_l}{r_{il}}-\frac{2\beta-1}{c^2}\sum_{k\neq j}\frac{\mu_k}{r_{jk}}+\gamma\left(\frac{s_i}{c}\right)^2\right.$$
$$+(1-\gamma)\left(\frac{s_j}{c}\right)^2-\frac{2(1+\gamma)}{c^2}\dot{\mathbf{r}}_i\cdot\dot{\mathbf{r}}_j-\frac{3}{2c^2}\left[\frac{(\mathbf{r}_i-\mathbf{r}_j)\cdot\dot{\mathbf{r}}_j}{r_{ij}}\right]^2$$
$$\left.+\frac{1}{2c^2}(\mathbf{r}_j-\mathbf{r}_i)\cdot\ddot{\mathbf{r}}_j\right\}$$
$$+\frac{1}{c^2}\sum_{j\neq i}\frac{\mu_i}{r_{ij}^3}\{[\mathbf{r}_i-\mathbf{r}_j]\cdot[(2+2\gamma)\dot{r}_i-(1+2\gamma)\dot{\mathbf{r}}_j]\}(\dot{\mathbf{r}}_i-\dot{\mathbf{r}}_j)$$
$$+\frac{3+4\gamma}{2c^2}\sum_{j\neq i}\frac{\mu_j\ddot{\mathbf{r}}_j}{r_{ij}}$$

An equation for calculating the acceleration of mass i under the influence of gravity, according to the Theory of Relativity. When most laypeople see such an equation, they usually panic and freeze, like a deer caught in the headlights of a speeding vehicle. The reaction is quite natural and does not betray a lack of intelligence or curiosity. With rare exceptions, human brains are simply incapable of thinking through concepts such as relativity and quantum mechanics. Physicists nevertheless manage to do so, because they set aside the traditional human way of thinking, and learn to think anew with the help of external data-processing systems. Crucial parts of their thought process take place not in the head, but inside computers or on classroom blackboards.

A person who wishes to in uence the decisions of governments, organisations and companies must therefore learn to speak in numb do their best to translate even ideas such as 'poverty', 'happiness' and 'honesty' into numbers ('the poverty line', 'subjective well-being le rating'). Entire elds of knowledge, such as physics and engineering, have already lost almost all touch with the spoken human language, maintained solely by mathematical script.

More recently, mathematical script has given rise to an even more revolutionary writing system, a computerised binary script consisti two signs: and 1. The words I am now typing on my keyboard are written within my computer by different combinations of and 1.

Writing was born as the maidservant of human consciousness, but is increasingly becoming its master. Our computers have trouble und how *Homo sapiens* talks, feels and dreams. So we are teaching *Homo sapiens* to talk, feel and dream in the language of numbers, which can be understood by computers.

Eventually, computers might outperform humans in the very elds that made *Homo sapiens* the ruler of the world: intelligence and communication. The process that began in the Euphrates valley 5,000 years ago, when Sumerian geeks outsourced data-processing fro human brain to a clay tablet, would culminate in Silicon Valley with the victory of the tablet. Humans might still be around, but they would be able to make sense of the world. The new ruler of the world would be a long line of zeros and ones.