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Digitization, Perception, Cognition, and Categorization: Consequences for Accounting[1]

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Abstract

Hundreds of thousands of years ago, our perceptions developed beyond their analog origins to include digital modes. It was a key transformation that may well have distinguished genus homo from its predecessors. Since digitization necessarily discards at least some of the information contained in continuous analog magnitudes, it is not obvious that digitization would prove to be a useful improvement and promote survival and flourishing of the species. Yet, it has been a spectacular success, playing a key role in development of human mind, cognition, and civilization. We examine how digitization altered the perceptions and cognition of our environment and enabled us to go on to create a different world.

As a prerequisite, digitization predated accounting in pre-history. An immediate consequence of digitization is the way we categorize (or classify) observations to create data, confidence we place in the categories we create, and how we use those categories. Categorization is a central feature of accounting practice and regulation. Learning to categorize constitutes a large part of accounting education and training. We reflect on the properties and limitations of categorization, as well as the consequences of insufficient attention to limitations of accounting categories we create and prescribe in the form of accounting and financial regulations and rules. In the excitement about the power of digitization, we should not neglect to attend to limitations and potential blind alleys associated with digitization, which are equally important.

Keywords: Accounting, Digitization, Human Perception, Cognition, History
JEL Codes: B10, L51, M40

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Digitization, Perception, Cognition, and Categorization:
Consequences for Accounting

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Development of our perceptions beyond their analog origins to include digital modes was a key transformation that occurred long ago. It may well have distinguished genus homo from its predecessors. Being discrete, digitization necessarily discards at least some of the information contained in continuous analog magnitudes. For this reason, it is not obvious that digitization would prove to be a useful improvement and promote survival and flourishing of the species. Yet, as we now know, it has been a spectacular success playing a key role in development of human mind, cognition, and civilization. We examine how digitization altered the perceptions and cognition of our environment and enabled us to go on to create a new and quite different world.

Being a prerequisite, digitization must have occurred hundreds of thousands of years ago in pre-history, long before evolution of accounting. An immediate consequence of digitization is the way we categorize (or classify) observations to create data, confidence we place in the categories we create, and how we use the categories in our lives. Categorization is a critical aspect of accounting practice and regulation. Learning to categorize constitutes a large part of accounting education and training. Perhaps it is time to reflect on the properties and limitations of categorization, as well as consequences of insufficient attention to limitations of accounting categories we create and prescribe in the form of accounting regulations and rules. It is common to think today of the power of digitization. Attention to its limitations and potential blind alleys associated with digitization is equally important.

Perception

Let us start with human perceptions. We naturally experience our five sensory perceptions—vision, hearing, smell, taste, and touch—in analog, not digital forms. The sun is bright, and firefly is dim; lion's roar is loud, and cat's meow is soft; flame is hot, and snow is cold, etc. Numbers and accounting have become so ingrained in our modern way of thinking and living that it is easy to overlook the fundamentally analog nature of sensory perceptions. Digitalization of perceptions is not natural; it is a civilizational construct.

We share the analog nature of our sensory perceptions with other mammals as well as many other life forms. Our hominid ancestors perceived their environment almost entirely in analog forms on ordinal scales such as brightness, height, and heaviness, etc. Star X may be seen to be brighter than star Y (an ordinal relationship) but not twice as bright (a ratio relationship). Human sensory perceptions were in analog form, as they still are for animals as well as untutored humans who grow up in non-numerate, e.g., some tribal societies. We know that in some isolated non-numerate tribal societies without a developed number system, counting may be limited to one, two, three, four and five, followed by many. A father of ten may not be able to express the size of his family in a number, but has no difficulty noticing that Little Johnny is missing at the mealtime.

Without a numbering system and the ability to count (i.e., to associate the cardinality of the set being counted with a number), untutored humans and animals (including insects) can still perceive and compare magnitudes, such as understanding that basket of 20 apples has more than a basket of 15, and that the pheromone density on one ant trail is greater than on another.. However, without words for counting, accuracy of analog estimation declines. Gordon (2004, p. 496) reports: "Performance with quantities greater than three was remarkably poor, but showed a constant coefficient of variation, which is suggestive of an analog estimation process." Ability to perceive and respond to different analog magnitudes should not necessarily be interpreted as ability to think digitally and to count. Also see Pica et al. (2004) and Frank et al. (2008).

Digital Dawn

In some distant past that is difficult to know, perhaps 250,000-1,500,000 years ago, human ancestors transitioned from analog alone to a hybrid analog-digital perception of their environment. The initial objects of this freshly acquired digital perception may have been people, animals, trees and fruits whose discreetness could be directly perceived.

We don't know when the distinction between smaller and larger sets of people, animals or trees came to be concretized in the form of differences between their numerosity. But it must have happened long before numbers were conceived of, perhaps physical aids and supplements to memory played a key step towards the development of our faculties. Some of these aides remain in use to this day.

Fingers of our hands first, followed later by toes of our feet, that we can easily see and touch, were almost surely among the earliest of such aids to memory. Indeed, some readers may remember as do I using fingers to learn to count, add and subtract in early childhood. Human fascination with hands and fingers also appears in paleo-art on cave walls in all parts of the world (see Exhibit 1). Tally marks on cave walls purposefully made to keep track of somethings (Exhibit 2) and on bones (Exhibit 3) date from some 20-50 millenniums ago. In more recent history, various societies used strings and knots (Inca *kippu* in South America), seashells, cowries, and beads in various parts of the world. We do not know the objects whose numbers were being tracked by any specific surviving device. It could have been the number of animals hunted or the number of persons in the group. Whether the 29 notches on the Lebombo bone represent days in a lunar month remains in domain of speculation. Varied memory aides that have survived through history do suggest that many such devices were created independently in various societies.

(Insert Exhibits 1, 2 and 3 about here)

Symbolic Representation

In modern life, we are literally swimming in an ocean of symbols. They are everywhere around us in forms such as languages, writing, computers, currency notes and coins, traffic signs, fire alarms, statistics, social media and myriad others. These are human artifices that define the modern civilization. For early humans to recognize each discrete object or event and to record it in some physical form such as a line marked on a wall, must have required them to develop a heretofore novel cognitive faculty of symbolic representation. For example, each mark or bead may represent one animal, one sunrise or one person. Since there is little physical resemblance between, say, a deer and a wall drawing of the deer, this symbolic representation of one object or event by another was a huge leap in abstraction. Even a graphic representation of an anoa in rock art (see Exhibit 4) has little in common with a flesh-and-blood deer that the hunter sees. Acquisition of this new faculty may have been caused, or at least accompanied, by co-development of human brain.

(Insert Exhibit 4 about here)

This was a big deal because few other life forms possess this faculty. A great deal of what distinguishes us human beings from other forms of life involves symbolic representation and ability to manipulate symbols. Humans can create, represent, use, and manipulate symbols. This is of fundamental importance. Afterall, numbers, gestures, language, art, money, and communication are all consequences of the development of our symbolic representation faculty which is revealed in cave art. It is amazing and fortuitous that the human ancestors were able to represent real live animals and people before their eyes by drawings on their cave walls and seed the origins of civilization.

Numbers

Every school child learns, understands and uses numbers, 1, 2, 3, etc. Yet, if we ask, “what is 2?” some of us might point to two apples and two cars as examples in which “two” is used without actually answering the question. The answer is not necessarily obvious because despite its familiarity from early childhood instruction, number is an abstract concept and a human artifact.

While symbolic representation was a huge advancement in human development, symbols themselves are not numbers. While numbers can be and are often used as symbols, they have independent existence beyond their symbolic role. Numbers can be used as especial kind of symbols that demand a level of abstraction beyond usual symbols. Neither a hash mark nor a wall drawing of a deer is a number. Let us explore how the concept and meaning of numbers might have arisen in the distant past.

The origin of the concept of numbers lies in the recognition by some ancestor that two hash marks for two animals, two hash marks for two sunrises, and two hash marks for two arrows had a property that was common across the three very different objects or phenomena in our example, as well as across the hash marks that symbolized each set. For convenience, we might call this common property their “twoness”, and two is simply the label for this property. Similarly, properties of larger sets could be labeled three, four, and so on. Labeling of shared cardinality of sets of very different things was a stunning conceptual advancement at the root of digitalization of human cognition.

Amazingly, this idea of numbers could be applied to anything that is perceived in discrete units. By developing this abstraction of numbers, humans separated the numerosity of objects in a set from the objects themselves. Although our distant ancestors were primarily interested in real (experienced) things and events, their invention of numbers had revolutionary consequences for their lives, brains and for us.

At some time after they became aware of the common numerosity of various sets, human beings created labels for each level of numerosity. Sets sharing the "Twoness" property came to have a label two, and similarly for other levels of numerosity used within their own group, probably taking the form of sounds first, followed by written markings. These sounds may well have contributed to the development of language. We do not know what those sounds, and the earliest markings were. But we do have surviving evidence of markings from early history of China, India, Mesopotamia, Maya and many other civilizations (see Exhibit 5 for symbolic representation of decimal numbers in some societies).

(Insert Exhibit 5 about here)

The evolution of digital concepts and faculties was a major step in the development of human brain. Digitization is necessary for (a) classification of objects into categories (such as tree, animal, and person) and sub-categories (such as oak, maple and cedar tree); (b) tally marks, (c) numbers and counting; and ultimately to (d) development of language. Each of these steps must have taken a long time, perhaps tens of thousands of years, and was a major accomplishment towards creation of modern humans and their civilization.

Decimal has become the most popular number system in common use over the recent two millennia. Residual elements of other systems such as sexagesimal in units of time (60-minute hours and 60-second minutes), and Roman numerals on clock dials still survive. Modern digital computers use binary numbers (0-1 or off-on) which have been used in various parts of the world since the first millennium BCE. Popularity of the decimal system is related to human anatomy. Digit refers to fingers and toes and the digital label focuses on their discreetness. Our 10 fingers and 10 toes were, in most likelihood, the early instruments for counting as most of us did in the first grade.

Expansion of Digitization

Digitization arose from naturally discrete domains of people, trees, and animals, etc. However, for reasons we shall soon discuss, it did not remain confined to things that could be counted. Instead, it expanded to occupy continuous (analog) domains outside its discrete boundaries in an imperial march. We consider some examples of this expansion and explore why digitization covers so much of our lives today despite its manifest limitations of discarding information when applied to continuous analog domains?

Digitization is everywhere, including continuous magnitudes of temperature, height, time, brightness, sounds and economic welfare. Normal human body temperature is 37 degrees Celsius. Highest mountain peak is 29,032 feet above the mean sea level. A solar year has 365 days, 5 hours, 48 minutes, and 46 seconds. A

100-watt incandescent electric light bulb gives out 1,700 lumens of light. United States had gross domestic product of $23 trillion in 2021. Inability to hear sounds below 40 decibels implies mild loss of hearing. And so on. It is almost impossible to describe or visualize so much of our world and experiences without expressing them in digital form.

Why the Digital Expansion

As mentioned earlier, almost all our direct sensory perceptions take analog form and are inherently continuous. Distance, time, temperature and weight are four examples from everyday experience. You might respond an inquiry about your body temperature with "37 degrees Celsius", giving a digitized magnitude. This is not because you experience your body temperature in that form, but because you may have become accustomed to using a mercury thermometer in which the analog length of the mercury column is read out by numbers marked on a discrete scale. Early humans, like us, experienced degrees of hot and cold, not temperature measured in a digital number.

We have digitized just about everything around us even though digitalization discards information. Analog magnitudes of distance, time, and temperature, etc., are inherently continuous/ Representing them by numbers calls for discretization and rounding off by adding or discarding small amounts. This means that compared to true analog magnitudes their numerical representation always adds some noise; yet we see digitization everywhere.

Why has digitization been such a spectacular success? The explanation may lie in two critical features of digital systems. Although I shall mention only the decimal digital system, the argument also applies to many other number systems. One of them is a symbol to represent nothing—Sanskrit *shunya* (zero). Why have a symbol when there is nothing to represent? Yet, zero has added immense power and functionality to digital systems, allowing us to represent (in combination with place value system) numbers as large as we can imagine with mere two, five or ten discrete symbols with unimaginably great economy. It is possible that Nagarjuna's highly influential *Madhyamika* Buddhist or *Shunyavada* philosophy in the third century of common era may have led mathematicians familiar with this philosophy to propose a symbol for *shunya* in the century that followed.

The second feature is the place value system, so the magnitude represented by a symbol depends not only on itself but also on its relative place. Value of the same symbol in decimal system becomes 10 times larger, when it is moved one place to the left and 10 times smaller if it is moved one place to the right. These two features of our number system which likely spread to Europe and Arabia greatly simplified arithmetic operations using simple algorithms for addition, subtraction, multiplication, and division which are easily mastered by even first graders today. In combination together, zero and place value system allow us to represent numbers as large as we can imagine with only a fewdiscrete symbols with unimaginable economy.

As we learned to use numbers to represent our direct sensory perceptions, and scientific and socioeconomic phenomena, our cognition and how we see our world has been altered by digitization. For example, introduction of national income accounts in the first half of 20th century has changed how we see and deal with economic matters. Until ta century ago we could not know or compare the levels and rates of change in the gross domestic products of various economic systems. Most science, medicine, engineering and a great deal of production and logistics on which our civilization depends will not be possible without digitization. However, our immediate concern here is more limited and focused on the accounting. Let us turn to accounting.

Digitization and Accounting

Evidence from virtually all ancient civilizations—Egypt, Mesopotamia, China, India, Greece as well as others--reveals organizations, especially temples and the king's household, to be intensive users of numbers for accounting and accountability. Number of cattle, volume or weight measures of grain and other valued commodities were recorded by scribes who, almost always, had high status associated with their literacy, and quite likely to their ability to change fortunes of others by use of their control of accounts. Well-appointed tombs of scribes in Egypt, and archeological findings from Sumer and China present ample evidence of the wealth accruing to those who controlled the accounts and numbers. Kautilya's *Arthasastra* (3rd century BCE, see Kangle 1963) details how use of numbers to track operations, transactions, and inventory has been essential for kings as well as craftsmen, traders, and businesses over the millennia.

Twentieth century's technological innovations, first mechanical, soon followed by electronic, introduced a quantum leap in this well-established pattern of digital accounting. Costs in financial services used to be essentially variable, mostly costs of clerical salaries and office space, roughly proportional to the number of client accounts and transactions, etc. Development of digital technology has replaced these variable labor costs by largely fixed costs of software development and maintenance. This digital transformation has introduced great economies of scale in businesses where labor cost of keeping accounts was a major expense. These economies, in turn, have led to consolidation of banks, trading exchanges, and mutual funds, and introduced index and exchange traded funds (ETFs) which have substantially reduced the cost of trading securities. Rise of e-commerce in the recent decades is another example.

Digital technologies have enabled real time monitoring, managerial control, and auditing in many industries. For example, supervisors at United Parcel Service (UPS) know the precise location of each delivery vehicle and what their drivers are doing at any time (Gonnerman 2023). Point-of-sale (POS) systems enable retail industry to track their sales and inventory in real time not only at store but at the enterprise level and establish supply chain links to order replenishments. In the travel industry where empty airline seats and hotel rooms are perishable, digital technologies link reservation systems to pricing and promotions. Introduction of artificial intelligence and business analytics has rapidly expanded in auditing, facilitating quick and precise temporal and cross-sectional comparisons, forecasting, and visualization of data for decision making.

Limitations of Digitization: Classification and Human Motivations

However, the advances in computing and communications technology—speed, memory, detail, and analysis—need not blind us to two fundamental aspects of accounting and symbolic representation that remain essentially unchanged: classification and human motivation. Ignoring the consequences of these limiting aspects of technology will continue to bring disappointment and grief if not properly recognized by those with authority to write accounting and auditing rules and regulations.

Classification. All accounting requires us to classify or partition various objects, events, and transactions into a finite set of mutually exclusive and collectively exhaustive categories. That is the essence of accounting. Devising a scheme of classification requires us to specify the relevant attributes of objects of classification, and to choose cut-off points for each attribute to help choose the category in which each object is placed. For example, we may use a twelve-month cut-off point to determine if a receivable is categorized as a current or non-current asset. Most accounting classification schemes use multiple attributes of objects of classification.

The important issue worth noting here is that neither the selection of classification attributes, nor the selection of cutoff points, is made any easier or more efficient by the digital technologies. This issue is often ignored. Unless we are careful, greater computing power and memory may give us the illusion that technology does or will help us solve the classification problem. That is not the case. In fact, technology may make it worse. Let me explain why and how.

We live in a world of infinite detail. As in fractal mathematics, we can look at any element of our environment and find additional detail in it. There is no "finest" element because one can always get into additional finer details. This means that no two objects or transactions are exactly alike, and pursued in enough detail, every transaction is unique in some respects, and similar to others in some other respects.

Since the accounting ideal is to define and implement a uniform and consistent scheme of classification, we face a dilemma. If through classification, we seek to put any two objects or transactions with *any* similarity in the same class, we may end up with very few—even a single—class because most pairs will be similar in at least some respects. On the other hand, if we seek to put any two objects or transactions with *any* differences in different classes, we end up with each object in a class by itself. Neither the similarity nor the difference basis of classification yields a useful accounting system (Sunder 1984). Accounting rules and standards choose some specific attributes for classification, but that does not solve the dilemma of the uniform classification. In a world of multiple attributes relevant for classification, it is not possible to satisfy both the similarity and difference criteria by any classification scheme. Uniformity and consistency of classification by written rules in a fractal world is an impossible goal that the rule makers cannot resolve. Digitization does not help either.

Human Motivations. As discussed above, accounting rules and standards consist of attributes and cut-off points for classification of all transactions into a finite number of categories. Classifications implied by a given scheme has consequences for the people involved. If a person does not like the category in which a transaction is placed by the scheme, it may take one of two actions: (a) change the attributes of the transaction beyond the cut-off point so the classification scheme would place it in a preferred category; or (b) add new attributes to the transaction which are not covered by existing rules and claim that the classification scheme is inapplicable to the modified transaction to gain preferred classification (see Dye et al. 2015).

Both these phenomena have been played out repeatedly during the past century. Accounting rule makers have made over fifty attempts over six decades, without evident success, to get long-term leases capitalized on corporate balance sheets. Banking regulators have written Basle I, II and III rules in their attempts to limit the amount of risks banks are allowed to take, again without much evident success. Were the Basle I rules written by regulators who were not smart enough? The process is repeated because banks change their behavior in response to any given set of rules. This is the second (human motivations) problem.

Digitization of accounting does little to address the classification and human motivation problems described above. On the contrary, one might argue that a certain degree of misplaced confidence in the new digital computer-enabled power to impose regulators' will on companies may have worsened the problem.

Concluding Remarks

Commented [SS1]: Editor: Please note that I have moved the first two paragraphs of this section towards the end of this section.

Accounting is quite likely the first attempt by early humans to artificially construct a digital representation of their environment, first in their minds, but also in the physical world of cave walls, bones and wood that have survived to our day. Symbolic representation of environment and experiences were improbable and astonishing achievements in abstraction that appears to be unique to genus homo and its descendants. Physical evidence of this incredible achievement is available on cave walls in all parts of the world. We can only guess and try to infer the cognitive processes and advancements from surviving objects. Abstraction and symbolic representation may have been that the distinguishing characteristics of the brains of our ancestors. This model of symbolic representations succeeded so spectacularly, that today we often perceive many if not most aspects of environment in digital forms; even continuous magnitudes such as temperature, weight, and time are represented digitally, and not how our senses experience them directly.

In the recent century, the development of digital computing and communications technology have made significant contributions to accounting education practice and research. However, regulator's frequent misunderstanding of what is achievable by the power of digital computers in a world of limitless detail through written rules has repeatedly led financial reporting into blind alleys.

If accounting rule makers do not understand or recognize the fractal character of our world with its endless detail, they can easily acquire a false impression that digital revolution has increased their power to get their regulations implemented in practice and have their intended effect. Their taxonomies in accounting (as well as in banking and other domains of financial regulation) are evidently based on a false finite-dimensional concept of our environment. Failures of XBRL, IFRS, and Basle I, II, and III in achieving their respective stated goals arises from their failure to comprehend the nature of the challenge before them (Sunder 2011, 2016).

In the field of law, statutory laws are deployed in parallel with common laws, the first consisting of written rules and the second being a matter of social norms and community judgment. Even criminal courts make life-and-death decisions based on their judgment about social norms. These judgments cannot be based on written rules only. In a world of statutory law alone, they might enter the facts of each case into a computer and let it tell us if a crime has been committed. Judges and courts will hardly be needed. Perhaps one day, accounting rule makers will also learn from their failures, understand this limitation of written rules, and not be blinded by their illusions about the power of digital computers. No matter how powerful the computers may be, classification in a world of endless detail cannot be done by written rules alone; we shall continue to need judges and accountants.

Let us hope that accounting rule makers would learn from lawyers and the writers of Oxford English Dictionary in the 19th century. The language and meaning of world words is too wild to be tamed by written rules. In fact, excessive precision of meaning destroys a natural language, a topic for another day.

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Exhibit 1: Human Hands and Fingers in Paleo-Art from Argentina's Cueva de las Manos

(Accessed January 8, 2023: https://ichef.bbci.co.uk/news/976/cpsprodpb/C1C4/production/_101140694_c0116800-cave_of_the_hands_argentina-spl.jpg.webp)

Exhibit 2: Tally Marks in Jackknife Cave
(Accessed January 9, 2023: https://www.flickr.com/photos/badgerdx/4637001123)

Exhibit 3: Tally Marks on Lebombo and Ishango Bones
(Accessed January 9, 2023:
https://www.facebook.com/104277267987791/photos/a.153958599686324/24263274
0818909/?type=3&theater)

Exhibit 4: 44,000 Years Old Ancient Hunt on the Wall of a Cave in Sulawesi Indonesia
(Accessed January 9, 2023: https://www.nature.com/articles/s41586-019-1806-y/figures/2)

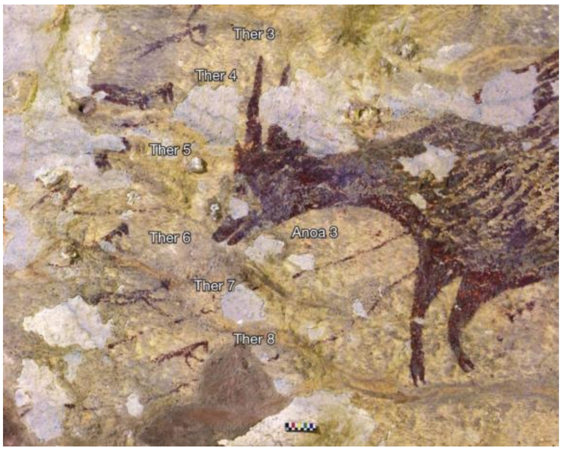

Exhibit 5: Decimal Numbers and Numeral Systems

Teresa Neves 2019 (Accessed January 10, 2023:

https://teresanevesblender.wordpress.com/2019/12/13/y02-numbers-and-numeral-systems/)

Modern	0	½	1	2	3	4	5	6	7	8	9	10	50	100	500	1000
Roman			I	II	III	IV	V	VI	VII	VIII	IX	X	L	C	D	M
Greek			Α	Β	Γ	Δ	Ε	ΣΤ	Ζ	Η	Θ	Ι	Ν	Ρ	Ο	Α
Sanskrit	०	१/२	१	२	३	४	५	६	७	८	९	१०	५०	१००	५००	१०००
Arabic	٠	١/٢	١	٢	٣	٤	٥	٦	٧	٨	٩	١٠	٥٠	١٠٠	٥٠٠	١٠٠٠
Burmese	၀	၁/၂	၁	၂	၃	၄	၅	၆	၇	၈	၉	၁၀	၅၀	၁၀၀	၅၀၀	၁၀၀၀
Chinese			壹	贰	叁	肆	伍	陸	柒	捌	玖	拾	拾伍	佰	佰伍	仟
Ethiopian	◆		፩	፪	፫	፬	፭	፮	፯	፰	፱	፲	፶	፻	፭፻	፲፻
Georgian			ა	ბ	გ	დ	ე	ვ	ზ	ჱ	თ	ი	ნ	რ	ფ	ჩ
Hebrew			א	ב	ג	ד	ה	ו	ז	ח	ט	י	נ	ק	תק	
Japanese	零	半	一	二	三	四	五	六	七	八	九	十	十五	百	百五	千
Javanese	꧐		꧑	꧒	꧓	꧔	꧕	꧖	꧗	꧘	꧙	꧑꧐	꧕꧐	꧑꧐꧐	꧕꧐꧐	꧑꧐꧐꧐
Korean		반	일	이	삼	사	오	육	칠	팔	구	십	오십	백	오백	천
Mongolian	᠐	᠑/᠒	᠑	᠒	᠓	᠔	᠕	᠖	᠗	᠘	᠙	᠑᠐	᠕᠐	᠑᠐᠐	᠕᠐᠐	᠑᠐᠐᠐
Thai/Laos	๐	๑/๒	๑	๒	๓	๔	๕	๖	๗	๘	๙	๑๐	๕๐	๑๐๐	๕๐๐	๑๐๐๐
Tibetan	༠	༡/༢	༡	༢	༣	༤	༥	༦	༧	༨	༩	༡༠	༥༠	༡༠༠	༥༠༠	༡༠༠༠