



ХҮМҮҮНЛЭГИЙН  
УХААНЫ  
ИХ СУРГУУЛЬ  
*Бүтээлч оюун ухаан таны ирээдүйн амьсгал*

# Verbal and mathematical thinking: Ideas to explore

Chuluundorj.B

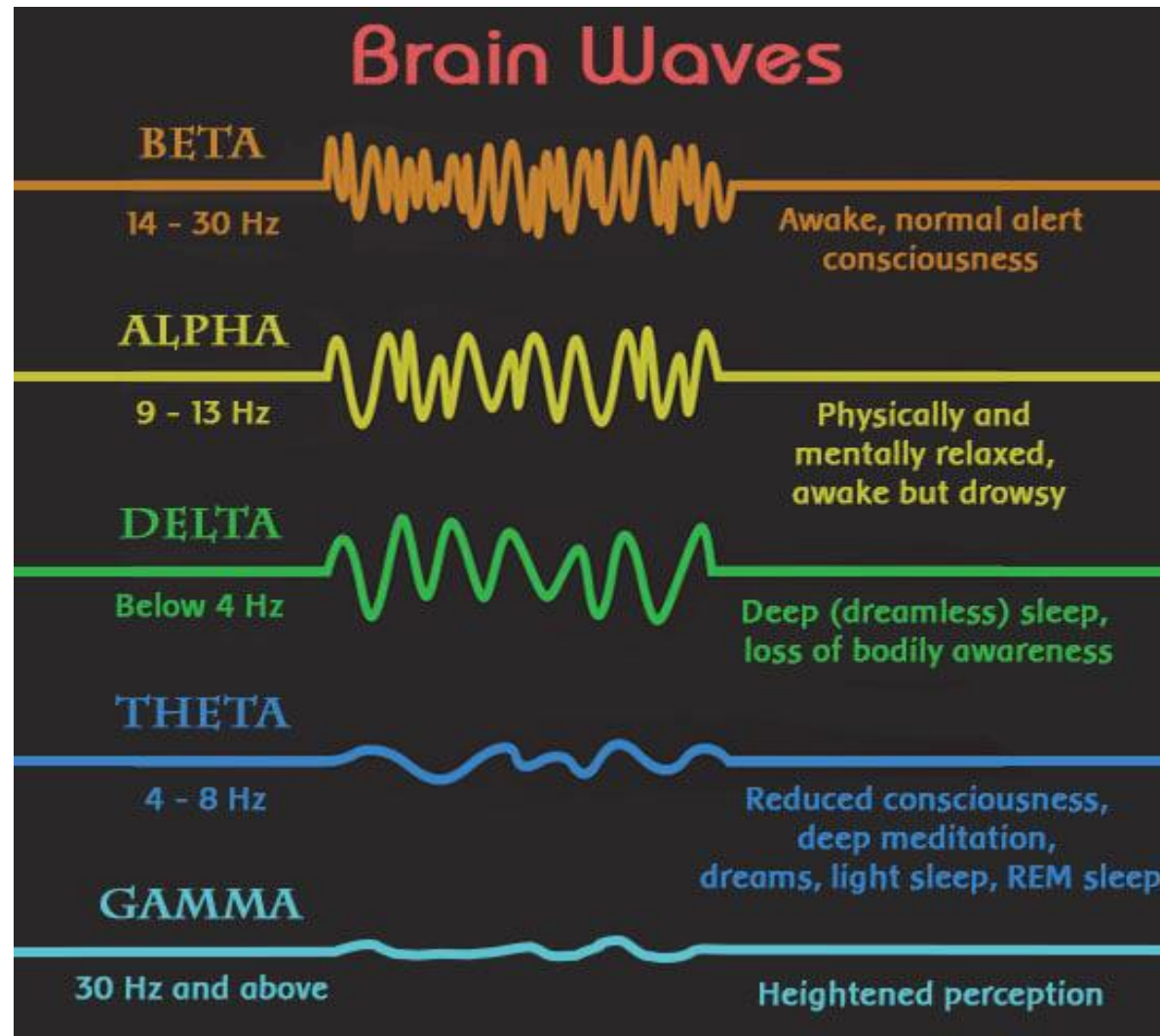
2018

## 1. Methodological issues:

Brain mind and information processing - a reductionist approach - biological phenomena are reduced to chemical and finally physical models – wave - particle duality.



Adaptive representational network (ARN): an acquisition, storage, distribution and utilization of energy are most critical adaptive problems for all life forms.



Connection between basic cosmic waves (electromagnetic waves) and energy waves in the brain (alpha, beta, theta, delta, gamma)

Beta waves (14-30 Hz) - concentration at the beginning of meditation.

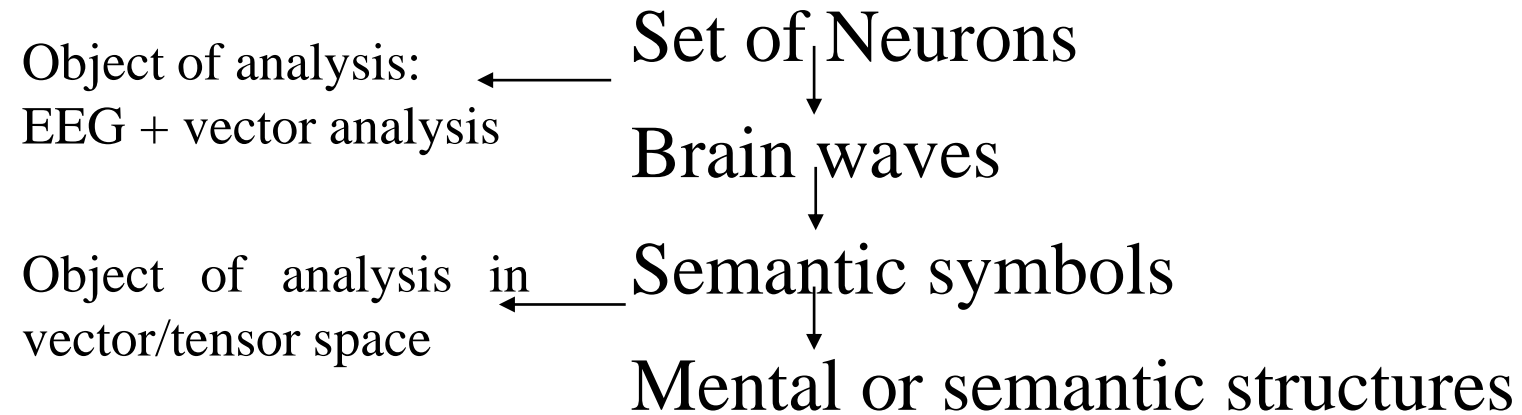
Theta waves (4-8 Hz) - dream like imagery, a gateway to subconscious, creativity, to learning and memory.

Alpha (9-13 Hz) - deeper states of consciousness, developing a creativity and problem solving, mind concentration, transmitting mind forces to others in unique “spiritual” space.

Delta waves (0-4Hz) - a signal of the subconscious, intuition, Wisdom.

Gamma waves (30Hz and above) – meditation, highest level of enlightenment.

## 2. Vector analysis



According to Civen der Malsburg, brain states may be regarded as semantic symbols.

The semantic symbols  $\approx$  subsets of the set of all cells in the brain.  
(Nervous structures with dynamical links. 1996, Germany)

Semantic symbols + brain waves  $\longrightarrow$  to describe the mechanism transforming brain energy to spiritual power.

Left hemisphere – mathematical and verbal cognition, logical functions

Right hemisphere – whole image, skills, emotion, intuition

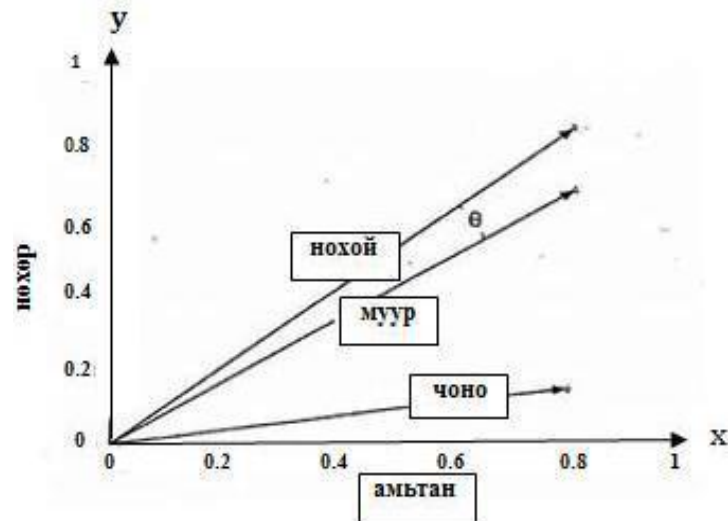
Broca's area – sp.production, Wernicke's area – sp.comprehension

## Euclidean and non – Euclidean geometry:

Human memory organization: Words and numbers, verbal and number operations

Two-dimensional semantic (metric) space - a distance between components of subsets is measured by using standard Euclidean distance function:

How an information is stored in human mental space (semantic memory)



**нөхөр**-friend,  
**амьтан**- animal,  
**нохой**- dog,  
**муур**-cat,  
**чоно**-wolf.

$$d(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$$



Cosine of two vectors (Euclidean dot product) must be applied to analysis of distance between components of a set.

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{i=1}^n A_i \times B_i}{\sqrt{\sum_{i=1}^n (A_i)^2} \times \sqrt{\sum_{i=1}^n (B_i)^2}}$$

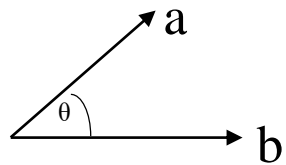
Similarity based mapping of objects, events (goods meeting same customer needs, duplicated or common components in a set.

Similarity measurement – Vector or scalar (only magnitude as a speed, distance, volume, charge, time, temperature, mass, age)

Cosine similarity function

$(\cos \theta = \frac{\sum_{i=1}^V x_i \times y_i}{\sqrt{\sum_{i=1}^V x_i^2} \times \sqrt{\sum_{i=1}^V y_i^2}})$  is used in measuring angle between two vectors

the cosine angle between the two input vectors.



$$\cos \theta = \frac{\textit{Adjacent}}{\textit{Hypotenuse}}$$

Cosine similarity is applicable to analysis of values or benefits affecting custom decision making (as comparison of two vectors using angular distance between them)

## Visual perception

Retinotopic perception (visual pathways, visual area of the brain)

Non – retinotopic perception - time – of arrival theory: time – of – arrival into a spatial code – arrival times for the different parts of the figure to perception.

Geometrical representation of the inputs into linearly – separable internal representation (manifolds)

Manifold is an object in which each point has neighborhood that is equivalent to a neighborhood in Euclidean space.

Multi – sensory (audio visual) representations linked to motor representations.

Decision boundary is the result of fusing adjacent Voronoi e' cells that are associated with the same class. (Distance based models. Chapter 8)

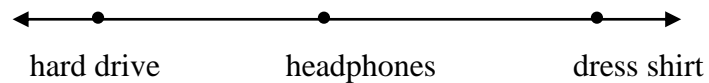
Case for Neuromarketing:

Customer valuation of product

Sensitivity metric of consumer value perception

Product whose features, characteristics and overall value:

- can be evaluated before purchase (hard drive hard disk)
- difficult to gauge /measure/ in advance (dress shirt)
- Hybrid - headphone



Vector space analysis of consumer's product valuation and benefits

Values: Cultural values – socio - cultural environment, beliefs (*CV*)

Personal values – closely linked to needs (*PV*)

Consumption values – elegant house, prestigious car etc. (*CoV*)

Benefits: social benefits – social status (*SB*)

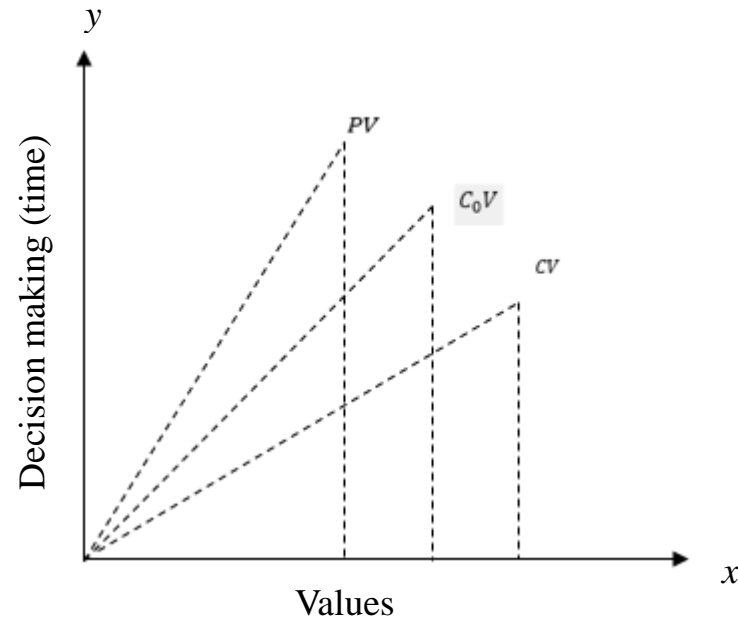
affective benefits – feelings (*AB*)

functional benefits – concrete attributes for using (*FB*)

epistemic benefits – curiosity, novelty (*EB*)

aesthetic benefits – sense of beauty (*AeB*)

## Vector analysis



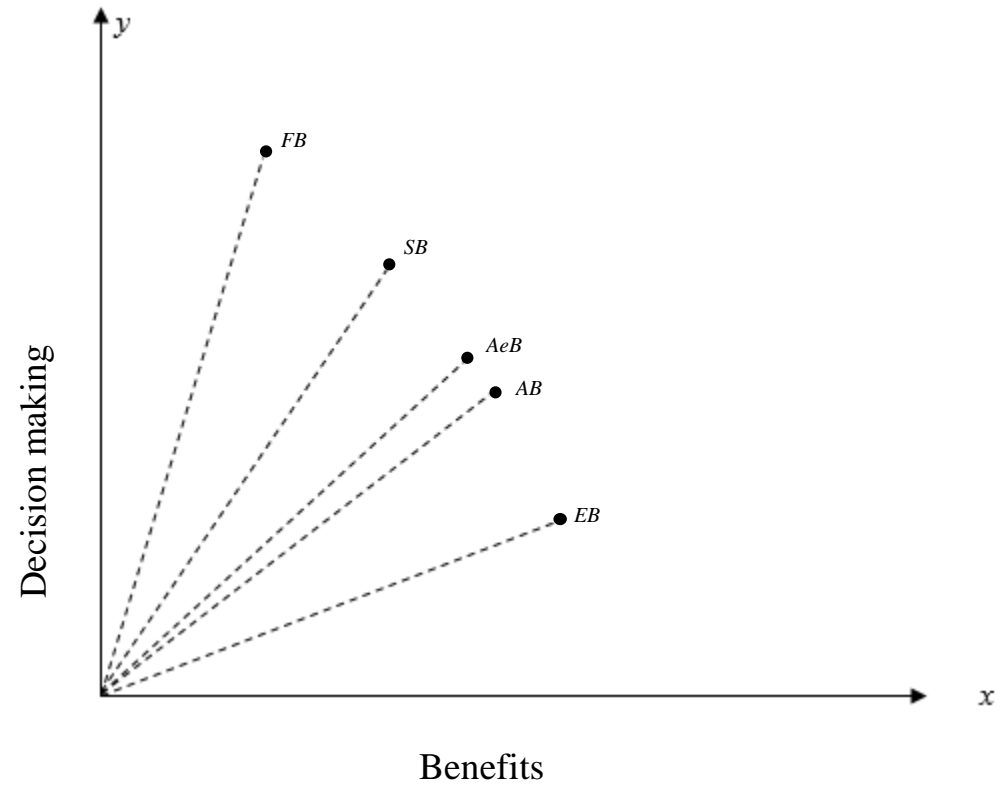
Euclidean dot product formula

$$A \cdot B = \|A\| \|B\| \cos \theta$$

$$\text{similarity} = \cos(\theta) = \frac{A \cdot B}{\|A\| \|B\|} = \frac{\sum_{i=1}^n A_i B_i}{\sqrt{\sum_{i=1}^n A_i^2} \sqrt{\sum_{i=1}^n B_i^2}}$$

*(A<sub>i</sub> and B<sub>i</sub> are components of vector A and B respectively)*

## Metrics and distance

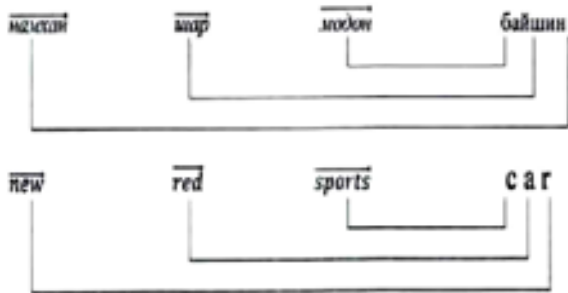
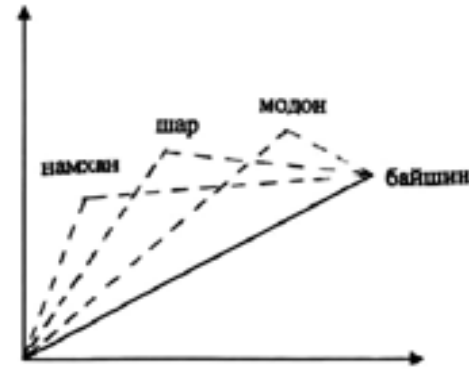
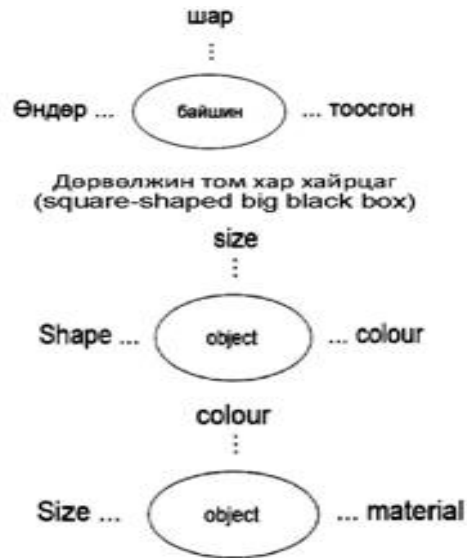


$$d(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$$



Similarity of attributive features of object (size, color, shape etc) is a reflection of human perception in mental space:

Distributional functions are linear motions on semantic vector/tensor spaces.c



To compare a number sequence , sequence of object properties , sequence of values in human perception

Classification (clustering) of objects according to a degree of similarity between them.

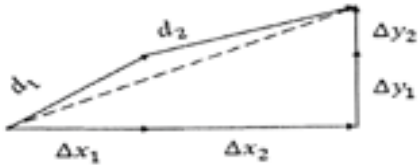
Color	Cost
Size	Taste
Material	Healthy

Information about different choices → value representation – to evaluate the potential outcomes related to different choices – neural computations.

Product features and imagination – interaction between memory and decision making – geometric space contains economic value representation in decision making.

## Vector addition and multiplication

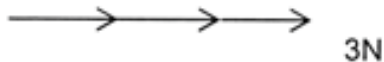
$$F_{net} = \sum_i F_i = F_1 + F_2 + F_3 + \dots$$



$$d^2 = \Delta x^2 + \Delta y^2, \quad \tan \theta = \frac{\Delta y}{\Delta x}$$

$$d = \sqrt{\Delta x^2 + \Delta y^2}, \quad \theta = \tan^{-1} \frac{\Delta y}{\Delta x}$$

Resultant force of three constituents:



Vector sum of all forces (common effect of components) – linear transformations.

Mixed effect of semantic and pragmatic forces – NON-linear transformations

Mixed effect of product values or benefits └── Linear effect  
└── NON - Linear effect

Vector addition

$$PV + C_0V + CV$$

$$F_{net} = \sum F_i = F_1 + F_2 + F_3 + \dots$$

Resultant force of three constituents



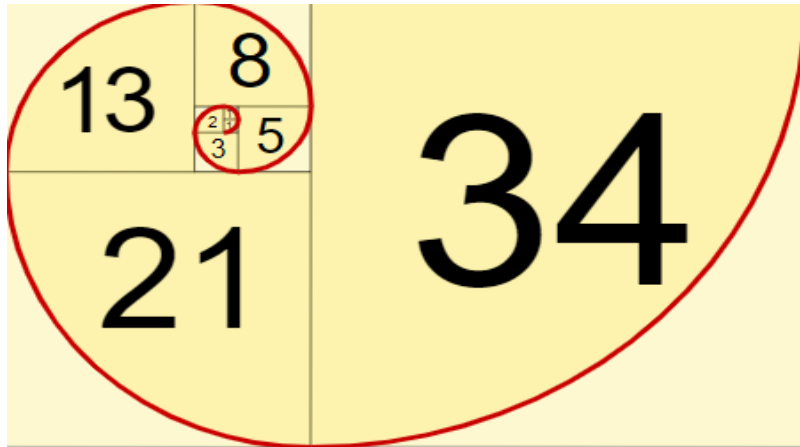
Vector/tensor space: Advertising space on the Internet - the primary source of revenue – sale of advertising space - Nash equilibrium – Game theory. (Nash, John Equilibrium points in n-persons game 1950. NAS)

### 3. Number sequences and operations Linear and exponential growth (function)

Comparison of the spontaneous activity of the brain neurons with the random properties of the sequence of prime numbers can shed certain light on the problem. Whether mathematics belongs completely to the outer world or it is a production of our brain activity. All types of information are encoded by nerve cells into sequences of pulses of similar shape. Brain neurons use sequences as main instrument for intercells connection. (A, Bershadskii. Hidden periodicity and chaos in the sequence of prime numbers).

### Fibonacci Sequence

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, ....



For example 5 and 8 make 13, 8 and 13 make 21, and so on



This spiral is found in nature!

Where is some similarities (or basic differences) between number sequence (weight) of values, benefits

### Arithmetic Sequence

In an Arithmetic Sequence **the difference between one term and the next is a constant.**

Constant – based Linear changes

### Geometric Sequences

In a **Geometric Sequence** each term is found by **multiplying** the previous term by a **constant.**

Linear and *NON*-linear changes:

$\leftarrow r \rightarrow$

$r^2$

$r^3$

...



Primes behave almost like a crystal (quasicrystal) (can only be divided by 1 and themselves). Different materials (atoms) produce different X-ray diffraction patterns → one-dimensional strings of particles as a long prime sequence.

Repetitive structures in music, rhythmic beats and looping breaks (Beatles' song, Mozart effect) have analogy to mathematical structures and number operations in spatial-temporal reasoning.

Sequence of components in verbal and visual perception and its reflection in sequence of syntax components

*adj 1    adj 2    adj 3    adj 4    N*

Хуучин жижиг хүрэн модон байшин

(Old    small    brown    wooden    house)

*adj 1    adj 2    adj 3    adj 4    N*

New    Japanese       red    sport    car

$$(a + b)m + (c + d)n$$

*c    d    n    a    b    m*  
*Намхан цэнхэр хаалгатай өндөр төмөр хашиа*

*a    b    c    d    e    f    j*     $(c + d)n + (a + b)m$   
 Old large wooden house with extra bedroom decorating.

$$(a + b + c)d + (e + f) \cdot j$$

Sequence of components as a reflection of object features or properties (size, color, shape etc) → weight – based sequence of values or benefits of a product.

## Number operations

Number (and vector) operations in relation to verbal structures

addition and multiplication in verbal and other mental structures

Хар цамц (black shirt) Хар шөл (meat soup), Хар шөнө (dark night), Хар санаа (hostility)
---

$$1+1+4=2\times 3$$

$$1+4+1=3\times 2$$

## Order of operations

BEDMAS (PEDMAS)

B-Brackets

P-Paranthesis

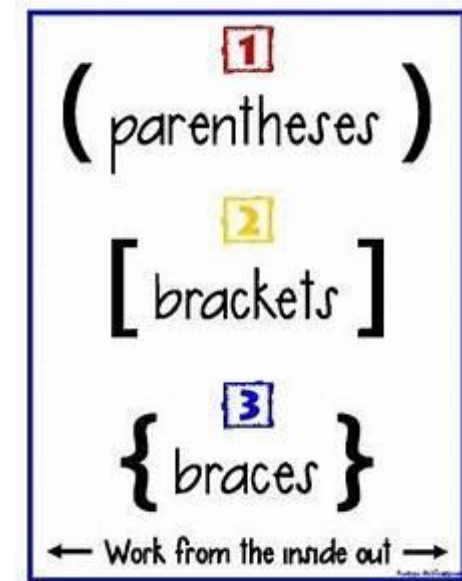
E-Exponents

D-Division

M-Multiplication

A-Addition

S-Subtraction



PEMDAS presents an effective instrument of analysis at discourse level.

Order of Operations

Do things in Parentheses First

$$6 \times (5 + 3) = 6 \times 8 = 48$$

Exponents (Powers, Roots) before Multiply, Divide, Add or Subtract

$$2 + 5 \times 3 = 2 + 15 = 17$$

Multiply or Divide before you Add or Subtract

$$2 + 5 \times 3 = 2 + 15 = 17$$

Following propositions must be described in terms of BEDMAC and PEMDAS.

1. Гэр хорооллын оршин суугчдыг орон сууцтай болгох – public housing
2. Байрны зээлийг бага хүүтэй олгох – decreasing loan percentage
3. Эрчим хүчний хангамжийг шийдэх – improving electricity delivery
4. Утаа арилж агаарын бохирдол буурах – cleaning up the smoke and reducing air pollution
5. Хүн амын эрүүл мэндэд учрах эрсдэл буурах – decreasing health risks for people

Propositions {1; 5}  
Propositions (2; 3)  
Propositions [(2+3) · 1]  
Propositions [4+5]

Concluding proposition:  $5 \times \{[1 + (2+3)] \times 4\}$

————→ text analysis in computer science.

“Мэдээлэл, мэдлэг, бодол санааг горизонталь ба вертикал сүлжээнд логик, учир шалтгааны шаталсан болон шугаман холбогдлоор нь эрэмбэлэх”

# Matrix/text

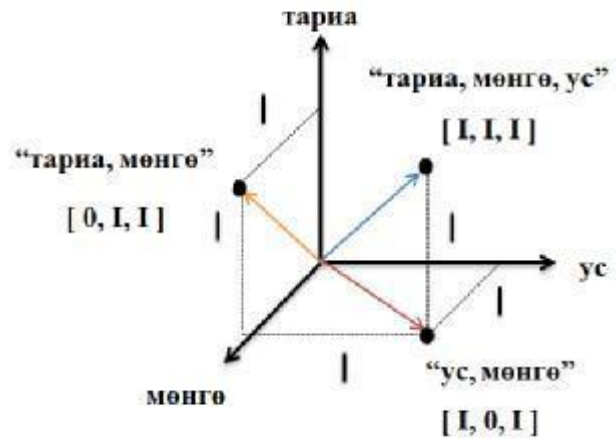


Fig. Similarity measure-inner product

	ус	тарна	мөнгө
doc_1	1	1	1
doc_2	1	0	1
doc_3	0	1	1

Table. Vector space similarity

Problem identification and problem solution are case for analysis in Euclidean and NON – Euclidean space.

Complex Problem solving space:

Traffic game: problem demographical change -  
unemployment in provinces – city physical devpnt  
planning

Lung health – air pollution – unemployment in  
provinces.                    ↓                    ↑

housing -                    Lack of financial - heating (power)  
support                    system

Text/data analysis -sequence of propositions (эрэмбэлэгдсэн мэдлэг)

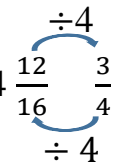


Order of number operations - Randomization of text (data) structures according to its degree of significance, hierarchy of logico-semantics relations. Order of operations also supports to predict a transition to next semantics or structural components, to build logico-semantics tree of a text, web.

## Prime factorization

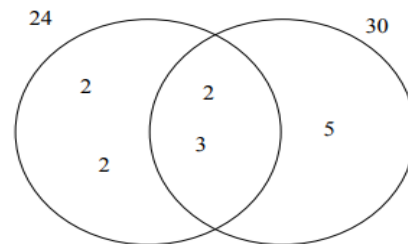
GCF is used to simplify common factors reducing largest common factor.

GCF of 12: 1, 2, 3, 4, 6, 12 /  
of 16: 1, 2, 4, 8, 16 / can be simplified:  $4 \frac{12}{16} \frac{3}{4}$

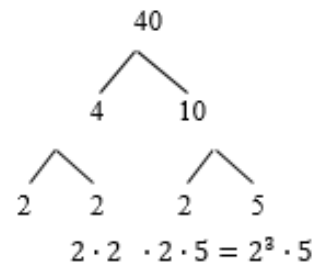
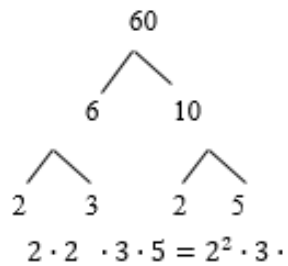


		Оюутан	Student	Студент
1	to study	+	+	+
2	university/college	+	+ -	+
3	gender	-	-	+

According to Venn diagram,  $\text{GCF}(24, 30) = \underline{2} \times \underline{3} = 6$ , prime factorizations:  $24 = 2^3 \times 3$ ;  $30 = 2 \times 3 \times 5$



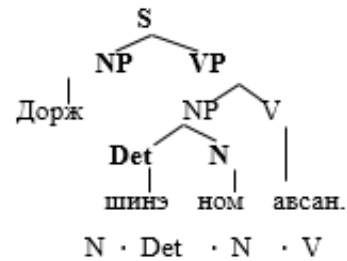
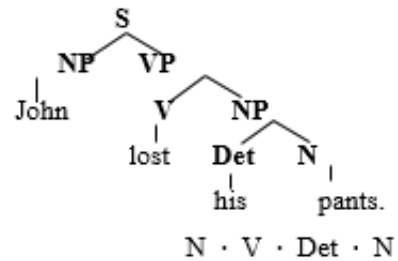
Prime factorization of 40 and 60.



List of ALL of the prime factors: 2, 3 & 5

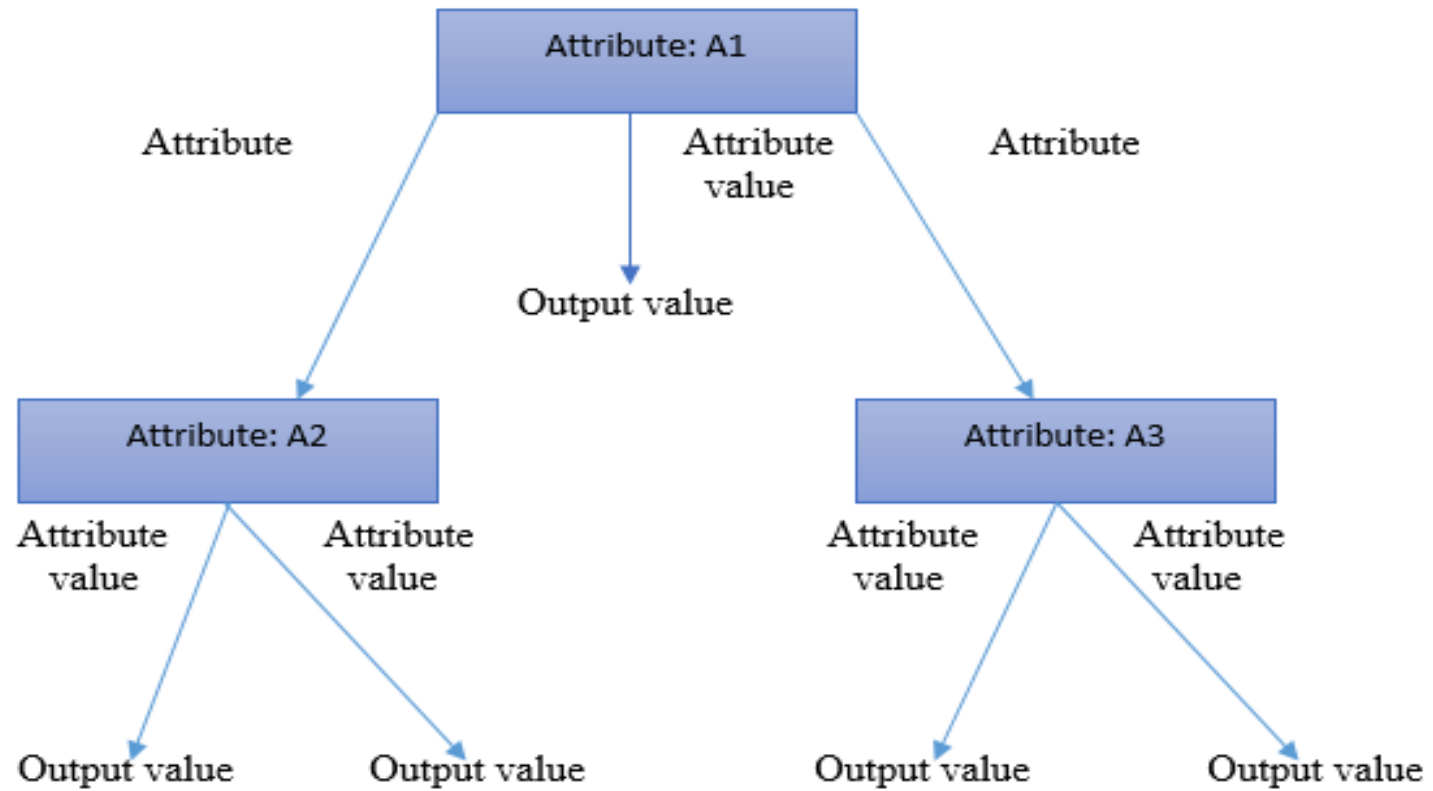
Complete list of factors:  
**LCM** =  $2^3 \cdot 3 \cdot 5 = 120$

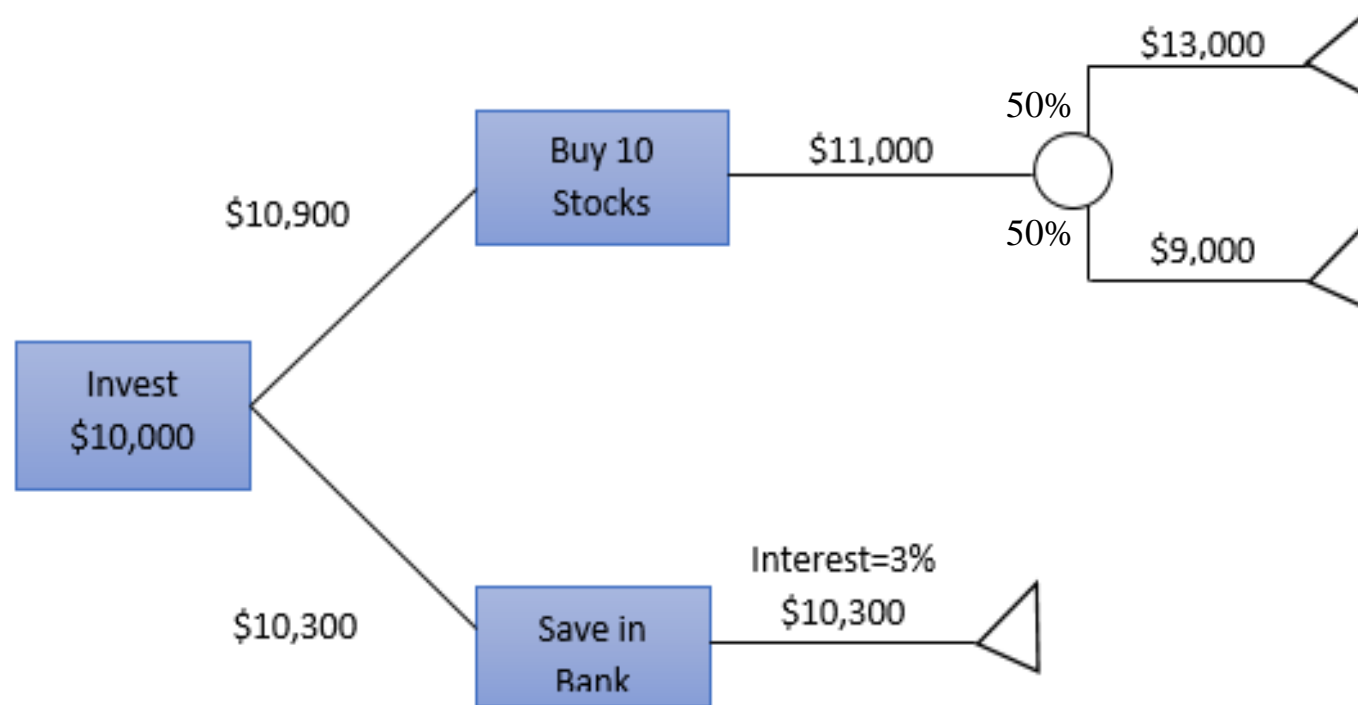
Following trees present another case to use **GCF** in the syntax:



Prime factorization must be applied in natural and social sciences to:  
 clustering of objects and structures.  
 analysis of complex problems leading into subproblems  
 building decision tree

## Factorization in building Decision tree





LCM multiplication operation must be applied to description of common semantic component in metaphor:

The country went from conflict to peace building.

Brain went from sad to happy.

multiples of 3:3, 6, 9, 12, 15, 18 ... /  
multiples of 5:5, 10, 15, 20, 25 ... / LCM=15

In above named sentences, cohesion between N and V leads to semantic transformation → metaphorical thinking.

Metaphors on economics:

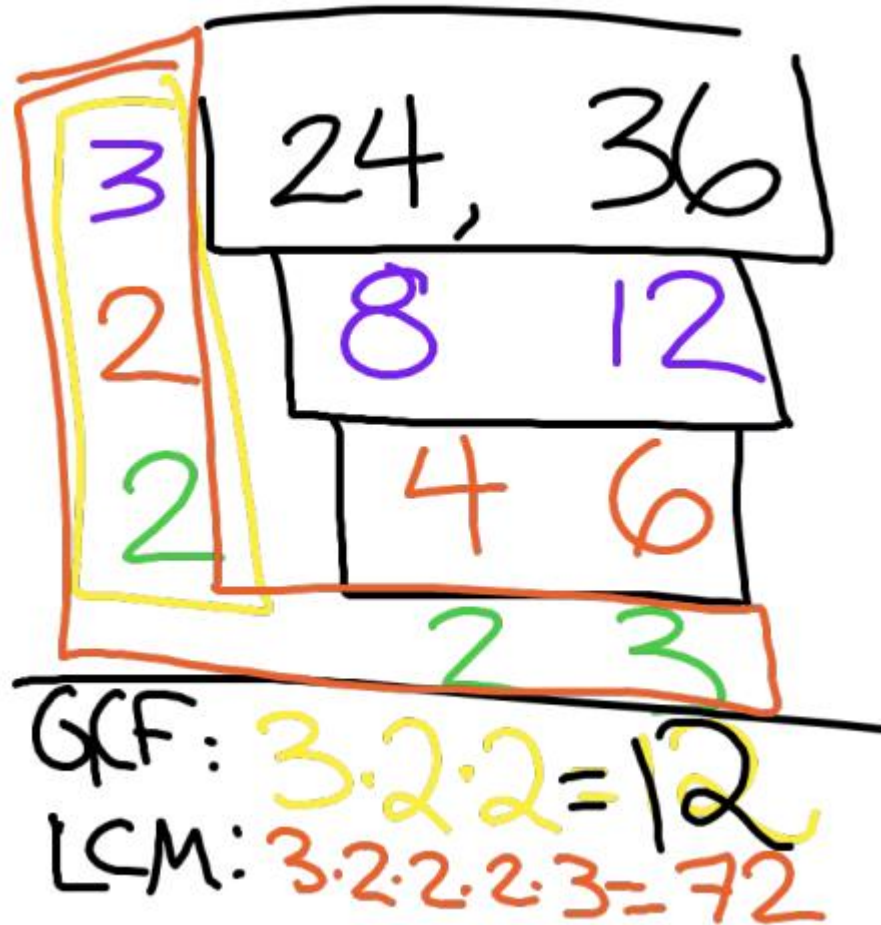
A useful metaphor for production in an economy comes from the kitchen

Economic growth springs from better recipes, not just from more cooking

In human relational economics a few individuals or a few states are richer than the whole nation or even than the global village!  
How is this to be entertained in terms of its LCM?

# Cake Method (Ladder method)

To find GCF and LCM of 24 and 36





Number theory → to cryptology, digital signatures, user identification, breaking of codes (of computers or credit cards)

Factoring digits to find a prime number → to secure or break codes. RSA algorithm (Rivest R.L, Shamir A, Adleman L; A method for obtaining digital signatures and public key cryptosystems ACM V.21. 1978) is used for on-line transaction today.

RSA algorithm uses prime factorization GCD (greatest common divisor  $\approx$  GCF) of a large number into its constituent primes. (GCD (54, 24)=6)

Cryptography or encryption - logging your credit card in the bank transaction - prime factorization (world's largest prime number have 23, 249, 425 digits)

Quantum computer – quantum simulator means a new way to factor a large number.

**THANK YOU**