Perception Times of Numbers and Detection of Geometrical Talent

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Abstract

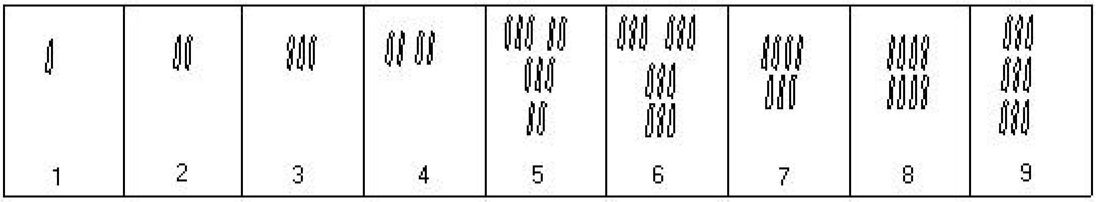
It is a very remarkable and well-established fact that in the human brain at least two different mechanisms of number –perception have evolved. For the first three natural numbers 1, 2 and 3 a mechanism called "subitizing" is in action and these numbers are perceived in almost equal times of about 500 msec. For higher numbers another mechanism operates and the perception times become gradually longer. We wanted to investigate the question, whether different presentations of numbers such as sets of randomly distributed dots or geometric figures (regular or asymmetric polygons) could effect the perception time. The result is definitely yes and there emerge many surprising phenomena. The perception time can be significiantly shorter or longer depending on the form of presentation of numbers. For example, numbers in form of random patterns of dots are perceived more speedily than numbers in forms of orderly aligned bars. Another effect is that geometrically talented pupil have significantly shorter perception times for geometrically presented numbers. This could possibly be helpful as a test for detecting distinguished geometrical talent.

Key Words: Perception times of numbers, subitizing, geometrical talent.

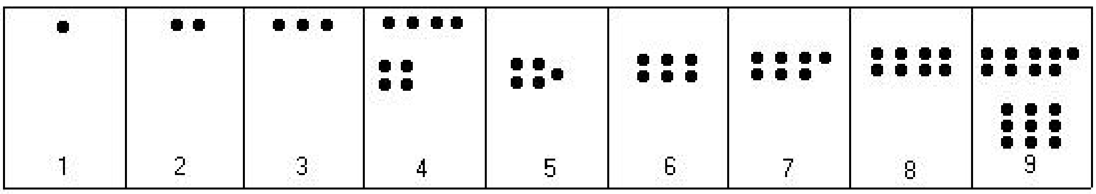
Introduction

It has been known to psychologists for more than a century that there is a strict and very low limit on the number of objects that we are able to apprehend immediately. For an excellent exposition (and to a certain extend modelling and explanation) of this phenomenon see Dehaene [1],. (See also Ifrah [2]). This limit can directly be read from the following short list of notations of numbers through different cultures and centuries (fig 1).

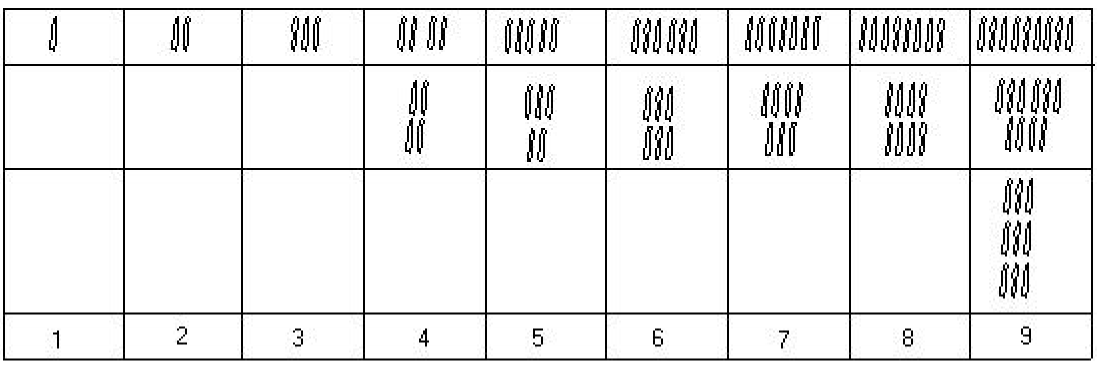
Egyptians: Hieroglyphic Symbols



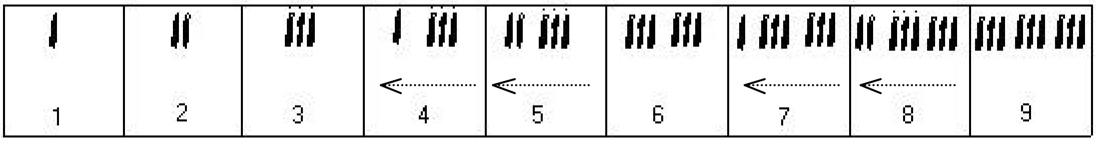
Greeks: Epidauros, Argos and Nemea Symbols



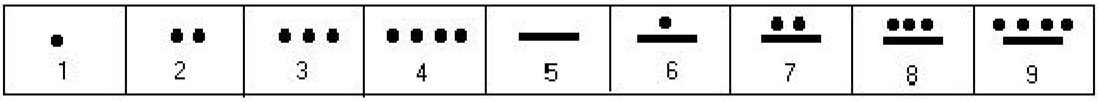
Hittites: Hieroglyphic Symbols Anatolia



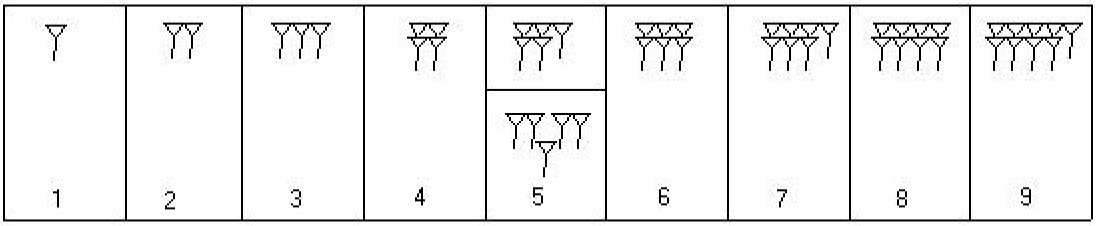
Lydians: Anatolia



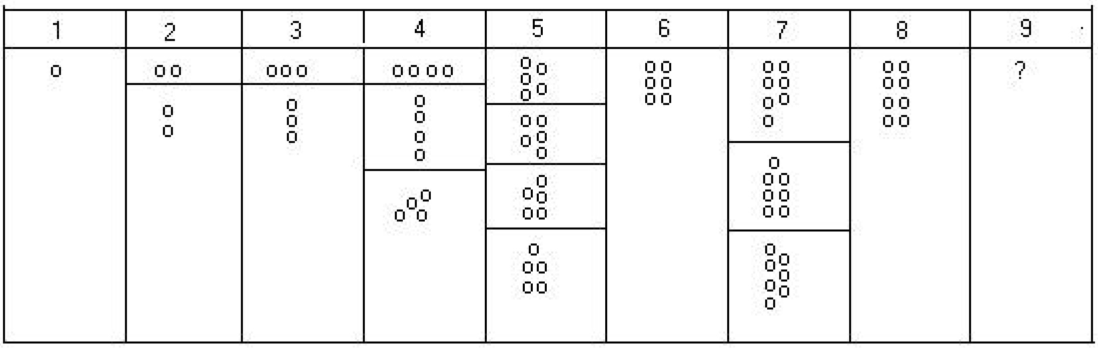
Mayan: Before Colombus Middle America



Mesopotamians: Sumerian Cuneiform Symbols



Urartus: Hieroglyph Symbols



Etruscans

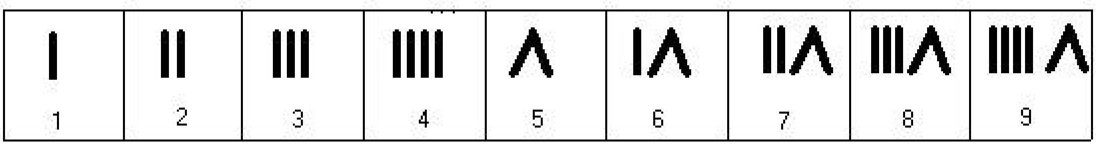
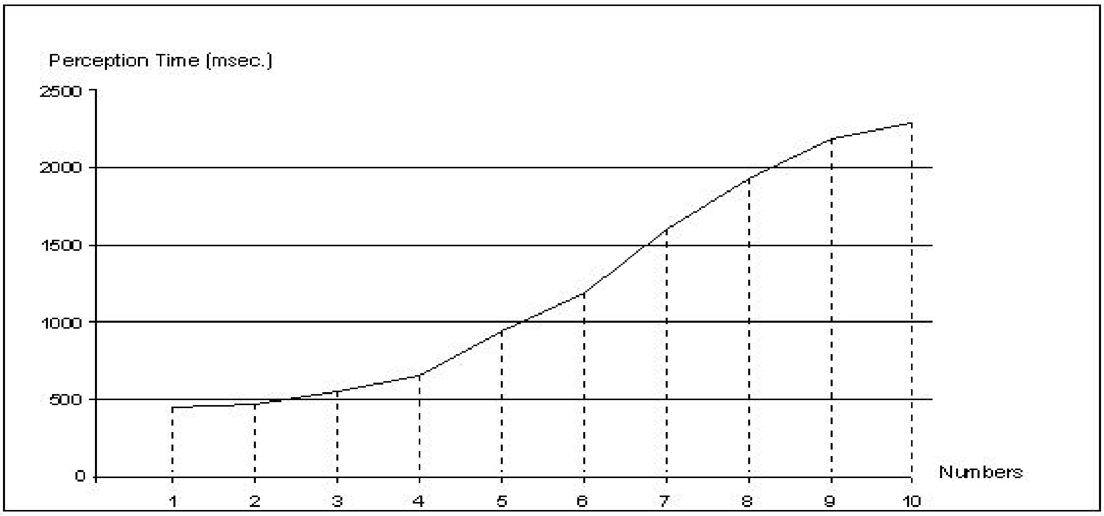


Figure 1

It is very remarkable and must be more than an accident or intercultural influence that the first three (or at most four) numbers have a most simple and natural representation whereas with the fourth (or fifth) number a new kind of notation begins. In many cases an obvious process of restructuring or decomposing of new numbers beyond three is discernible, but in some cases three has no such simple mechanism; various organizational principles and preferences seem to emerge and evolve.

The perception-time measurements are in accordance with this observation. This is defined as the time to name a number of bars (or dots). Numerous experiments (s. [1]) gave the result that the first three (or four) numbers are recognized "immediately" in about half a

second (which is probably the physiological lower limit to recognize any well-defined object consciously) and beyond three (or four) a steadily increasing time of recognition is required.
We give below an example of our own measurements made on a group of 30 adults (with ages between 20 and 50, who had at least secondary school education). The numbers were



presented as sets of orderly aligned vertical bars.

Figure 2

For this immediate recognition the term “subitization” or “subitizing” is used. It seems to be an inherent difficulty of mankind to comprehend large numbers instantly and nominally; therefore internal relationships between numbers are used as clues to understand, to name and to represent the numbers and this process takes time: Several seconds for the man, several millennia for mankind!

This state of the affairs stands in sharp contrast to the image processing and pattern recognition capabilities of the homo sapiens. The reason for this discrepancy could be sought in our evolutionary roots and might have to do with the fact that quickly recognizing the types of animals would bring more advantage than counting their exact number.

This point of view was our starting point and leading motive for the present work: Could it have an effect on perception-time, if we use different presentations of numbers such as randomly distributed dots or geometric figures? In this work we used regular polygons as geometric figures whose edges represent the numbers. (We plan to use biologically meaningful figures in future work.)

Perception-Time Experiments With Computer

We designed two experiments. In the first experiment we used the group of 30 subjects referred to above and presented the numbers as randomly distributed dots or regular polygons on computer screen. (see fig 3).

The computer was connected with an electronic circuit especially designed for this purpose with a button easily usable by the subject. When the subject pushed the button, a figure appeared on the screen and when the subject pushed the button again, the figure disappeared. The subject was instructed to push freely the button, try to recognize the number, and then when he believes that he recognized it, to push the button again. We declared that, the correctness of perception was more important than the speed of perception; but he should try to perceive the number as quickly as possible also. After he pushed the button twice, we asked him to name the number. The perception-time was measured and recorded by computer. In the evaluation we discarded the wrong answers, which were less than 2 percent of all tries. In every run, every subject was shown 100 figures from the same series (either randomly

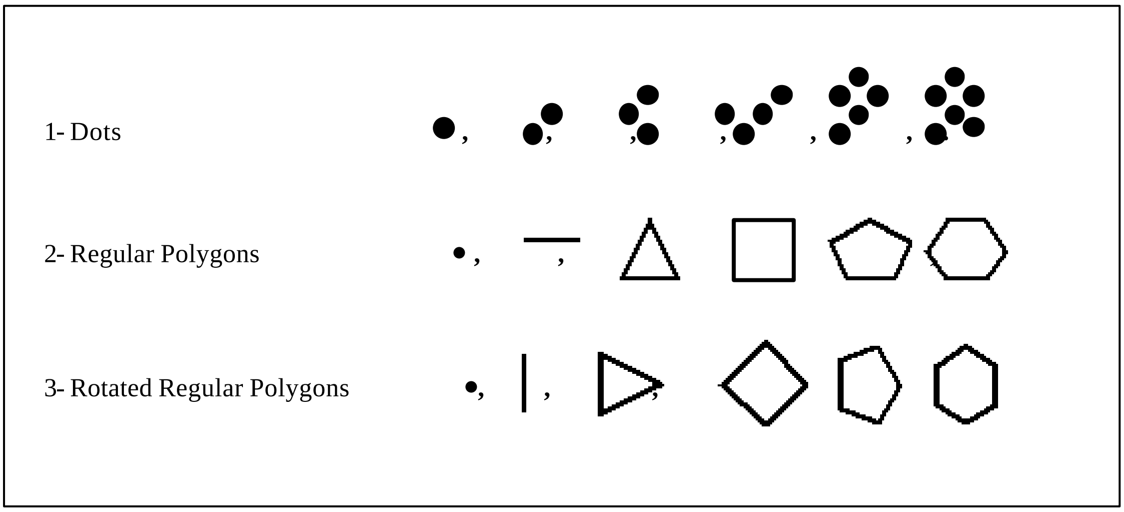


Figure 3

distributed dots or regular polygons or rotated regular polygons) and these figures were chosen randomly by the computer from 1 to 10. Even the placement of these figures on the computer screen was random (they occupied less than one quarter of the screen area). We then computed the average perception-times of the subject for all numbers from 1 to 10 and than took the grand average over all subjects.

The results are shown in Figure 4 together with the result of bar-perception from figure 2. (Figure 2 was obtained by applying the same procedure).

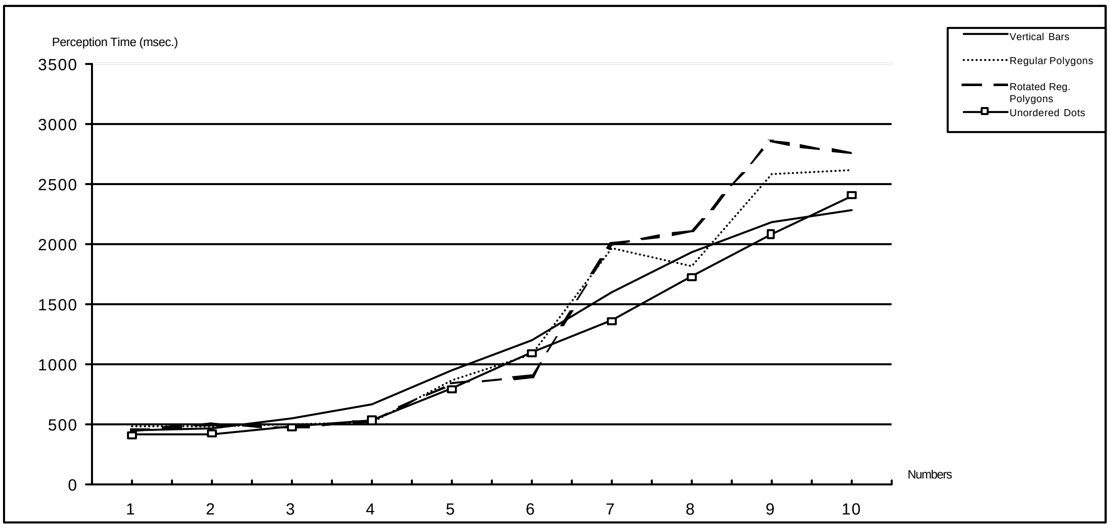


Figure 4

During this experiment we noticed that several subjects showed a remarkable phenomenon. They recognized geometrically presented numbers in clearly lower perception times. This was an indication for us that a kind of geometric talent or inclination could be reflected in perception-time measurements. This phenomenon led us to design the following second experiment. In a secondary school we determined, according to the evaluation of their teachers, the following two groups: The first group (a total of 20 pupils) was successful in geometry lessons and the second group (a total of 17 pupils) was successful in algebra lessons but not so successful in geometry as the first group. We then applied our method of the first experiment to these two groups and used the series of vertical bars or rotated regular polygons (from 1 to 8).

The results are shown in figure 5 and figure 6.

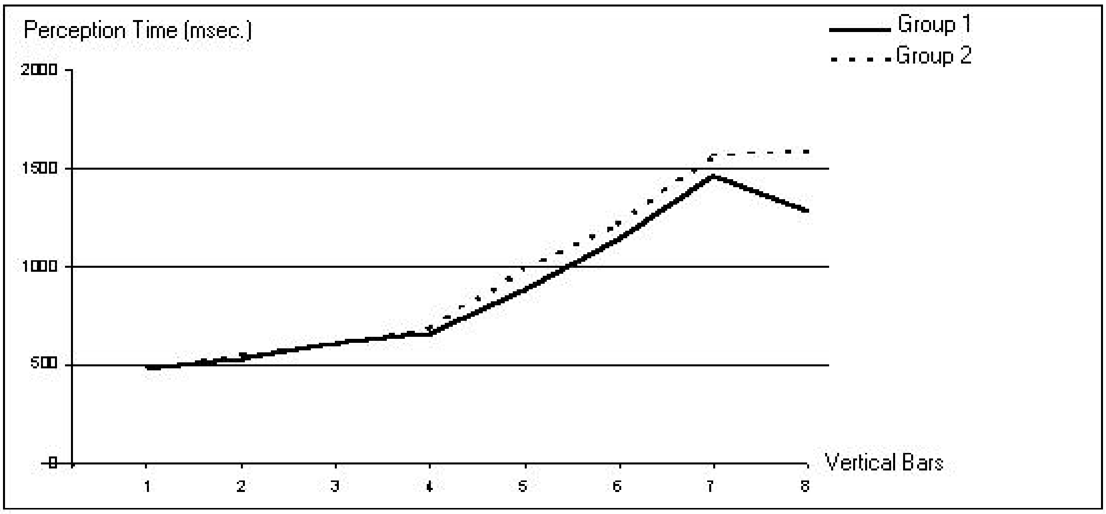


Figure 5

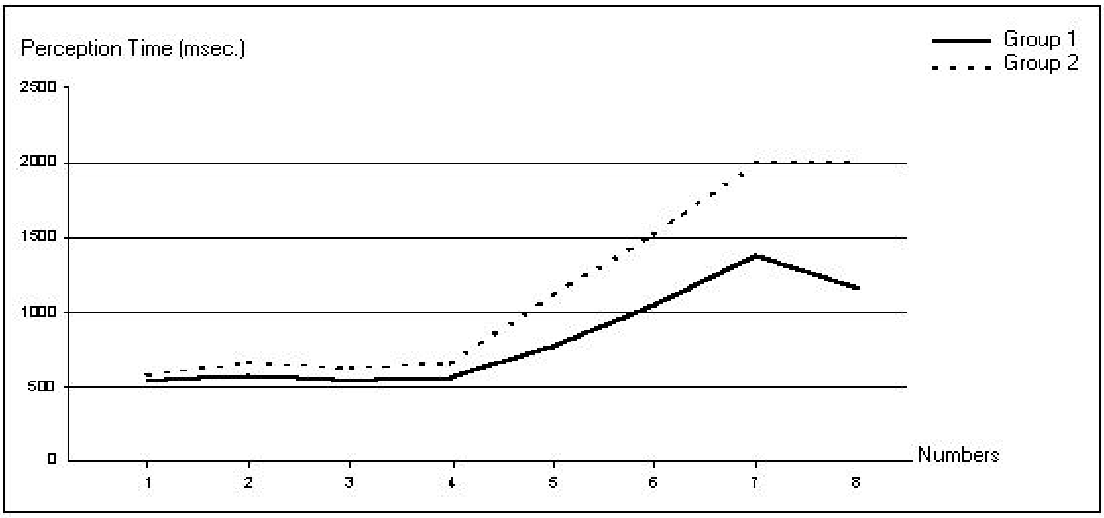


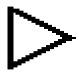
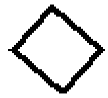
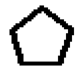
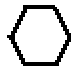
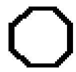
Figure 6

Discussion

In our opinion, the most important conclusion of the first experiment (figure 4) is that numbers presented in form of randomly distributed dots are perceived in most cases in shorter times than numbers presented in form of vertical bars or rigid geometric polygons. The reason might lie in the fact that in nature we are seldom exposed to vertical bars or rigid polygons but very often to small groups of unordered objects. At this point we regretted that we didn't use more biological representations, but we shall do it in a future work.

As curiosities we want to note that a regular octagon is perceived in shorter time than a regular heptagon and a rotated regular hexagon is perceived in shorter time than a regular hexagon in normal position! This value is even shorter than the time for six unordered dots.

The conclusion of the second experiment is that pupils with success in geometry lessons do have significantly shorter perception-times than the other group, if the numbers are presented by geometric objects (regular polygons). We verified this by doing statistics with t-test also. For 5% significance level and one-sided comparison ($t > 1.645$) we had the following table, which means that for numbers 3 to 8 the difference in perception times was significant. (see the table below)

Figures								
t	0.807	1.353	2.174	2.505	4.635	4.905	3.732	5.538

When the numbers were presented by vertical bars, then perception times for 1, 2, 3 and 4 do not differ, the perception times for 5, 6, 7, 8 are slightly shorter for the group successful in geometry lessons, but not significantly.

We believe that this second experiment could be developed into a test for detection of geometrical talent.

References

[1] S. Dehaene, The Number Sense, Oxford University Press, New York, 1997.

[2] G. Ifrah, Histoire Universelle Des Chiffres, Editions Robert Laffont, S. A. , Paris, 1994.