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Role of Semantics in the Organization of Mental Lexicon

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Abstract

Mental lexicon refers to human word store. It is a systematically organised linguistic knowledge of an individual, represented in the brain. During speech production and comprehension, this mental lexicon is consulted upon for information access regarding the target word. Several studies on word and non-word recognition using speech shadowing task (Marslen-Wilson & Tyler, 1980, 1981) reveal that words are accessed within a fraction of a second from mental lexicon. Hence the speed and accurate access of words from a large number of words in the mental lexicon may be attributed to the mechanism of organization of words while the organization of mental lexicon is argued to be based on semantics. The role of semantics is emphasized to make a significant contribution to the complex yet easily accessible organization pattern.

In this paper, an attempt has been made to review the influence of semantics on mental lexicon and its organization drawing support from semantic models and theories proposed to explain the same. The influence of one's language in organization has also been highlighted while emphasizing the need for such research in Indian languages.

Key words: Mental lexicon, Semantic features, Semantic Representation.

Language is a mode of communication which is used to pass on messages and information to each other. Any language generally consists of body of words for use by people who are of the same community, geographical area, cultural tradition &/or nation. It has been in the interest of researchers in the field of Psycholinguistics, Neurolinguistics, Speech Language Sciences, and Cognitive Linguistics, since decades to study language for its nature and dynamics of organization and representation of it in the brain.

While language production is a continuous process of selecting the words that best corresponds to the meaning of a message the speaker wishes to express (Levelt, 1989), language comprehension is a continuous process of deciphering the meaning of words, spoken or written. Hence words carry the core information upon which all communication is built (Vinson 2008). These words of a language are stored in the brain of individuals. This storage of words available for access during speech production and comprehension is termed as mental lexicon which is a part of semantic memory. Semantic memory, along with word store also consists of knowledge about objects and events, language, and its use to refer to objects and events. This knowledge that is formed from perceptual and action experiences of individuals is known as 'concepts'.

I. Mental Lexicon and its Organization

Mental lexicon and its organization has recently received immense attention by researchers who are interested in understanding how concepts are stored, organized, how words are mapped onto concepts (semantic representation) for word meanings in the mental lexicon.

Mental lexicon is estimated to be composed of large number of words. There can be two views regarding the storage of words in mental lexicon. It can be viewed as either highly organized system or it might be haphazard and unorganized. However there are reasons to view mental lexicon as a highly organized system.

First evidence is from the fact that mental lexicon stores large number of words. An educated adult native speaker of a language knows more than 150,000 words and will be able to use 90 percent of these according to a study done by Seashore and Eckerson in 1940.

The second reason why mental lexicon is likely to be organized is that words can be located and retrieved within fraction of a second. This is very evident from the speed of normal speech production and comprehension. Various studies employing speech shadowing task have supported this with experimental evidence which prove that native speakers of a language can recognize a word of their language in 200 milliseconds or less from its onset (Marslen-Wilson & Tyler, 1980, 1981). In many cases this is well before all syllables of the word being heard.

Further evidence supporting this assumption can be obtained from studies using non-word detection task wherein subjects are able to make lexical decision within 500 milliseconds, thus proving that speakers are able to conduct orderly search through their mental word store in a surprisingly short length of time. Hence it is established that there are certain principles based on which mental lexicon is organized.

Earlier researchers studied mental lexicon within the broader framework of semantic memory, emphasizing role of semantics and word meaning as the organizational principle of concepts in the mental lexicon. Hence the models proposed were based on shared meaning of words, in which meaning was assumed to be playing determining role in its organization. Researchers, in fact considered concepts and word meanings as being the same or at least linked on a one-to-one mapping (Humphreys, Price & Riddoch 1999; Vigliocco & Vinson 2005) and research findings involving word meanings is often extended to concepts as both are treated as completely interchangeable. This review shall focus on the role of semantics in organization of lexicon by understanding the various models and theories put forth to explain patterns of organization underlying words in mental lexicon.

II. Semantic Models of the Mental Lexicon

The models developed to study organization and representation in mental lexicon can be broadly classified as either based on Holistic theories or based on Feature theories. Holistic theories assume that word meaning is holistic and indecomposable and study the relations between meanings of different words in order to study their organization (Eg: Collins & Loftus, 1975). Feature theories, on the other hand assume that word meaning can be broken down into features and study the relation between words in terms of their feature overlap and feature properties (eg: Smith, Shoben & Rips, 1974).

Semantic features described in these models are individual elements of meaning which, when combined, add up to the meaning of the word. In the following sections, models proposed to explain organization of mental lexicon based on these theories have been discussed.

a) The Hierarchical Network Model

The Hierarchical Network Model of semantic memory, developed by Collins and Quillian in 1969, based on holistic view, was the first model to provide detailed description of representation and retrieval of information from semantic memory. The model was conceptualized using Artificial Intelligence program written by Quillian in 1968. The two factors that influenced the development of this model were efficient storage of information in the semantic memory and ability of inferential reasoning from the stored information which is crucial for comprehension.

According to this model the structure of semantic memory is assumed to be a network of concepts. Figure 1 shows how information might be stored according to this model. Each concept is referred to as 'node' or lexical entry. The model is hierarchically structured in which the information about most general concept are found at the highest node of the network followed by information about more specific concepts at the lower levels. The attribute that distinguishes each concept from the concept above (or concepts beside) it is also noted under its node. The concepts are connected to each other by logical relations. Authors have specified two different type of logical relations namely ***category membership relation*** and ***property relation***. Thus, meaning of a concept is represented by total configuration of category membership relation and property relation that the concept has with other concepts in the network.

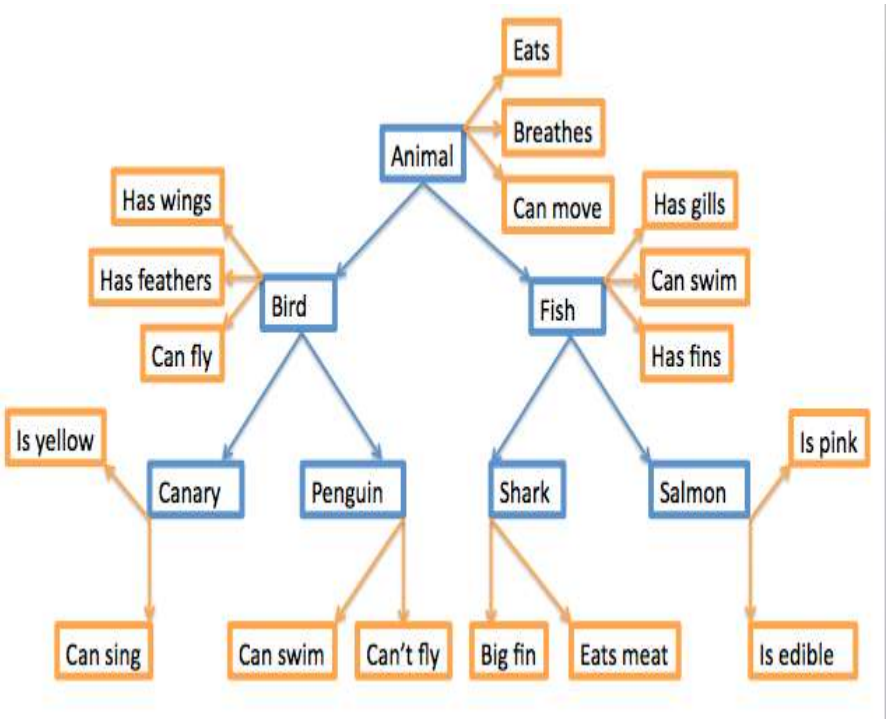

Figure 1 *– Hierarchical Model (source: Collin's and Quillian (1969)*

The above model is based on one of the important assumptions called Cognitive Economy. The principle of Cognitive Economy ensures that information stored at one level of hierarchy is not repeated at the other levels and also common properties belonging to a particular category is only stored at the highest concept level (or node) to which they might apply. For e.g.: property 'eats' is stored with the highest level of concept i.e. 'animal' and not with lower concept like 'bird' because all animals can eat and 'bird' being lower concept it can be logically inferred that 'bird' can eat too. Hence, the property 'eats' is stored at highest level only. Thus the cognitive economy plays a crucial role in determining the information stored at each node. The principle of cognitive economy is also extremely efficient in explaining the tremendous storage capacities of mental lexicon. Properties which are unique to one particular member of the category are stored separately as one of their properties, for instance ostrich cannot fly even though it belongs to the category 'bird'.

In support of this principle of cognitive economy, the model of Hierarchical Network was subjected to testing for its assumptions and predictions using behavioural measures such as sentence verification and reaction time experiments. Cognitive economy, which is one of the important assumptions on which the model is based, is violated by the experimental results which indicated that the properties are associated with each category in the hierarchy

and not just at the highest category. For instance in a verification task involving two sample sentences such as 'an animal breathes' and 'a bird breathes' the models predicts that first sentence is verified faster than second sentence. However experiments revealed that time taken for verification of both the sentences are equal hence refuting the assumption. Conrad (1972) also argued against the assumption of cognitive economy. She stated that the degree of association present between the concept and property determines the time in verification rather than number of levels.

The model also fails to explain the typicality effect where in all the instances of a concept may not be equally good exemplars of it, for example, in a study done by Rips, Shoben, and Smith (1973) subjects verified that a robin or a sparrow is a bird much faster than they can verify that an ostrich or a penguin is a bird. The model also failed to predict the influence of familiarity effect where in familiar terms are verified faster irrespective of their position in the hierarchy. This is supported by studies which have shown that it takes longer time to decide whether or not a "dog" is a "mammal" (lower level) than to decide that it is an "animal" (higher level) (Smith, Shoben, & Rips, 1974).

Thus, the hierarchical network model was successful in describing the organization and retrieval of semantic memory even though it was unable to explain certain phenomena that resulted following behavioural experiments. However this model formed the basis for the future models that were developed, providing the necessary framework for the same.

b) Semantic Feature Comparison model

The network models described earlier were predicting inconsistent results concerning the organization of semantic memory and mental lexicon. In an attempt to overcome these problems semantic feature comparison model was developed by Smith, Shoben and Rips in 1974. According to this model, the concepts in the semantic memory are stored as set of attributes called semantic features and the meaning of a word is not an unanalyzable unit but rather can be represented using this set of semantic features (Smith et al. 1974). For example the concept 'Robin' will be stored in the semantic memory with the following features- has wings, lays eggs, has feathers, can fly, is red-breasted, eats worms and 'bird' as - has wings, lays eggs, has feathers, can fly, eats worms.

The semantic features are classified into two types namely 'Defining features' and 'Characteristic features'. Defining features are those features which are essential to define the concept whereas Characteristic features are those features which are often associated with a concept but which are not essential to its definition. While defining features are shared by all the members of the category, the characteristic features are specific to only few members of the category but not necessarily shared by all members.

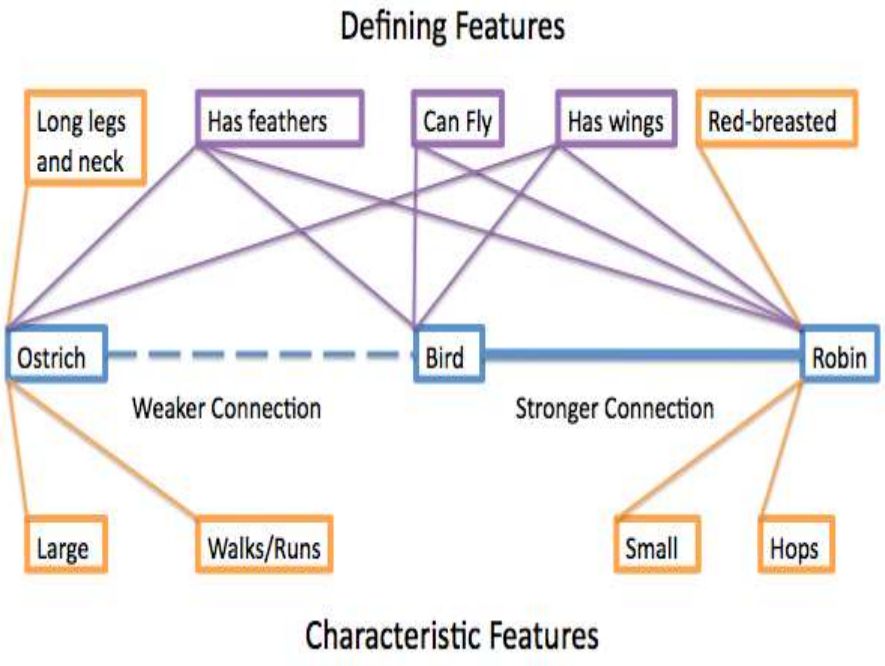

Figure 2 *– Semantic Features Model (source: Smith et al., 1974)*

Example for defining features for the category 'bird' are: has wings, lays eggs, and has feathers. An example for characteristic feature is 'can fly' because all birds cannot necessarily fly (Eg: Ostrich) but still they belong to the same category (Figure.2). Thus 'robin' is considered as typical category member possessing many of the defining characteristic features and 'ostrich' as a atypical category member which may possess few of the characteristic features of the category. This model also assumes that superordinate member of a category has less number of features compared to subordinate members. In other words subordinate members have greater number of defining features than superordinate members.

The predictions of this model were tested using sentence verification tasks involving a statement with a subject and a predicate. This model has been highly successful in accounting

all the main findings in semantic memory literature. The predictions of this model were accurate for most of the instances tested because the predictions were based on semantic similarity and relatedness between the subject and predicate. However, even this model has shown few shortcomings in its predictions (Holyoak & Glass, 1975; McCloskey & Glucksberg, 1979).

This model assumes that meanings are represented in terms of defining features along with characteristic features but researchers argue against this model that it is impossible to identify defining features for all meanings (Fodor, Fodor & Garrett 1975; Fodor et al 1980). Also going by the assumption of this model, if word meanings were to be decomposed, speakers would always erroneously produce word 'animal' for the target word 'dog' (Roelofs 1997; Levelt, Roelofs & Meyer 1999). In order to answer this argument a computational model was developed by Bowers in 1999, wherein inhibitory connections were introduced laterally between lexical units which allow correct production of both subordinates and super-ordinates.

McCloskey and Glucksberg (1979) also proposed an alternative to Smith, Shoben, and Rips' model. This model is similar to Smith, Shoben, and Rips' in that verification time is determined by the relatedness of the subject and predicate. However, it differs from Smith, Shoben, and Rips in three fundamental ways. First, the model does not recognize the distinction between defining and characteristic features. These features are considered as labels for the extreme ends of a continuum. It is also reasonable as it has always been impossible to know exactly where to draw the line between the two. Second, the model uses only a single comparison stage for all sentences unlike previous model where comparison was assumed to be taking place at two levels. Third, it uses a Bayesian decision mechanism which considers the output from the comparison process as both evidence for and evidence against the truth of the statement.

c) Spreading activation model

In order to deal with the shortcomings of their previous model and to account for the experimental evidence, Hierarchical network model was added with several more processing and structural assumptions which led to the development of Spreading activation model by Collins and Loftus in 1975.

The modification mainly involved breaking down of the rigid hierarchy so that direct connections can be formed between any two concepts or features. Unlike semantic feature comparison model, this model does not rely entirely on semantic feature comparison of one lexical item to another for understanding their representation. Instead, this model assumed that mental lexicon contains interconnected units of information labelled as nodes or lexical entries (Figure 3). These connections between nodes were named as links which leads to association between the nodes. The thickness and the length of the link determine how closely two words or concepts are organized. These connections may not be based on logic all the time. Personal experiences play a role in the formation of links, which might not be necessarily logical.

According to this model, when the node for one word is activated, a pulse of activation spreads along its links to the other nodes which are then activated, which in turn send their activation to other nodes through their links. Activation is proposed to be weakened over the length of the links and at each node it passes through, until it completely dissipates. Hence this model provides excellent evidence to explain aspects of priming in lexical activation. It also explains various phenomena of lexical organization and activation studied such as familiarity effect, typicality effect, and direct concept- property (feature) associations.

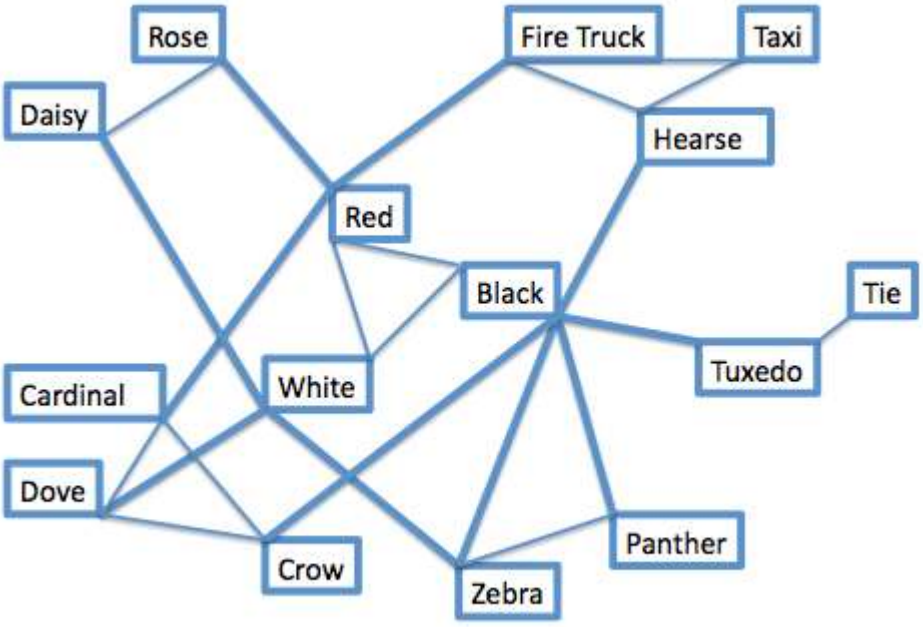

Figure 3 *– Spreading Activation Model (source: Collins and Loftus (1975)*

However the drawbacks of this model is that, according to this model the organization of mental lexicon becomes idiosyncratic from person to person since the personal experiences play vital role in formation of links. Along with semantics, it has been established that the phonology, grammatical class and morphology of lexical items under consideration also determines its organization which has not been accounted in this model.

The above mentioned factors were accounted for in the revised spreading activation model proposed by Bock and Levelt (1994) where in the syntax, morphology and phonological aspects of word/concept was accounted for (Figure 4).

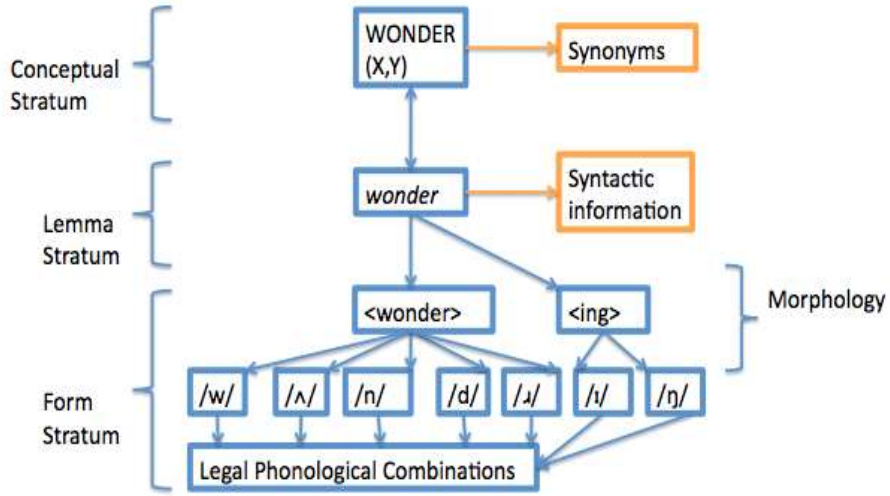

Figure 4 *– Revised SAM (source: Bock and Levelt 1994)*

d) The Adaptive Character of Thought (ACT) model

The ACT model was developed by Anderson (1976; 1980; 1983). The model involves a complex description of a spreading activation model of semantic memory, combined with a production system for executing higher levels operations involving distinctive and procedural knowledge. It is a computational based model which assumes that the organization of words in the mental lexicon is based on semantics. The ACT model assumes that the words and their meanings or concepts are separately represented in the brain unlike those discussed in the previous models. This is assumed based on the fact that there are concepts stored in the brain of individuals without a word associated to it. However there are no words for which concepts are not associated (Fellbaum, 1998).

The model proposes that knowledge about a concept and how it is linked to other concepts depends on the environment and context in which the concept occurs frequently. This model also differs from other semantic models wherein it does not only rely on factual meaning and association between words but also on function and context of each word with another, to organize them. In other words, ACT model organizes words based on their real-world, practical relationships with each other and not just abstract meanings (Anderson, 1996).

e) WordNet model

In recent days organization of mental lexicon is studied using WordNet (Miller 1995), which is an electronic lexical database. In this database words are organized into sets of synonyms called synsets. These synsets are further organised into a Hierarchical Network Model. However, one problem that arises is that all the words may not have exact synonyms. In order to solve this, the model uses notions of hyponymy and hypernymy for words with non-exact synonyms. For instance in the word pair robin/ bird, robin is the hyponymy and bird its hypernymy. These words are then hierarchically organised as in Collins and Quillian's model (1969). Similar to Hierarchical Network Model the main drawback of this model is that it does not consider discourse semantics and hence cannot effectively account for concepts which are functionally related.

The above models based their explanation for organization of mental lexicon solely on semantic property of concepts. It is based on the evidence that semantics plays a determining role in storage and organization of words. However further research in the field supported the notion that, apart from semantics which definitely plays a determining role, there are also other variables contributing for organization and that there exists a very complex relationship among all these variables involved in organization. Recent literature states that mental lexicon contains several types of representations including phonological, semantic, morphological and orthographic (Bonin 2004; Gairns 1983; Levelt 1995) which are considered as the other variables. Other possible factors contributing to the organization of lexicon are as follows:

a) Age of acquisition of the word

b) Frequency of usage of the word

c) Orthographic property of the word

d) The penultimate sound

Apart from these, it also has particular pragmatic, stylistic and affective features that make it fit to one context of discourse better than another (Randhall 2007).

f) Computational and Statistical models

Recent models proposed based on these evidences, thus vary in terms of their approach to explain organization. For instance, Connectionist Model does not believe that words are organized based on shared meaning alone. The proponents suggest that the word's lexical representation may not be localized in any node but is distributed across many nodes and the representation depends on weightage and correlation between each processing unit encoding orthographic, phonological and semantic properties of words.

An entirely different approach which seeks to discover representation of words in terms of their relationship to other words without making any prior assumptions about which principles are more important have also been implemented. The models based on this approach are Latent Semantic Analysis (LSA, Landauer & Dumais, 1997) and Hyperspace Analogue to Language (HAL, Burgess & Lund, 1997). These models use large corpora of texts and computational techniques in order to compute aspects of word meaning based on the co-occurrence of word with other words found in same linguistic context. These models, however, were criticized as focussing only on relationships among words and are not grounded in real world experiences.

Even though featural theories received strong criticism, recently alternative types of featural approaches have been witnessed in Cognitive Science and Neuroscience research (eg: Allport, 1985; Warrington & Shallice, 1984 ; Farah & McClelland, 1991). These approaches assume that conceptual features are grounded in perception and action and also that conceptual features are the building blocks of semantic representation which are in-turn embodied in concrete interactions with the environment (Vigliocco & Vinson 2005). Concepts of different semantic fields differ in the sensory related properties or motor related properties depending on the semantic field they fall into.

In order to gain deeper insight into these conceptual features researchers have employed speaker generated features norms. These norms are obtained by asking speakers of a language to provide a list of features that they believe to be important in describing and

defining the meaning of a given word (Cree & McRae, 2003; McRae, de Sa & Siendenberg 1997; Vigliocco, Vinson, Lewis & Garrett 2004; Vinson & Vigliocco, 2002).

Several models of semantic representation employing connectionist framework, based on speaker generated norms have been developed (Farah & McClelland 1991; Devlin, Gonnerman, Andersen & Seidenberg 1998; Hinton & Shallice 1991). A model based directly on speaker generated features norms was developed for object nouns by McRae, et al. in 1997. A model for both words referring to object (object nouns) and words referring to events (action nouns & verbs) called "*Featural and Unitary Semantic Space" (FUSS)* model was developed by Vigliocco,Vinson, Lewis and Garrett in 2004.

Featural and Unitary Semantic Space (FUSS) model is a statistical model based on the assumption that meanings of words are grounded in conceptual featural representation and some of which are organized according to modality. Second assumption is that the conceptual featural representations are bound into a separate level of lexico-semantic representation. This lexico-semantic representation provides interface between the conceptual knowledge and other linguistic information such as syntax, morphology and phonology. This model implements self-organizing maps which are sensitive to featural properties such as number of features for each concept, featural weights and correlation among features of different concepts. The model allows different properties to exert different influences depending on the characteristics of a given semantic field. This gives rise to a map with different semantic field boundaries for object nouns and events. In case of object nouns the boundaries in the map are smooth with semantic field boundaries well defined (Figure. 5). For events there are no clear boundaries among different fields (Figure. 5). Results obtained from the model show that the model predicts semantic effects seen in behavioral experiments better than any other models. The model has also embodied real world experiences which help to better ground to reality, by using speaker generated feature norms which are considered to be psychologically salient.

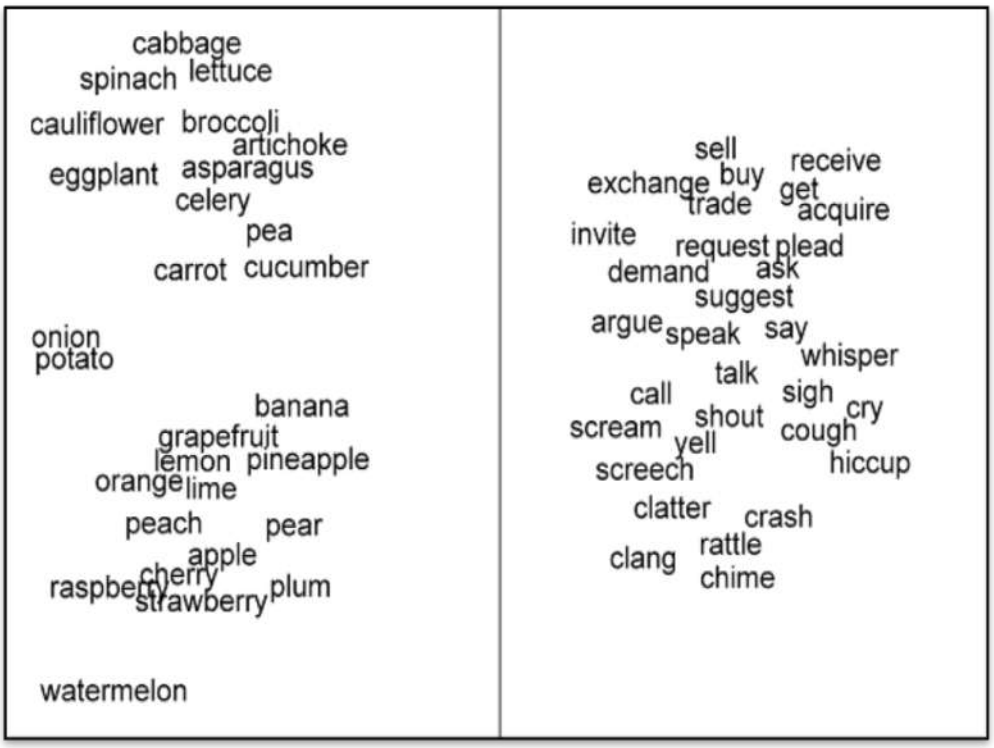

Figure 5: Two-dimensional representation of semantic proximity in FUSS (Vinson & Vigliocco, 2002; Vigliocco, et al. 2004 in Vigliocco & Vinson 2005).

The models proposed so far have been quite successful in capturing the overall representational principles for organization of words and they have never the less accounted for the fundamental phenomenon. Future research should focus on exploring the organization of abstract words/concepts which leads to better understanding of organization in the mental lexicon.

III. Influence of Language Structure in the Organization of Mental Lexicon

The words of a language greatly influence in shaping the conceptual knowledge and conceptual features as the conceptual knowledge and word meanings in any language have one-to-one mapping. It is also true that there exists no word meaning without an underlying concept. Therefore, the language of the speaker plays a role in the organization and representation of conceptual knowledge. In particular, the mapping of conceptual features into linguistic features varies from one language to another. For example, in languages such as English and Italian there are different words for the body parts ‘foot’ and ‘leg’ while Japanese have a single word ‘ashi’ which refers to both ‘foot’ and ‘leg’ (Vigliocco & Vinson 2005). Similarly English and Hebrew speakers have a large repertoire of verbs corresponding

to different manners of jumping whereas Italian and Spanish speakers do not (Slobin, 1996 b). If we assume that linguistic categories are a projection of conceptual categories, cross linguistic variability have important implications. The differences in the semantic structures of a language influence the conceptual structures too. Hence there is a possibility that the linguistic properties play a role in shaping conceptual representation.

Studies on Indian Languages

During past three decades, as witnessed in the literature, studies involving representation and organization of mental lexicon have received a lot of importance in Western languages. There is a dearth of such studies involving semantic representation, organization, semantic modeling and theories in Indian languages. In depth understanding of these aspects of semantic representation involves study of variables associated with them by establishing norms related to these variables. Studies of mental lexicon involving Western languages cannot be directly generalized to Indian languages as India is a multilingual and multicultural nation. Also, Indian linguistic picture presents coexistence of more than one and often more than two or three languages in an individual almost throughout the country which may have an influence on the organization of the mental lexicon in an individual. Therefore, there is an immense need to develop such feature norms in Indian languages.

Kannada is one of the Indian languages spoken in the southern parts of India predominantly in the state of Karnataka by around 70 million people (Census 2001). Despite the fact that it is one of the 40 most commonly spoken languages in the world, studies related to representation and organization of mental lexicon of this language, is still in its infancy. Large scale data base rendering information about which feature characterizes which concepts are also very few in literature. No such normative database for speaker generated semantic features currently exists in Kannada Language. Such norms can be extended to develop semantic theories and models for Kannada language as the models developed based on feature norms are very good predictors of behavioural phenomenon than any other models. These theories and models can further be compared for similarities and differences if any, with existing semantic theories and models of other languages. This can provide valuable insights about semantic representation of Kannada language in typical individuals.

Semantic feature norms in particular can help tremendously in language teaching strategies for both normal and disordered population. It can improve the quality of current

treatment techniques such as Semantic Feature Analysis (SFA) used for treating Anomia and Treatment of underlying features (TUF) for Broca's aphasia, by providing strong empirical evidence. The norms provide data regarding weightage of each feature and its production frequency, representing a given concept. Knowing this information helps in selection of appropriate features for explaining a concept, taken up for therapy. Hence studying organization and representation of mental lexicon in Indian languages is a promising and potential area of research.

To Summarize

To summarize, an attempt has been made in the present paper to review the theories and models developed to study semantic representation in the mental lexicon. These models are based on semantics, developed in order to understand the organization of words in mental lexicon. Importance of speaker-generated feature norms which are currently used in experiments to construct recent models of mental lexicon have also been discussed. The paper also emphasizes the crucial role of semantics in shaping conceptual representation. The influence of semantic structures and properties of one's language on the organization and representation of words were also highlighted. The paper emphasizes the need for the study of influence of multilingual and multicultural factors such as those that exist in the Indian context in shaping conceptual representation. Owing to the richness and vastness in its application to Language Sciences and Language Pathology, there is an immense need to prioritize research in Indian languages in the area of mental lexicon and its organization.

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