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<u>Does the way we speak affect our perception of numbers?</u>

Mathematics is often thought of as a universal language. Perhaps it even represents the harmony of numerous and diverse cultures. We have adopted a Hindu-Arabic counting system; taken letters from the Greek and Latin alphabets; and created a wealth of symbols to go in between. Yet, despite this, perception of numbers and mathematical understanding seems to vary from person to person. There are probably a few factors that contribute to this, but one of them may be the way in which we talk about maths, and subtle linguistic differences.

Counting

By the time you reach secondary school, counting becomes second nature. In English, that is. The moment you enter the French classroom, and learn that sixty is '*soixante*', seventy is '*soixante-dix*' (sixty-ten), eighty is '*quatre-vingt*' (four-twenty), and ninety is '*quatre-vingt-dix*' (four-twenty-ten), counting becomes a chore again. Reflecting on this somewhat arbitrary peculiarity, you come to the realisation that English has its numerical quirks too. Why do we use eleven and twelve and *then* go to thirteen, fourteen and fifteen - why not oneteen and twoteen? Or the mystery of where the 'u' in forty goes? There is an inclination to say that although this is slightly bizarre, it does not affect our understanding of numbers in any meaningful way. Yet, other languages demonstrate more regular counting systems, and there is evidence that shows the greater efficacy of these, comparatively. In certain languages, one of them being Mandarin, numbers such as 21 are written as two-ten-one, and 92 is written as 9-10-2. In one study, first grade students were told to represent numbers such as 42 using blocks of ten and blocks of one. Children from the US, France or Sweden ended up being more likely to use 42 unit blocks, whereas those from Japan or Korea (where the counting system is like the Mandarin system) were more likely to use four blocks of ten and two unit blocks. While language seems a likely cause of this outcome, it would have been hard to control other factors, such as teaching style, during this experiment, which may make the link between language and mathematical understanding seem slightly tenuous. However, an experiment carried out in Wales proves the hypothesis much more convincingly. In Wales, around 80% of students are taught in English, and the other 20% are taught in modern Welsh, but they still study the same curriculum and are taught in a similar way to one another. Modern Welsh has a counting system that resembles Mandarin, rather than English. Six-year-olds taught in Welsh and English were asked to estimate where a number would lie on a number line from 0 to 100, and the Welsh children did significantly better. A professor at Oxford, Ann Dowker, explains that it is likely that it was because Welsh children had a more precise representation of two digit numbers, due to the linguistic difference in their counting system. The organisation of the number system has such a noticeable impact on the way children view numbers due to the fact that it allows children to see the relationships between numbers - viewing all natural numbers as a web rather than isolated values. It makes basic mathematical functions, such as multiplication and addition, implicit through the language itself.

Visualisation

At times, mathematical processes are described in the way they physically look on the page. Although natural and intuitive, doing so at a young age can hinder understanding of various concepts. The first and most basic example of this is with fractions. It has become fairly common to refer to fractions as ‘x over y’, for example ‘one over three’ instead of ‘one by three’ or ‘one third’. Rather than describing the mathematical meaning of the fraction, we are describing the way it looks on the page, encouraging us to view the fraction as independent numbers separated by a line, instead of a ratio or division. In a study done (Boulet 1998), when students were asked to illustrate a fraction they were given, they ended up illustrating the numerator, denominator and the fraction bar (vinculum) as separate entities, highlighting a blatant misunderstanding (through no fault of their own) of what a fraction actually is.

A similar instance of describing the visual representation rather than mathematical meaning occurs when doing addition, multiplication, and even division. Phrases such as ‘carry the one’, although simple and even useful, do not actually give a full picture of what is happening. In the same way, during long multiplication (with two two-digit numbers), we are told to ‘put a zero’ in the second row without explanation, instead of grasping the fact that we are multiplying by the tens unit. Perhaps this is linked to our inexplicably confusing counting system - I doubt that it would be as difficult to comprehend if the language itself insinuated a multiplication by ten. Similar issues arise during division and subtraction. Perhaps teaching style is partly to blame for this, but it is clear that we have coined misleading terms with which we describe mathematical actions, and that is a purely linguistic problem.

The previous issue was taking the depiction of the numbers on the page too literally; a second issue, is slightly the opposite - not focussing enough on what mathematical concepts actually look like. The first instance of this, is the number 'a billion', or maybe more precisely, the lack of understanding of the true disparity between a million and a billion, through just the terms themselves. Often, to fully explain the difference, comparisons need to be drawn. A clear example is time - a million seconds is 12 days; a billion seconds is 32 years (and a trillion seconds is 31,688 years!). However, with regards to this misunderstanding, there are some relevant, although damaging economic outcomes, such as the fact that fiscal policy does not discriminate between millionaires and billionaires, although it probably should, but that's a hefty discussion for another time. It is likely that language is somewhat to blame here - a million, a billion, and even a trillion are very similar words - giving the impression that the three are looped together under the subsection of 'large numbers' and not leaving space for distinguishing between them.

Exponents and factorials tend to have the same effect. A simple symbol, for example the '!' for factorials does no justice to the sheer size of numbers such as 50!. The brevity of the sign is what seems to be deceiving. The lack of a language-based description, and the use of solely a single punctuation mark is what alters the perception of the number, and makes it hard to visualise. Unlike the lack distinction between a million and a billion, there are no real issues that stem from this inability to visualise, but it *is* entertaining to see how surprised people are with facts about folding paper to the moon.

Homonyms

Maths is filled with seemingly mundane words which have an entirely different mathematical meaning. Looking back on this essay, I'm sure I've used at least five or six. Some obvious examples include the number sets - 'complex numbers' and 'imaginary numbers'. I must confess - I have no studies to prove this hypothesis, but having talked amongst my peers and with my teachers, I genuinely believe that people have preconceptions about these topics even before approaching them, due to their everyday meaning: they believe 'complex numbers' to be complicated, and imaginary numbers to be a hard concept to grasp. Even labels like 'rational' and 'irrational' are misleading - it is not necessarily explicit that 'rational' refers to 'a number that can be expressed as a ratio', as 'rational' now has the more common meaning of 'sensible'. The issue, in this case, is etymology. Words have mutated over time, yet old-fashioned terms have remained, warping our perception of numbers.

In some cases of mathematical homonyms, the distinctions between the meaning of the two words is slightly more nuanced. Take infinity, for example: mathematical infinity and colloquial infinity both refer to a similar concept, which differs in a discreet manner. A study was done to investigate whether languages which differentiate between mathematical infinity and colloquial infinity give rise to a better understanding and more sophisticated way of communicating on the topic. Korean is a language where the two infinities are separate terms, and so English and Korean students were asked to have monitored discourse on the topic of 'infinity'. Data showed that despite similar mathematical capabilities, the approach to the discussion on 'infinity' was evidently dissimilar. The discourse of the English speakers was more processual; meanwhile, the Korean speakers talked of infinity in a more structured and mathematically astute way. Again, unfortunately, not all the variables can be controlled, but it seems intuitive to say that language does play a role in this observed difference.

With certain terms, most prominently, physical terms such as 'weight', the colloquial version is used 'incorrectly', if you take the mathematical definition of the word to be 'correct'. 'Weight' during casual conversation refers to the definition of 'mass' - unchanging and measured in kilograms. In terms of physics, 'weight' refers to a force (measured in Newtons), and can change depending on gravitational pull. Naturally, having to almost 'unlearn' your definition of weight can prove quite confusing. Another example is of the phrase 'in general', which, in mathematics, is used to describe a result where there are no exceptions. The colloquial use of the phrase is quite the opposite - often denoting a claim that is mostly true but has a few exceptions. To correct this, mathematicians sometimes use 'generically', which perhaps complicates things further.

Conclusion

The intersection between linguistics and mathematics is a fascinating one; maybe even one that is not researched enough. Perhaps this is because our mathematical capabilities do not suffer detrimentally, even if our counting system makes little sense or if we have the same word for 'infinity'. Yet it is ironic that, arguably, the most universal of all languages is still more variable than it seems - not just from culture to culture, but from one individual to the next. Maybe certain phrases should be avoided, as they perpetuate a less mathematical or logical way of thinking. But what I think is potentially more important, is encouraging delving more into the etymology of technical mathematical terms (even from a young age, explaining that 'fifty' is a modified version of 'five-ten'); describing certain functions and concepts in a more qualitative way so that become easier to visualise; and an increased understanding of the (subtle) differences between mathematical homonyms. Exploring language, especially mathematical language will be interesting, useful and could bring to light certain strategies to improve learning. After all, we think in language - there is no doubt it influences us immensely in everything - maths is no exception.

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