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Vector-Based Approach to Verbal Cognition

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A comparison of human mental space to a vector space is an effective way of analyzing of human semantic vocabulary, mental representations and rules of clustering and mapping. As such, Euclidean and non-Euclidean spaces can be applied for a description of human semantic vocabulary and high order. Additionally, changes in semantics and structures can be analyzed in 3D and other dimensional spaces.

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It is suggested that different forms of verbal representation should be analyzed in a light of vector (tensor) transformations. Vector dot and cross product, covariance and contra variance have been applied to analysis of semantic transformations and pragmatic change in high order syntax structures. These ideas are supported by empirical data from typologically different languages such as Mongolian, English and Russian. Moreover, the author argues that the vector-based approach to cognitive linguistics offers new opportunities to develop an alternative version of quantitative semantics and, thus, to extend theory of Universal grammar in new dimensions.

Keywords: verbal cognition, mental representation, verbal mapping, semantic space, scalar, vector space, tensor model, dot and cross product, eigen space and eigen-value.

I. Introduction

Multidisciplinaryapproach to a study of human verbal thinking considered the human mental space as an infinite mental continuum. Notions of Continuum (Cantor) and cardinality of sets are basis for measuring a mental lexicon, capacity of semantic memory and mechanism of human verbal mapping. Therefore, mental spaces must be presented as Euclidean and non-Euclidean spaces. Hilbert space generalizes the notion of Euclidean space and extends the methods of vector algebra from the two-dimensional Euclidean plane and three-dimensional space to spaces with any finite or infinite number of dimensions.

Semantic and pragmatic forces as constituents of human mental spaces present objects of modeling in terms of vector (tensor) space. As such, these mantic space, as a kind of human mental space, must be presented as vector space and semantic field - as a vector field. Language comprehension is symbolic through interdependencies of modal linguistic symbols embodied through references. Grammar is an emergent product of distributed auto-associator and pattern associator networks. In auto-associator network, all neurons are both input and output neurons. This is one of the reasons to apply vector (tensor) space theory to an analysis of mechanism of embedding input signals and organization of knowledge about the human mental space.

According to researchers of Max Planch Institute, semantic network can be treated as having directed and undirected links (Ana, S. M., Henrik, O., & Lael, J.S. CS. 2013. 37/1 P 129). It means that semantic sets as a fuzzy sets with links between nodes are the constituents of vector (tensor) space.

II. Vector Representation of Word Meanings

Spatio-temporal patterns of human mental lexicon, semantic vocabulary are the specific object to apply vector (scalar) method.

Human verbal perception of an object depends on particular coordinatization systems, of its intrinsic and extrinsic features. Intrinsic features of space-time (curvature, metric tensor) are objectively real. Artifacts of subjective coordinatization, particularly of verbal thinking spaces are extrinsic features. Embedding in neural associative sets has reflected combination of intrinsic and extrinsic features that caused semantic changes, transformations, and pragmatic interpretations.

According to researchers, the probability that a word and an object are paired is inversely proportional: the strength of the associations between that word and all other objects present on that trial (A-b, A-c, A-d); the strength of the associations between that object and all of the other words present within the trial (B-a, C-a, D-a) (D. Yurovski., C. Yu., & L. B. Smith. CS. 2013. 37/5 P 912).

The words in associative sets have values and links (directions), which mean that the associative sets of semantic vocabulary are an object of modeling in vector space. While concrete words can be represented

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within a single neural network, abstract words can be appointed to a substantial degree of links between representations in different neural networks (working associations). Concrete words share features ("taxonomic similarity"), whereas abstract words share contextual association. An experiment on associative semantics in Mongolian language illustrates the fact that concrete and abstract words differ in their association structure (Cognition and Information. University of the Humanities. 2002. UB. P 8).

Super-distributed representations serve to incorporate two or more noun concept representations, ad hoc creation of a contextual association. According to the experiment conducted at the University of the Humanities, association structure of abstract words in verbal cognition of children served as one of the markers of their cognitive development. Experiments on Mongolian language with participants, aged 3-4, have shown that verbs are strongly dependent on their contextual associations. Sharing of contextual associations is closely connected to generalization of words in semantic and pragmatic networks in clued memory ("**нарны хаалт** **<u>асаах</u>**"–"to switch an umbrella"-instead of "to put up one's umbrella";"**чихэр тайлах**"–"to take off a candy" -instead of "to unpack a candy", etc.).

Thus, abstract verbs are more dependent on ability to maintain the associations in analogy to abstract nouns.

Introducing scalar field to analysis of localization and interconnection between words of different classes (sets) in human semantic vocabulary has methodological significance.

Scalar-based modeling of human mental lexicon was shown by experiments on measurement of semantic spaces between words, conducted in psycholinguistics laboratory of the University of the Humanities (IJALEL. 2013. 2/4 P 192). Moreover, vector dot product is ($a \cdot b = \|a\|\|b\|\cos\theta_{ab}$) a powerful tool for modeling localization of different classes of words in human mental space and connections of these classes with different regions of the brain. A similarity in the distance between word groups can be measured by applying law of cosines and law of sines to vector product. A good illustration of this is experiments on associative links between words (**ор→буйдан, тохой→өвдөг**) in children's memory. For example:

"Please, take a play from the bed (go to the sofa)."

"Please, wash the elbow (knee)."

Upon a stimulation, such as parent's request, children use relevant for them associative links, and a distance between these "associated" words must be measured by using law of cosines: $a^2 = b^2 + c^2 - 2bc \cdot$ cosA. Stimuli (verbs) are a starting point for measuring a similarity (or a magnitude of associative relations) between words at the time of their response.

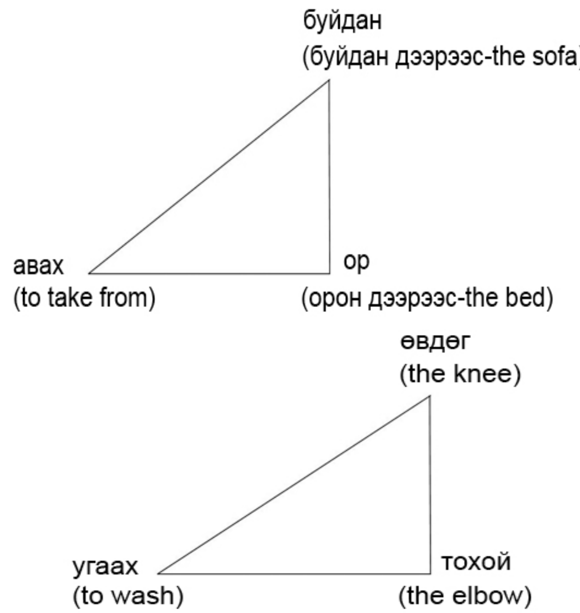


Figure 1

Similarity between these words is an effect of generalization principle in child semantic lexicon. That is why a use of law of sines as an addition is important in finding the direction of associative relations between words. Therefore, an application of the law of cosines and law of sines to human semantic vocabulary is efficient for understanding of universal principles of mental lexicon.

A relation between the size of a whole and the size of parts in language and music follows the Menzerath- Altmann law: the larger a whole, the smaller its parts. In language area it is described as "the longer a word (in syllables), the shorter its syllables (in letters or phonemes)"(Jaume, B., Antoni, H. F., Luria, F., & Ramon, F. C. JQL. 2013. 20/2 P 95).

An applicability of this law to typologically different languages, such as Mongolian, Chinese, English and Russian),is important in linguistics.

Human semantic memory has strong effect on spatial perception. Chinese language is a specific case for such perception. RH lateralization of Chinese character processing has left an advantage of a visual field (LVF)/RH. This lateralization difference between Chinese single character and two-character word processing means that reading of the two-character words requires a decomposition of the words into their constituent characters and, thus, involves more HSF (high spatial frequency)/LH processing (Jamet, H. H., & Sze, M. L. CS. 2013. 37/5. P 880).

Additionally, the idea of lateralization difference can also be used in comparison of traditional Mongolian and Cyrillic scripts. Horizontal and vertical writing in scripts is a phenomenon and, thus, a matter of description in terms of spatial and verbal cognition.

Therefore, two models of mathematical cognition, such as segmented linear model and log-linear model,are interesting methods to organize semantic memory(David, L., & Noach, S. CS. 2013. 37/5 P 778).

An association between color perception and mathematical cognition is directly related to verbal thinking. For some people, numbers have colors(Stanislas Dehaene. Numerical cognition. 1993. Oxford. P 75) and a human ability to communicate is a basis for such kind of multi-modal integration that underpins mental, semantic lexicon. This idea also refers to high order verbal structures.

III. Vector – Based Analysis of Syntactic Structures

Syntax is a highly distributed language process, which sharply contradict shyper localized function. Syntactic structures must be presented in conceptual spaces and vector field, and they are used to describe as emantic potential with pragmatic (illocutive) force. However, mapping of events and objects in the brain (verbal mapping) is different. As such, primitives of mental mappingis a product of primes, whereas proposition and concept - are the products of a unit. Also, an integration of discrete structural elements (words or musical tones) into sequence-perceiving complex acoustic, non-verbal or mathematical structures (symbol) is a product of blending. This has been demonstrated in experiments on metrical stimuli for analysis of musical, numerical and syntactic structures.In these experiments, primary colors are associated with small numbers and more complex colors are associated with larger numbers. Basic metaphor of these arithmeticis an intuitive notion of divisibility and decomposition of an integer into product of primes.

In numerical grammar, some words combine additively – forty-three (40+3), whereas others combine multiplicatively: seven hundred (7x100) (David, L., Noach, S., & Aleah, C. CS. 2013. 37/15 P 793).This number processing is similar to syntactic processing. For example:

Хар бал (additively), **хар шөнө** (multiplicatively), **хар санаа**(multiplicatively).

A concept of perfect numbers in combination with prime numbers is also useful for description of deep structures, particularly proposition-based structures. Finally, syntactic priming is a reflection of an implicit statistical knowledge that is relevant to language processing, and the principle of sequence regularities is expressed in simple recurrent networks.

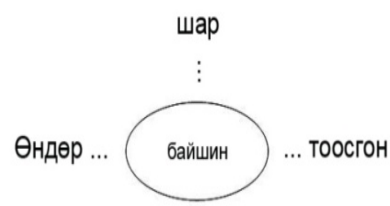
a) Analysis of word sequences: adjective-noun

In expressions containing attributive, causative, space-time and other relational properties, order regularities reflect the properties of specific regions of the brain. This suggests that some overlap between the cortical areas coding for numbers, space and colors may remain (Stanislas, D. 1997.P 38).

Color may be a more consistent feature of the typical evocation of a given distributed visual representation than size. Semantic relationships between nouns, verbs, and adjectives are a reflection of knowledge sequence represented in prefrontal association cortex and its connections, phrase structure rules and grammatical morphology sequence knowledge-in perisylvian pattern associator networks.

According to the researchers, structures adjective-noun (**шинэ машин**-new car), noun-noun (**хүрээ дуу**-city song) and verb-noun (**номавах**-buy a book) in semantic compositions, are based on human similarity judgments (Jeff Mitchell., & Mirella Laputa.2008. Vector-based models of semantic composition... Edinburgh, UK.) Adjective order (e.g., value, size, color) is substantially consistent across a large number of languages. In some adjective structures (**өндөр, шар, тоосгон; дөрвөлжин, том, хар**),semantic force presents object-oriented vector. For example:

Өндөр шар тоосгон байшин (tall yellow brick house)



Дөрвөлжин том хар хайрцаг (square-shaped big black box)

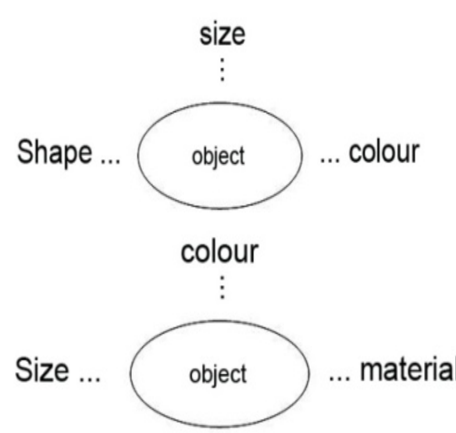


Figure 2

Such structures are interpreted in tensor space with syntactic reduction nn^{L} with vectors $N \otimes N$ (Edward Grefensette., & Mehrnoosh Sadrzadeh… 2010.) In Mongolian language, distributional function is also applied to an analysis of attributive structures as linear transformation in tensor (vector) space.

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If noun (**байшин**) is represented as vector, adjectives are determined by distributional behavior of the noun.

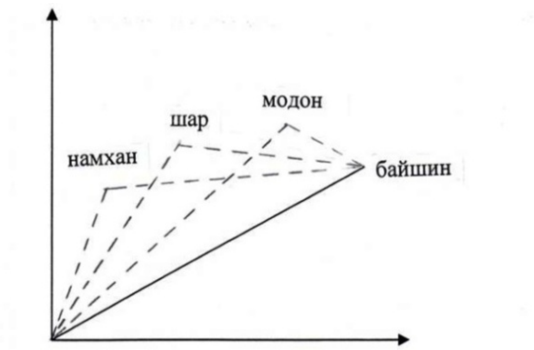


Figure 3: "***Намхан шар модон байшин***"

Typical features of an object (size, color etc.) in human perceptual space (topological tensor space) area basis for a calculation of cue validity:$c_x(A) = P(x|A)$.The question is: how typicalX_1, X_2 *and* X_3values for Aare related to the features (adjectives**намхан**, **шар**, **модон**) of the object (**байшин**)in case of $X_1, X_2 and X_3$.Complex expression with two or more adjectives must lead to superposition of instances. Superposition of complex adjectival expressionist is a case of semantic interference where a trace of 2nd rank tensor is implied.

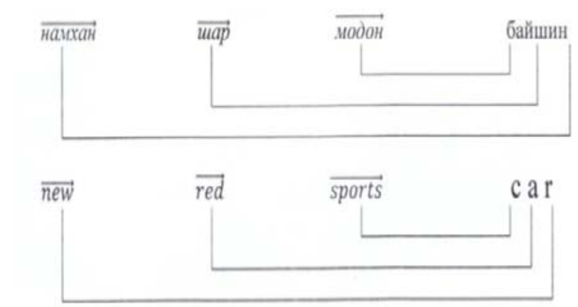


Figure 4

According to psycholinguistic experiments, color affected shape recognition as an intrinsic feature of the shape. Mechanism of binding of intrinsic and extrinsic features in working memory, for example, binding of color and shape, determined similarity and difference in verbal perception of people.

Vector-based analysis of sequence regularities in above named structures proposes that implicit statistical knowledge in working memory reflects the relevance of intrinsic and extrinsic features of an object to verbal cognition.

b) Analysis of word sequences: Verb-noun aspect of polysemy

In multi-word expressions, complex effect of semantic and pragmatic forces raises an issue of linearity and non-linearity:

Авах (to take)
- **ном**(book)-distance is longer in terms of cohesion. Direction is linear
- **санаа** (idea)- distance is closer in terms of cohesion. Direction is non-linear.

Ширээ (table)
- **засах**
- **булаалдах**
  - direct meaning, no change in semantics (to take table)
  - change is semantics (to make a career)

Examples "catch a ball, catch a disease" are similar to the above-mentioned Mongolian structures. An important comment on lemma about the high dimensional vector has been made by Katrin Eric and Sebastian Pado (Katrin Eric., & Sebastian Pado. A structured vector space model for word meaning in context. EMNLD. 2008.).

In the experiments conducted by Mongolian researchers, a correlation of the predicate and arguments (or object) differs from verbs (predicate) that have similar meanings and nouns (argument or object) of the same semantic group.

	Амрах	Онгойх	Ужрах	Харанхуйлах
Сэтгэл	+	+	+	+
Дотор	+	+	+	+
Санаа	+	-	-	-

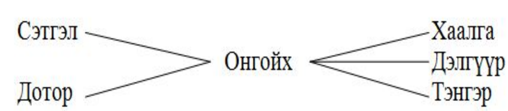


Figure 5

The perception tests of "noun-verb"… in Mongolian language showed different levels of interpretation for children and adults:

Ширээ булаалдах
- to take table (children)
- to make a career (adults)

A computing of a similarity or difference between the vectors of a predicate and arguments (object) is not an ending point. Applying vector cross product is one way to analyze complex effect of semantic and pragmatic forces on semantic transformations in different directions. Pragmatic force F is applied to an "illocutive key" (a displacement r) from a specific point of rotation. The question is: which part of F causes the "illocutive key" to turn?

In some situations, pragmatic force can support intention flow which is perpendicular to a plane containing both vectors.

$$A \otimes B = |A|\,|B|\,\mathrm{Sin}\theta$$

$$\vec{F} \otimes \vec{r} = |F|\,|r|\,\mathrm{Sin}\theta$$

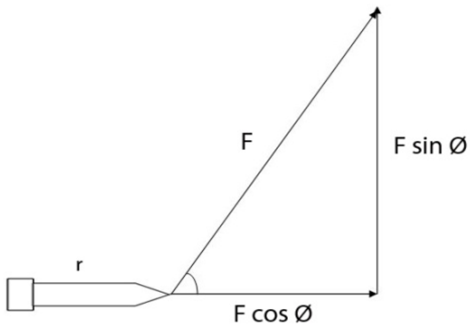


Figure 6

Perlocutionary effect depends on torque (intentional force) and magnitude ($\|\text{Force x Length vector}\| = \|\text{Force}\|\|\text{length}\|\mathrm{Sin}\theta$) with a comment what vector product is anti-commutative.

Semantic/pragmatic pressure on word in different directions causes semantic cohesion and coherence what presents a case of entanglement as a result of non-linear combination of semantic and pragmatic forces. In terms of quantum coherence however, a moment of synthesis of semantic and pragmatic meanings is two forces having the same carriers. The carriers of these meanings at neuro-psychological level are significant "particles" for verbal perception and present an object of interpretation in terms of tensors of ranks 2 and 3. It means that dyad and triad tensors are effective for modeling of cohesion and coherence of semantic and pragmatic forces in syntactic structures.

c) *Action/event as an object of analysis in vector (tensor) space*

Semantic "energy" distribution throughout mental (semantic) space in verbal mapping of action/event structure must be analyzed in scalar modeling and differential geometry. Event and action present basic primitives for mental syntax. In working memory, events are organized into hypothesized sequences of more general states (actions in a process of making coffee), encoded in a set of neural units expressing features or states. Sequences of these states can be referred to higher level sequences which form multi-level hierarchy (Marten, S., Andy, E., & William, S. Topics in CS. 2013. 5/3. P52).

Neuropsychological analysis of sentence structures suggested that verbs have a distributed representation of prefrontal components with thematic attribute, argument structure and sub categorization in sentence-level sequence; posterior components which support flavor attributes and implementational com-ponents of premotor and motor cortex. This is related to specific mechanism that generates syntax structures from basic primitives (Vlasova, P., Pechenkova, E. B., Akhutina, T. B., & Sinitsin, B. E. 2012. вп. 4/129). Moreover, goal-directed sequential concept manipulation is based on distributed semantic representations, phonologic and morphologic sequence knowledge and sentence-level sequence knowledge. In typologically different languages (like Mongolian, English and Russian), differences in sentence structure are particularly reflected in commutative and associative properties of vector addition. For example:

U + V = V + U (commutative property)
U + (V + W) = (U + V) + W (associative property)
SOV S + (O + V)
SVO S + (V + O)
The boy caught the ball.

Ах ном авав.

Брат купил велосипед.

Vector dot product that describes sentence structures can be used in relevance to component analysis of such structures.

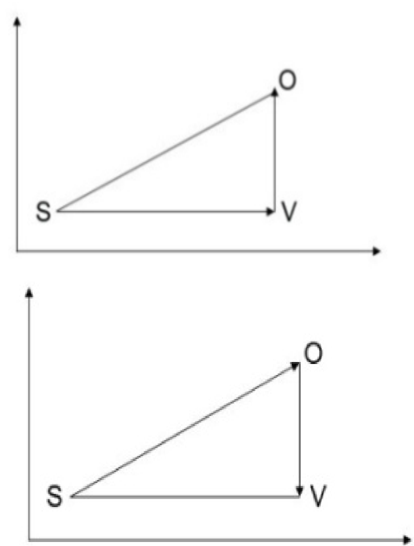


Figure 7

Semantic force (of a word, sentence etc.) changes distance of the word (strong or weak link, but no direction). Also, as a vector, semantic force has magnitude and direction (→) that change semantic volume (density or distance) of the word. In the first case, semantic force behaves as a scalar, in the second case – as a vector.

At sentence level for connection of words, denotative and connotative components of word semantic structure drive interaction. This interaction is affected by a semantic force in one direction, by a pragmatic force or a combination of semantic and pragmatic forces -in the other directions. However, it is not clear how isomorphism/homomorphism can be related to interpretation of SOV and SVO.

It is known that tensor products of A and B over R module ⊗AxB → A⊗B are important in interpretation of existence of bilinear homomorphism in typologically different languages. In this connection, a compositional distributional analysis provides a way to interpret sentence structures in tensor (vector) spaces (Grefensette, E., Pulman, S., Sadrzadeh, M. & Coecke, B. (1998). Concrete sentence space for compositional distributional models of meaning). In tensor spaces, the syntax relations, including distributional meanings of verbs as weighted relation, are represented by linear maps. For example:

The boy caught the ball (S-V-O)

Ах ном авсан (S-O-V)

Брат купил велосипед (S-V-O)

$$Verb = \sum_i (\overrightarrow{sbj_i} \otimes \overrightarrow{obj_i})$$

The verb in this context is created by context vectors of the subject and object.

In typologically different languages, such as English, Russian (SVO) and Mongolian (SOV),the context vectors of subject and object can be calculated in two different ways:

$$\overrightarrow{Sbj\ Verb\ Obj} = \overrightarrow{Sbj} \odot (\overrightarrow{Verb} \times \overrightarrow{Obj})$$

$$\overrightarrow{Sbj\ Obj\ Verb} = Sbj \odot (\overrightarrow{Obj} \times \overrightarrow{Verb})$$

SVO structure in tensor space N⊗S⊗N corresponds to the type $n^R s n^L$ (n^R -right adjoint, n^L -left adjoint). For example:

They ate the meat. The man opened the letter. Брат купил книгу.

In syntax of the typologically different languages, implicit statistical analysing of working memory can be used in relation to language processing:

John gave his daughter a book–John gave a book to his daughter.

The girl threw the ball to the boy – The girl caught the ball from the boy.

Parallels in Russian and Mongolian languages:

Брат подарил книгу другу – Брат подарил другу книгу.

Ах найздаа цаг дурсгасан – Ах цаг найздаа дурсгасан.

These structures support the idea of tectonics of syntax structures that reflect tectonics of actions. This is in agreement with a concept, which suggests that a reciprocal manipulation of two or more distributed representations is particularly determined by a neural instantiation of the association of a verb with a specific argument structure. The simplest method to calculate the number of vectors acting in different directions is vector addition. Applicability of rectangular component method to interpretation of such structures is an issue having methodological…

Vectors presenting object components have different magnitude of direction of subject and predicative component (action verb).Moreover, Attributive relations and different features of manner are objects of description in Cartesian coordinates by using resultant vector. For example:

Овсгоотой зоригтой эр эрэлд мордов.

Мэхтэй, тэнхээтэй эр л давждээ.

She has been taking new efficient medicine.

Молодой знающий инженер продвигает дело.

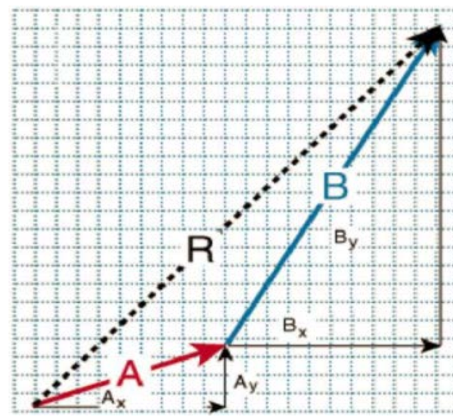


Figure 8

In addition, use of resultant vector in analysis of multi component structures is an effective addition to traditional interpretation of manner of action. For example:

Хүү ахтайгаа ширээ зөөв.

The boy with his brother moved the table.

Хүү дүүтэйгээ ширээ зөөв.

The boy with his younger brother moved the table.

The boy heard the door slamming all night long.

In manner incorporating languages (English, Russian and Chinese), manner representation is closely connected to intrinsic movement and movement in peri personal space. However, in path incorporating languages (Japanese and Turkish), path incorporation is represented posteriorly, in cortices supporting the spatial location components (Stephen, E.N. 2012. The neural architecture of grammar. P42.). Interestingly, "manner-action "structures are also connected in different ways and those illustrate the universality of addition and multiplication operations for mathematical and verbal reasoning.

айгаад (feeling the fear) 〉 гүйх (to run)
түргэн (faster)

бодоод (to think) 〉 хариулах (to respond)
оновчтой (precise, right)

Path incorporation must be presented by applying vector addition, while commutative law $\vec{R} = \vec{A} + \vec{B}$; $\vec{R} = \vec{B} + \vec{A}$ can be referred to syntax structures in different ways depending on typology of language. Also, use of associative law $(\vec{A}+(\vec{B}+\vec{C}) = (\vec{A}+\vec{B})+\vec{C})$ is effective for structures with two or more components which express manner or path. Complex vector can be applied to these multi component structures.

d) Schema-based transformations

Rules for mental transformations, based on rules (mechanisms) of perceptual spaces (modalities), are a basis for semantic transformations (clustering, embedding and multidimensional mapping).Cross modal organizational structures (COGs), supported by mirror neurons and corresponding image-schemas (container schema, source-path-goal schema, spatial relation schema, complex relations schema), are common in most languages. At deep level these image-schemas serve as a basis for semantic transformations: He goes through the doorway – The room is through the doorway.

He went through the forest – The road goes through the forest.

Машин голоор гарав – Энэ зам голоор гарна.
Ах галт тэрэгний буудал явсан –
Энэ гудамж галт тэрэгний буудал хүрнэ.

Among them, the source–path–goal schema has an internal spatial "logic" and built-in inference which are also stimulated semantic transformations. Differently, applying of vector method to force-dynamic-schema that generates passive structures leads to deeper analysis of neuro-cognitive mechanism for producing human mental transformations. Moreover, active and passive structures (Many critics disliked the play⟷ The play was disliked by many critics) are an object to interpretation in terms of vector/matrix transformations as structures involving two vectors. Formally, it is not a simple conversion.

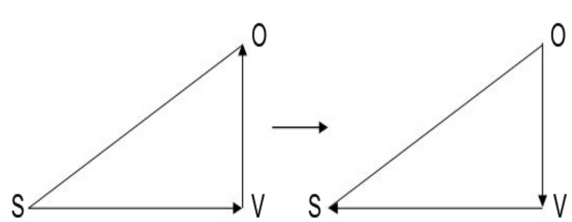


Figure 9

There is a change in a vector direction that is reflected in distance between components of sentence. Model of an event can have a complex structure and involve two vectors (agent and patent), counterforce and instrument. For example:

The window was broken by the boy.

The boy has broken the window.

The boy has broken the window by throwing a stone.

A vector-based description of passive structures without agents, for example"Аяга хагарчихжээ. Цай буцлав.", is significant in relation to isomor- phism/ homomorphism.

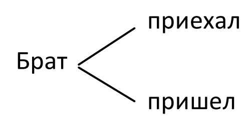
In visual perception, a transformation from egocentric frames of reference with respect to body (self-to-object relations) to all ocentric frames of reference with respect to external objects (object-to-object relations) is related to a transformation from active structures to passive ones (Wen, W., Toru, I., & Takao, S. 2013. CS. 37/1. P 177). There is also a possibility for an implication of stress tensor ($\sigma = F/A$) to interpretation of difference in active and passive structures.

Space-time dimensions of verbal perception have a marked representational granularity causing difference in event focusing. For example:

Энд ширээ байна.

Здесь стол стоит.

There is a table.



These and similar structures are examples of difference in mapping of event/action. Representational granularity in these structures of mental mapping gave rise to the phenomenon of linguistic relativity (known as Sapir–Whorf hypothesis).

In locative constructions, verb slot in the ground (or container) is associated with the semantic property of manner of motion (for ex., Lisa poured water into the cup)or with the semantic property of state-change (for ex., Lisa filled the cup with water).Thus, generalization leads to semantic change and transformations, such as motion → state:

Его захватил разговор – Он весь в разговоре.

Энэ бодол намайг эзэмдэв – Залуу бодолд автав.

Form the other side, state of subject can be transformed into a localization state (for ex., Колени дрожат – В коленях дрожь. Нуруугаар хүйт даав).

Vector-based analysis of dependency of verbal perception on coordinatization showed that semantic structures derive from deep mental structures. Semantic derivatives are important elements of semantic transformations. For example, markers for temporal relations originate from spatial expressions, which are products of human mental perception of complicated space – time relationships. In human verbal perception, the above named structures have eigen value for a vector under transformation.

Highly differentiated active and passive structures are an object of analysis of covariance and contra variance. Covariance and contra variance, as results of sensorimotor embedding, serve as vectorial expressions in the human motor frame. However, covariance and contra variance of vectors are different basic descriptions of the same object indifferent referential frames.

e) Complex structures

Complex structures in typologically different languages are an object to tests of memory-based accounts of syntactic complexity. In Mongolian language, dependency between encountered component (V-үзсэн) and memory-retrieved component(S, O) is flexible. For example:

Энэ бол охиныг үзсэн эмч Бат юм.

Охиныг үзсэн эмч бол Бат юм.

Бат бол охиныг үзсэн эмч юм.

Subject-orobject-extracted conditions can be determined by cohesion. In complex sentence, element formation is highly active in memory at the point of the dependency. For example:

Это был профессор который редактировал статью аспиранта.

Это был аспирант статью которого редактировал профессор.

It was John who consulted Ellen in the library.

It was Ellen who John consulted in the library.

When second element of dependency (consulted) is encountered, the object "Ellen, Ph.D. student" is retrieved from memory (Evelina, F., Rebecca, W., & Edward, G. CS. 2013. 37/2 P 387).

In complex structures, a component expressing particular relation must consist of two or three subcomponents (words) and, in this case, such structures must be presented in a complex vector model. An example is so-called "recursion" which is a process of inserting successive nested relative clauses into sentences and the realization of three or more different concept representations at the same time. For example:

Үсээ задгай тавьсан өндөр бүсгүй миний урд ссуна.

Нөхөр нь өчигдөр одон авсан өнөөх бүсгүй өмнөх ширээнд сууж байна.

The woman, whose husband was fishing for great white shark, sat down beside me.

The woman whose dress rustled when she walked sat down beside me.

For description of complex sentences, it is necessary to take into consideration that motion paths can intrinsically be divided into parts that belong to a single event. It means that there is a positive multiple of an event inthe human mental syntax motion vector (the derivative). Thus, a vector-based analysis of recursion, supported in the brain by a pushdown memory mechanism as a mirror recursion, suggests that the concept of complex structures is revised in dynamic dimensions.

Complex sentences have complex values as a common effect of two types of fields (or forces): semantic and pragmatic. Force density must be presented by a tensor, its stress function. This is one of the reasons to apply complex vector to these structures, and to develop unified field theory in cognitive linguistics.

IV. Discussion & Conclusion

In the recent paper we presented vector-based approach to human verbal cognition by providing a description of word meaning and syntactic structures. Human mental space is the basis for an application of vector (tensor) method to modeling of human verbal perception and mental representations.

Vector dot product is a powerful tool for modeling of localization of different classes of words in semantic memory, and connections of these classes with different regions of the brain. This idea is illustrated by means of examples in English, Russian and Mongolian languages and by result of experiments conducted at the University of the Humanities. The author suggests that application of the law of cosines and the law of sines to the modeling human semantic lexicon is an important addition to the vector method. Thus, interpretation of word sequences in vector space is an effective way for analysis of basic rules which regulate these sequences in typologically different languages.

A concept of cue validity and superposition is used for modeling of feature-based perception of an object and its properties. It is important to establish linear or non-linear correlation captured by cue validity in studies of human mental clustering. Furthermore, a superposition principle can be applied to the analysis of interference of components expressing different features of an object and action in syntactic structure.

A 2^{nd} rank tensor can be implied to the analysis of non-linearity in word sequences, and this presents interest in terms of dependency of verbal cognition on typology of language. In particular, the tensor-based analysis of sentence structures supports the idea that tectonics of syntax structures reflect tectonics of action/event.

Also, use of vector cross product for an interpretation of semantic and pragmatic forces at a sentence level allows a deeper analysis of neuro-cognitive mechanism behind mental transformations. This idea is supported by number of examples in English, Russian and Mongolian languages.

Experiments, conducted at the University of the Humanities, demonstrated that representational granularity in mental mapping leads to typological differences in languages. Additionally, tensor-based analysis of verbal perception on coordinatization showed that semantic structures are derivatives of mental structures. Another analysis, made on semantic transformations in different languages, suggests that vector (tensor) transformations, covariance and contra

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variance present vectorial expression in human motor frame as a result of sensorimotor embedding.

Finally, an application of vector (tensor) method to human mental syntax may result in high order verbal structures and provide a new opportunity to develop unified field theory in cognitive linguistics.

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