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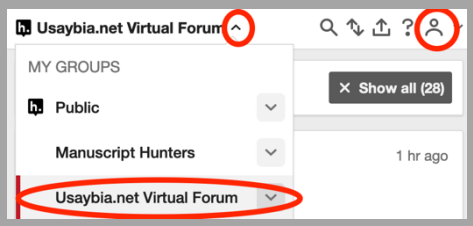

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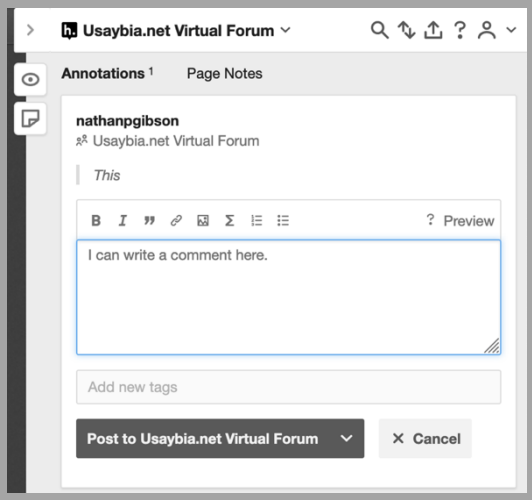

The Role of Traders in the Diffusion of the Indo-Arabic Numeral System in Antiquity

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Introduction

In this paper, we aim to answer a series of questions about the influence of trade on the diffusion of numerical systems. There are excellent historical accounts that focus on ancient trading, and others that focus on numerical systems. By merging information from these separately focused sources into a single narrative, our study aims to increase the understanding of the relationship between the development and influence of commercial trade and the adoption and evolution of improved numerical systems.

The most common system today for the symbolic representation of numbers is a positional decimal numeral system, commonly referred to as the Hindu-Arabic numerical system. It is a system based on a collection of glyphs or symbols, originally nine. Zero was a later addition, bringing the system to ten glyphs. The origin of zero has been a source of controversy, both when it appeared and where.

Indian mathematicians invented this system, between the 1st and 4th centuries AD. The glyphs were derived originally from Brahmi numerals, except for zero. The system was being used in Arabic mathematics by the 9th century AD, perhaps as early as the 7th century. The development of the numerical system was gradual, with a major step being Brahmagupta's conception of zero as a number in A.D. 628. After 700 A.D. the Brahmi numbers were replaced with zero and the decimal numbers. Here we will examine what is known about the relationship between trade and the Indian glyphs system that became the Indo-European numerical system.

Methods

Until recently the archeology of trade during antiquity in the Indian Ocean and the Red Sea has been largely discounted. Wrecks were hard to find and harder to get to, but among

other reasons for the discounting was the failure to understand the commercial importance of the conquest of Egypt by the Romans during the time of Augustus, Anthony, and Cleopatra.

However, the historical archive for this period is relatively extensive and complete. The Roman conquest of Egypt in A.D. 31 - including the Roman sack of the richest city in the known world, Alexandria, with tremendous wealth being moved from Cleopatra's hoard to Rome - also unlocked the Red Sea from Egyptian control. This allowed commercial travel by sea to occur between Alexandria and Felix ("Fortunate") Arabia and points east by Roman merchants in search of spices, and Indian merchants in search of red coral from the Mediterranean Sea and silver and gold bullion from Spain. The sea borne spice trade, funded by Egyptian wealth originally, moved between the Indian subcontinent and the Roman Empire and was two way, became vast, and was much faster and less expensive than the caravan routes of the time. Enough documents from this period have survived and proven useful in understanding the ancient trading enterprise and the use of numerical systems.

As a result, this paper mainly uses information assembled from the historical archive, such as the writings of Pliny the Elder and Claudius Ptolemy. A primary modern reference detailing ancient trading is Raoul McLaughlin's excellent study *Rome and the Distant East: Trade Routes to the Ancient Lands of Arabia, India and China* (2010), which describes in detail trade between Rome and India and the nature of the navigational practices involved in the Periplus of the Erythaean (Red) Sea. Likewise, a primary modern reference detailing the history of numerical systems is Amir Aczel's excellent *study Finding Zero: A Mathematician's Odyssey to Uncover the Origins of Numbers* (2015). Finally, we note The Man of Numbers: Fibonacci's Arithmetic Revolution, by Keith Devlin (2011). We draw upon these and other sources, such as the Muziris Papyrus. This document, from the 2nd Century A.D., describes a trading port on the Kerala coast of India and the financing of the trading vessel Hermapolion on its voyage from Alexandria to Muziris in search of spices. It returned from India with sixty boxes of nard from the Ganges, used in making perfumes in the Mediterranean world.

Results

Why did the Romans trade with India and need a productive numerical system?

The time was around 30 BC. First, frankincense and myrrh were needed for funerary and burial purposes in the Roman Empire. The upper and middle class ancient Romans burned their dead, where spices were burned as part of the process, mainly to cover up the odor of the burning corpses. A similar practice was practiced by the Jewish community of the time.

Spices were also needed in more mundane ceremonies of temple worship of the Roman gods. The Romans also used spices such as cinnamon and pepper, from India and Sri Lanka, throughout the Empire in the preparation and curing of salted meats.

It was not possible to grow such spices in the European climate. They had to be imported from Arabia and the East. Sailing down the Red Sea coast from Alexandria in search of trading zones for spices with reasonable ports was acceptable practice for the Romans after Egypt was opened. This involved a small amount of land travel from Alexandria to Red Sea ports such as Berenice, Myos Hormos, and Coptos, then down the Red Sea in large trading vessels to the Indian Ocean.

What is the primary evidence for Red Sea and Indian Ocean trade activity?

There is a document known as the Periplus of the Erythraean Sea (Red Sea) from the 3rd century AD, found in Alexandria (also referenced in McLaughlin 2010). This was essentially a map for traveling the ocean. It was written by an anonymous Greek merchant or captain based on personal experience in traveling the Red Sea and the Indian Ocean. It is believed to have been created in 50 A.D. It is thought that there were many such navigational aids in existence for the Red Sea and the Indian Ocean that have now been lost.

This map describes the lengths and conditions of the Red Sea routes used, key emporia and anchorage points along the routes, the disposition of the locals (hostile or not), and imports and exports of the region involved (see map from this paper, based on Lance Jenott, 2004).

By and large, such maps allowed traveling from anchorage to anchorage along the Red Sea and Indian Ocean coastline while traveling to and fro from the top (north) of the Red Sea. Such travel was slow, based on multiple overnight stops, but also provided an opportunity for trading along the way.

How did the Roman trade rhythms help to spread the Indian numerical system?

Seasonal monsoons across the Arabian Sea provided predictable wind propulsion of 6 knots per hour or better, 24 hours a day, to drive Roman merchant ships directly to the pepper rich southern India Tamil kingdoms and back. Hopping along the coast from sanctuary anchorage to port to sanctuary anchorage, and so forth, was no longer a strict necessity if you rode the monsoons, which the Romans learned by chance how to do it from a shipwrecked Indian sailor picked up in the Red Sea.

Thus, a direct voyage from Egypt to India could be carried out with proper exploitation of monsoon winds, which changed direction every six months, facilitating a return voyage. Roman ships with a destination to northern India would be required to cross 1000 miles of open ocean in seven days. Those following a southern course to Tamil India would be required to traverse 1,600 miles of open sea in just over ten days. Following a sea voyage from Egypt to India from Alexandria that began in July and lasted approximately 70 days, the Roman ships would be in an Indian port for approximately two months waiting for the wind to change direction. Usually Roman captains timed their voyage to reach India in early September when the monsoon was beginning to end and coastal trade routes were opening.

This gave merchants and crew on board time to locate desirable cargos, negotiate prices, and move and load items purchased. The trade winds would begin in again in November, and provide the propulsion to move the ship back to Egypt in December and January. The South West monsoon, which was a key for the voyage from the Red Sea to India, was named Hippalos after the Greek captain who first figured out the route by open water. The return voyage utilized the North East monsoon, with regular departures in December and January (McLaughlin 2010, Jenott and Lance 2004).

The point would be that the shipping costs when riding monsoons were nearly 30 times cheaper than land caravans riding camels or horses. It was also much faster, and it allowed linguistic and cultural information to diffuse across distances quickly, in addition to the physical commodities. Numerical systems were one conceptual item that diffused in this fashion.

Where did the Indian numerical system spread?

The Indian numerical system spread to the west and the east of the homeland of India. The spread to the east was aided by Buddhist monks and travelers on their way to and from southeast Asia (Burma, Cambodia, Malaysia, etc.). The spread to the west was aided by Indian astronomers spreading their new system to astrologers and astronomers in Persia and Iran, and also mathematicians in these areas. By 732 A.D. the new system had reached the House of Learning in Baghdad, Iraq. From Baghdad mathematicians such as Al-Kharizmi, who was Persian, wrote a landmark book called On The Calculation with Hindu Numerals in 825, and Al-Kindi, who was Arabic, wrote a four volume set called On the Use of Indian Numerals in

830. These works were largely responsible for the diffusion of the Indian system of numeration into the Middle East and Europe. (Devlin 2011).

The movement of the Indian numerical system to Iran to Iraq and then to Syria and Palestine and eventually to the Magreb and Spain and the Western Mediterranean was so rapid that it cannot be explained by other than sea trade. To quote McLaughlin (2010),

> *The early Roman system was successful because merchants involved in international business made such large profits that they could afford to pay the high-rate taxes imposed on the frontiers. The merchant community recouped these expenses by selling their eastern goods throughout the Empire to people with surplus money available to spend on exotic luxuries. The frontier tax was therefore an empire-wide tax on consumerism that made the businessman do the work of finding and extracting money from Roman communities who possessed disposable wealth. The Roman government paid out the revenues collected from mines and trade-taxes to the frontier Legions and wealth incentivized other merchants to supply the army for the sake of profit. Merchants were therefore performing the functions of army quarter-masters and wealth collecting tax officials (McLaughlin 2010).*

As the Roman Republic evolved into the Roman Empire during this period, it also changed its
army from a volunteer system of filling the ranks to a professional army. This change called for professional salaries for the legionares, and was a new and large expense for the government in Rome to fulfill. The sea-borne spice trade served to cover this additional expense in holding the borders.

How did three different forms of numerals (glyphs) perpetuate?

There were multiple forms of numerals (glyphs) in use in India at this time. There were no prescriptions or rules for what to use and when. This allowed differential borrowing of different forms. Arabian merchants chose to use what appeared to be the most useful glyphs from the Indian systems.

Three different forms of numerals (glyphs) arose in the middle ages. The borrowed or diffused "Arabic numerals" were introduced into Europe in the 10th century by Arabic-speakers from Morocco in North Africa (the Magreb). The numerals came to Europe proper usually by way of Andalusia. The first mention in Christian Europe was in Visigothic Spain (the Codex Vigilanus, written in 976 by three monks of the Riojan monastery of San Martin de Albelda). Gerbert of Aurillac studied in the Catalan abbeys for three years 967-969, where he focused on Arab science. He eventually became Pope Sylvester II in 999, a position from which he introduced a new model of abacus (the monastic Abacus of Gerbert), which utilized tokens representing Hindu-Arabic numerals. These were the Western forms of glyphs, eventually used with Latin, Cyrillic and Greek alphabets.

The glyphs known as Eastern Arabic were used with the Arabic script mainly in Iraq (a variant being used in Persian and Urdu). Brahmani glyphs (around two dozen variants) were

used in India and Southeast Asia, such as Bengali, Tamil, etc. The last were spread from India proper to the east by Buddhist missionaries and travelers.

Leonardo Fibonacci brought the Western Arab system from the Mediterranean port of Bugia, Algeria, where his father was a customs official, to Pisa, Italy. His book was *Liber Albaci* (published in 1202). It introduced Arabic numerals, zero and the decimal place system to European mathematics from the 12th century. It entered common use, replacing Roman numerals, from the 15th century, when they began being used in early typesetting. But Fibonnaci's introduction of the Western Arab system was limited to learned circles. Widespread understanding and usage of the positional notation in the general population was the result of a German pamphleteer Adam Ries, who wrote a book for apprentices of businessman and craftsmen in 1522 (Devlin 2011).

How did the diffusion of Arabic numerals follow the initial expansion of Arabic trade?

The initial expansion of Arabic trade involved extensive and complicated trade networks, seeking what the central Abbasid lands, being resource poor, lacked. This included wheat from Syria and Egypt, rice from Egypt, southern Morocco and Spain, olive oil from Tunisia, "ondanique" steel from India, iron from Europe, tin from the British Isles and Malaya, and silver from northern Iran, Afghanistan, and the Caucuses. Multiple agricultural advances occurred during a vast expansion of trade.

The diffusion of Arabic numerals followed the traded items up the Red Sea from 30 BC after the Roman conquest of Egypt by Octavian (Augustus). From this time on the Romans had access to the Indian Ocean and India, Sri Lanka, and other points in Asia. Over 120 large Roman merchant vessels per year departed from the top of the Red Sea to southern India to support this trade. This does not count the trading vessels coming from India to Sri Lanka and thence to the top of the Red Sea. But this type of trade was initially slow because it was characterized as "coasting" day by day when sailing along the Red Sea coast (see above for description of the Monsoon system).

What was the effect of the Golden Age of Arabic Cultural Advance?

The Golden Age of Arabic Cultural Advance occurred from 750 AD to 950 AD (over two hundred years), and supported a vigorous cross-fertilization of "once isolated intellectual traditions". Translation projects were carried out on books originally written in Greek to Arabic to Latin in the House of Wisdom in Baghdad (various disciplines translated included texts in math, medicine, and geography, etc.).

Many different scholarly communities participated in the concomitant diffusion of the Indo-Arabic numerical system from India. This diffusion included Iraq and thence to Alexandria, Tunisia, and then to the African littoral and to the Magreb and to Spain, including the Zorasturians, the Nestorian Christians of Syria, the Normans of Sicily and southern Italy, and others.

What were the effects of Roman taxation?

Taxes on spice were crucial to the support of the Roman treasury, being the main salary support of the Roman legions guarding the borders of the Empire. In fact, a main reason for the Roman invasion and conquest of Egypt was to establish control of the spice trade and to tax it. In the entire Roman Empire, the two areas that provided the most revenue to the Roman Treasury were Egypt and Asia Minor. These two provinces not only provided the resources to patrol and control their own borders, but provided financial wherewithall to support the poorer Roman provinces of Britain and Gaul. Many public works, such as public bathing houses, aqueducts, water systems, fortifications and roads were also paid for by the spice tax.

Taxation requires a productive numerical system. The enormously large spice trade was heavily taxed by the Roman government. All imports were taxed at their real value at the borders of the Empire before they were allowed to enter. The Romans used multiples of 1/100, which are equivalent to percentages, before there was a decimal system. The normal tax was 25 percent of the value of the item.

Conclusion

The Spice Trade through the Red Sea and the Indian Ocean had a continuous and prosperous life up until the age of Portuguese African expansion and the time of Columbus and the Spanish explorations in the New World. At that time, both nations sought a route that could reach India and the spice fields by traveling around Africa or sailing directly across the Atlantic to the New World and beyond to the Spice Islands. This was necessitated by two factors: 1) the onset of the Mongol invasions disrupting trade routes across the Middle East, and 2) the expansion of the Arab empire into the central and eastern Mediterranean by 700 A.D., with the same result. By the time the Mediterranean routes settled down into their normal activity and direction, the new numbers from Arabia also stabilized and were inserted into the new print medium available in Austria and Germany.

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