Review of Literature
2.1 Verbal Fluency and word retrieval in Children

The ability to generate words with speed and accuracy is one of the crucial elements of spoken word production. Successful generation of words involves accessing one’s own vocabulary repertoire or mental lexicon and retrieving the words specific to the target from stored word knowledge. The words act as a bridge in transforming a speaker’s thoughts, feelings and intentions into meaningful verbal communication. This proficiency develops throughout childhood with continuing expansion of words in the mental dictionary. With development, the complexity of the mental dictionary reservoir increases with the concept of every existing object getting stored in the form of a mental image along with its linguistic attributes.

The ability to retrieve a correct word from thousands of words in the dictionary requires a fundamental component of cognition, which is a meticulous categorization skill. This process of categorization is lifelong, growing in complexity with maturation and widening of the knowledge of the world around them. Attempts to understand the categorization of diverse world entities to similar mental representation in children are reported in literature (Carneiro, Albuquerque, & Fernandez, 2008; Lucariello, Kyritzis, & Nelson, 1992). Infants, as young as nine months, recognize that a name refers to a category of objects and actively uses few names to indicate the objects. At around 18 months, a rapid increase in vocabulary occurs as a part of categorization development (Gopnik & Meltzoff, 1992).

Verbal fluency (also known as word generation task / word list generation task / word fluency test / controlled oral word association / controlled verbal fluency test / controlled word association test / F-A-S test (corresponding to English letters, F, A and S) / fluency in controlled association / oral naming test) has gained popularity as one of the empirical procedures in tapping the organization of categorical knowledge. The data stemming from this procedure has been used to understand the lexical ability in healthy and disordered adults and children (Koren et al., 2005; Lezak, 1995; Mitrushina et al., 2005; Spreen & Risser, 2002; Troyer et al., 1997). This chapter reflects on current level of knowledge on both the theoretical and clinical perspectives of verbal fluency.
2.2 Historical overview of Verbal Fluency

Verbal fluency task involves evaluation of spontaneous production of words beginning with a particular letter or those belonging to a given class within limited amount of time (Spreen & Strauss, 1998). The utility of verbal fluency can be traced back to the late 1930s when Thurstone (1938) documented it as one of the components of intelligence and used it as a part of Thurstone’s Word Fluency test in Primary Mental Abilities Test (Thurstone, 1938). In this early test, participants were instructed to write down words starting with a given letter ‘S’ or ‘C’ in a given time period of 4-5 minutes. The task was found to be sensitive in patients with cerebral involvement (Pendleton, Heaton, Lehman, & Hulihan, 1982; Perret, 1974), lobectomies (Milner, 1964) and in differentiating individuals with brain damage from neurologically normal individuals (Cohen & Stanczak, 2000). However, the usefulness of this test has been restricted due to issues related to literacy, task duration, motor ability speed, fatigability and tediousness. Cohen and Stanczak (2000) also observed that the task did not clearly differentiate focal versus diffuse lesions nor anterior versus posterior lesions or left versus right lesions, but rather for detection of cerebral dysfunction alone.

The above stated limitations resulted in modification of the written format of the test to an oral format (Controlled Verbal Fluency Test; Benton, 1968) or Verbal Associative Fluency Test (Borkowski, Benton, & Spreen, 1967). This version of the test involved naming as many words as possible belonging to each of the letters F, A, or S separately within a 1-minute time limit (Bechtold, Benton, & Fogel, 1962 as cited in Mitrushina et al., 2005; Tombaugh, Kozak, & Rees, 1999). Even though the letters in FAS version were randomly selected without being based on word difficulty analysis, their norms continued to be used as a common task for many of the verbal fluency studies.

Benton, Hamsher and Sivan, 1994 as cited in Strauss et al. (2006) provided another version of verbal fluency, known as Controlled Oral Word Association Test (COWAT) or “COWA” using two sets of letters C-F-L and P-R-W, wherein participants were required to generate words belonging to each of these letters in one minute time span each. These letters were chosen based on the empirical evidence of word frequency, difficulty and word complexity as defined by the number of words beginning with each letter found in standard dictionaries of the English language (Borkowski et al., 1967).
In this letter based fluency task or commonly known as phonemic fluency or Initial Letter Fluency task, based on the chosen letter, participants are instructed to generate words beginning with a particular letter within the defined time limit. Generation of words specific to the category given (Semantic Category Fluency / semantic fluency) is also another version of verbal fluency used frequently in neuropsychological testing. In this task, the participants are instructed to generate words belonging to a particular semantic category within the restricted time limit. Both the phonemic and semantic fluency tasks are relatively easy and quick to run, requiring an administration time of approximately 5-10 minutes.

Verbal fluency tasks are available for clinical use as subtests of other standardized tests (aphasia / dementia / executive function / neuropsychological batteries) and also as stand alone tests. While some of the tests are semantic category based, others are phonemic based with varying letters or categories as the sub tasks. Some of the available standardized tests includes Neurosensory Center Examination for Aphasia, Multilingual Aphasia Examination, Neuropsychological Assessment of Children, Dementia Rating Scale, Delis-Kaplan Executive Function System, Kaplan Baycrest Neurocognitive Assessment, Test of Verbal Conceptualization and Fluency, Repeatable Battery for the Assessment of Neuropsychological Status, Woodcock-Johnson III Tests of Cognitive Abilities, Clinical Evaluation of Language Fundamentals-3, Boston Diagnostic Aphasia Examination, Western Aphasia Battery, CERAD, Addenbrooke’s Cognitive Examination, Stanford Binet Intelligence Scale, Iowa Screening Battery for Mental Decline, Short Cognitive Evaluation Battery 7-minute screen and Cambridge Semantic Memory Test Battery (Mitrushina et al., 2005; Spreen & Risser, 2002).

Along with tasks of phonemic and semantic fluency, alternative versions of fluency tests have also been developed to evaluate verbal fluency. Some of the versions of verbal fluency task are action fluency test (Piatt, Fields, Paolo, Koller, & Troster, 1999), homophone meaning generation test (Warrington, 2000), alternating/switching verbal fluency (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001), set test (Isaacs & Kennie, 1973), excluded letter fluency (Crawford, Wright, & Bate, 1995), modified Fuld verbal fluency test (Chiu et al., 1997), sound fluency task, free fluency task (Sauzeon et al., 2004) and rhyming fluency task (Kircher, Nagels, Kirner-Veselinovic, & Krach, 2011).
2.2.1 Initial Letter Fluency task

Phonemic fluency (letter fluency / formal-based fluency / lexical fluency / initial letter fluency / phonological fluency / letter-cue word generation) task involves the production of as many words as possible belonging to the specific letter within a fixed time frame. For example, if the specific letter provided is letter ‘P’, the examinee needs to generate words such as *pen, paper, police, powder* etc. within the time frame provided (60 seconds usually) without producing any errors such as repetitions or words not starting with the specified letter. It has been reported that a normal individual can generate about 12-14 words starting with a specific letter with children aged 6 years generating less than five words (Spren & Strauss, 1998; Troyer et al., 1997).

**Variations in letter stimuli used:** Variations in terms of letters used for phonemic fluency has been reported in literature. The initial and the most commonly used version of phonemic fluency is *FAS* task using the letters ‘F-A-S’ (Benton, 1968; Controlled Verbal Fluency Test) followed by Benton, Hamsher and Sivan, 1994 as cited in Strauss et al. (2006) who provided *COWAT* using two sets of letters ‘C-F-L’ and ‘P-R-W’. For investigating verbal fluency, different combinations of letters have also been reported in literature such as *P, F and L; S, N and F; S and P; N, A and K; P, M and R; B, H and R; T and N; F, L and M; S, T, P and C* (Lezak, 1995; Mitrushina et al., 2005; Spren & Risser, 2002; Spren & Strauss, 1998; Strauss et al., 2006).

Borkowski et al. (1967) developed the first norms for phonemic fluency task based on analysis of letter difficulty on all the letters of the English alphabet except X and Z using 1-minute test intervals with 66 maternity patients. Based on the analysis of difficulty, the letters were divided into three difficulty levels: hard (*Q, J, V, Y, K, U*); moderate (*I, O, N, E, G, L, R*) and easy (*H, D, M, W, A, B F, P, T, C, S*). Thus, *FAS* version includes easy letters while *CFL/PRW* version includes both easy and moderately difficult letters. Ruff, Light, Parker, and Levin (1996) and Spren and Strauss (1998) suggested that though both *FAS* and *COWA* are two versions of the same task, the raw scores are uncomparable due to the use of varying samples and different levels of difficulty. On similar lines, Barry, Bates, and Labouvie (2008) reported that *CFL* version was more difficult than *FAS* with increased difference in *FAS* task among normal participants. Contrary to this, Lacy et al. (1996) and Troyer (2000) reported a
high correlation between CFL and FAS tasks. Recently, Ross, Furr, Carter, and Weinberg (2006) reviewed the equivalency of the COWAT letter sets, and have established that these letters can be used interchangeably, whenever testing is done in English language.

**Variations in time frame used:** Apart from variations in the letter chosen for the phonemic fluency task, variations in literature in terms of the time frame of recording the word production have been reported. The time frame generally used for the task is one minute for each letter chosen. Few studies have used varying time frame of 30 seconds (Cohen et al., 1999), 90 seconds (Jurado, Mataro, Verger, Bartumeus, & Junque, 2000), 1.5 minutes (Harrison, Buxton, Husain, & Wise, 2000), 2 minutes (Holtzer, Goldin, & Donovick, 2009) and 3 minutes (Tucha, Smely, & Lange, 1999). Recently, the focus has shifted to analysis of the performance as a function of time, wherein, the word productivity is analysed at every 15 seconds interval of the sixty seconds time frames (Hurks et al., 2010).

Azuma (2004) reported that during phonemic fluency task, the word generation is less likely to be dependent on the automatic activation or organized in a network as seen during semantic fluency task. While generating words based on phonemic characteristics, participants need to involve themselves in attention-demanding active process of self-monitoring in order to prevent errors, suppressing previous responses and generating cues to access new items.

**2.2.2 Semantic Category Fluency task**

Similar to phonemic fluency task, semantic fluency tasks (category fluency / semantic category fluency / list generation task / conceptual fluency / free listing / category production task / semantic-cue word generation) also require word generation on a specified category within a time frame. For example, if the specified semantic category is ‘animals’, the examinee needs to generate the members belonging to the semantic category of animals such as tiger, lion, cat, dog etc. within the time frame provided (60 seconds usually) without producing any errors such as repetitions or words not belonging to the specific semantic category. Different versions of semantic fluency are generally reported in literature including animals, types of transportation and cars, parts of car, items in a supermarket, things in kitchen, fruits, vegetables, foods, drinks, groceries, first names of people, Girls’ names, Boys’
names, plants, tools, clothing, professions, colors, parts of human body, things that make people happy / sad, toys, countries, musical instruments, sports, cities, flowers, trees, U.S. states and inanimate objects (Carneiro et al., 2008; Lezak, 1995; Mitrushina et al., 2005; Spreen & Strauss, 1998; Strauss et al., 2006).

Among these categories, the most commonly used category universally is ‘animals’ (Lezak, 1995; Mitrushina et al., 2005; Spreen & Strauss, 1998). Ardila, Ostrosky-Solis, and Bernal (2006) reported that the performance on animal fluency task was comparable across languages and cultures with minimal differences across countries, different generations and education. While Spreen and Strauss (1998) reported word generation of upto 16 words belonging to a specified semantic category within the time frame of one minute in a normal individual, Spreen and Risser (2002) reported generation of 20 animal names on animal fluency task.

Variations in administration protocol: Different researchers have reported different versions of instructions, with the most common asking the participants to generate all the names of the category (‘animals’ or ‘fruits’) they can think of (Lezak, 1995; Ostrosky-Solis, Gutierrez, Flores, & Ardila, 2007) with scoring involving only words related to the specified category excluding error responses. Some of the researchers provided extra help by even providing exemplars of subcategory labels (Carneiro et al., 2008; Robert et al., 1998). For animal category, participants were asked to generate all the names of animals they can remember belonging to sea, air, forest, land etc.

Variations in scoring protocol: Though different types of categories are chosen for semantic fluency analysis, the authors have employed different methods of reporting their findings. Huff, Corkin, and Growdon (1986), for instance, reported the average of the total number of words produced on the categories of ‘vehicles’, ‘vegetables’, ‘tool’ and ‘clothing’ whereas Bayles et al. (1989) reported the average of ‘animals’, ‘fruits’ and ‘vegetables’. Similarly, in child research, Sauzeon et al. (2004), Kave et al. (2008) and Tallberg et al. (2011) had reported an average score for all the semantic categories together rather than the individual category score. While some authors provided ‘fruits’ and ‘vegetables’ as a single entity (Bayles et al., 1989; Kave, 2005), others considered them as a separate category (Rosselli,
Tappen, Williams, Salvatierra, & Zoller, 2009). Authors have also used the general category label of ‘supermarket goods’ (Martin & Fedio, 1983; Troster, Salmon, McCullough, & Butters, 1989) or provided category names of ‘objects that can be bought in a supermarket beginning with the letter M’ (Lipowska, Bogdanowicz, & Bulinski, 2008).

However, with the recent understanding of distinct representations of different semantic categories in the brain, researchers have started giving more attention towards understanding variations in semantic fluency performance across categories. For example, comparison of performance on animals, fruits, vegetables and clothing (Rosselli et al., 2009), an easy category of animals and hard category of fluids (Mayr & Kliegl, 2000), easy categories of birds, clothes, body parts and colors versus hard categories of insects, fabrics, fluids and writing utensils (McDowd et al., 2011), tools versus fruits (Capitani, Laiacona, & Barbarotto, 1999) and living categories of animals and plants versus non-living set of vehicles and tools (Antonucci, Beeson, Labiner, & Rapcsak, 2008) have also been reported in literature.

In animal fluency task, while some researchers did not consider derivative names (dog, doggie) and supraordinated categories (bird, fish, insect, mammalian, etc.) into consideration (Carnero, Lendiñez, Maestre, & Zunzunegui, 1999 as cited in Ostrosky-Solis et al., 2007), others did not consider intra-species denomination variations or diminutives (horse/mare, horse/colt), variations within the same species (german shepherd, greyhound etc.) during scoring. Some authors specified consideration of extinct, imaginary and magical animal category items like dragon, dinosaurs, mammoth and unicorn (Ostrosky-Solis et al., 2007; Strauss et al., 2006).

The task of generating items related to a category (e.g., animals / fruits) involves the concept of categorization. Categorization plays an important role in understanding, organizing, and identifying things we encounter in the world (Carneiro et al., 2008). Nelson and Nelson (1990) reported that verbal fluency helps in understanding the development of categorization and semantic knowledge in children. In the development of semantic categorization, children exhibit different types of categorization. One such categorization is based on taxonomic relationships, wherein there exist a relation between words based on the
shared properties or similarity among the category members. Categories such as *dog-animal*, *apple-fruits* are some of the examples of taxonomic categories. Another form of organization is **thematic** categorization, wherein words belonging to distinct taxonomic categories share a functional (e.g., *coat-hanger*) or situational relation (e.g., *table-stove*). For example, *dog-bone*, *apple-tree* are examples of thematic pairs. **Script** categories / Slot-filler categories involve items playing the same role in a script. For example, *eggs* and *cereal* belong to the script category of breakfast food items.

The ability to categorize based on taxonomic / thematic / slot-filler relationships are important for day to day functioning and communication. Studies have suggested that by two years of age, children exhibit identification of these categorizations (Fenson, Vella, & Kennedy, 1989); by preschool, they start using these relationships in communication (Blaye & Bonthoux, 2001) and by first grade are able to verbally justify the relationships (Smiley & Brown, 1979). Some researchers have found that young children tend to group items based on thematic relations (Smiley & Brown, 1979) or script categories (Lucariello et al., 1992). Development of taxonomic category relationships is reported by 7-8 years of age, rightly attributed to the rapid development of vocabulary and world knowledge (Lucariello et al., 1992). Although all the relationships are available from an early age, there is a lack of consensus among researchers on the shift from thematic to taxonomic or from script to taxonomic categories with development (Nguyen & Murphy, 2003).

On category generation task, Nelson and Nelson (1990) found that kindergarten children produced more items in the context constrained slot-filler (e.g., naming of animals found at the zoo) than in the taxonomic condition (e.g., naming animals) as compared to second grade children where they organized better on taxonomic than slot filler condition. Categorization skills are also found to be dependent on experience, cultural and environmental exposure. Kindergartners with preschool experience were observed to generate more category items in an organized manner as compared to kindergarten children with no prior school experience. The authors suggested that children progress from organization of concepts based on contextual, script based information (e.g., foods we eat for breakfast) to less contextual dependent organization based on their experience (e.g., food).
Chapter 2

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Raboutet et al. (2010) illustrated the three mechanisms of retrieval while performing semantic verbal fluency task. The first retrieval process was described as inter-categorical process or switching which accounts for search and retrieval of different semantic categories. Switching involves shifting from one subcategory to another. For example, if a child produces the following animal names on semantic fluency task: lion, tiger, snake, lizard, cat, dog; the number of switches is two as the child produced the categories of feline (lion, tiger), reptile (snake, lizard) and household pet (cat, dog) animals. Along with switching process, semantic fluency tasks also require intra-categorical process or clustering which involves production of exemplars belonging to the same category. In the previous example, feline, reptiles and household animal categories are the three clusters retrieved during the animal fluency task. Children, during retrieval also involve themselves in the third process, which is a hierarchical exploration of retrieving both common and specific examples from within a category. For example, production of category exemplars such as milk, cheese, yoghurt etc. under the category label of dairy for a task of naming items found in supermarkets.

2.3 Models of Verbal Fluency

Models of verbal fluency as described below are various representations and scientific explanations based on different researchers' perspectives attempting to illuminate its intricate aspects. Generally, the domain of verbal fluency is explained from the viewpoint of lexical access, control, semantic memory and lexical store models.

2.3.1 Lexical Access Models

As Roelofs (2002) appropriately described, lexical access is an efficient process by which information (word’s meaning, syntax, morphological units and sound structure) about words is retrieved from memory in order to construct articulatory programs for the concepts to be verbally expressed. In simplified terms, it relates to how words are retrieved from the mental dictionary when required. The verbal fluency task has been used as a method for testing lexical access in non-clinical as well as in disordered population (Cohen et al., 1999; Koren et al., 2005; Riva et al., 2000; Weckerly, Wulfeck, & Reilly, 2001). It is believed that better a person’s ability to assess lexical items from the lexicon, the more items the person would be able to generate (Troyer, 2000).
a. Serial Model of Word Production (Levelt, 1999)

In this model, the word production is considered as a staged process, starting with selection of target for production and ending with initiation of articulation. In the first stage of conceptual preparation, the individual needs to choose a particular lexical concept for expression followed by retrieval of a word or lemma from the mental lexicon in constructing a message. In the next level of phonological code retrieval, the speech sounds (phonemes) of the word become available along with the number of syllables and stress pattern. In the phonological encoding stage, the phonemes are assigned to syllable position resulting in phonological word as the output. The production and execution of complex articulatory programs corresponding to each syllable occurs in the final two stages.

Though Levelt’s model explains the process of word production, it focuses only on lexical node selection and not on the activation of semantic competitors or the bottom up processing. With respect to verbal fluency, this model does not explain how the error production (such as semantic errors, unrelated words or non-words) occurs or how sometimes words sharing both semantic and phonological features are produced (example: panda, panther during the animal fluency task).

b. Interactive Model (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997)

One of the connectionist theory, Dell’s two-step interactive activation model, involves two steps of interactive activation retrieval mechanism. The model is called 'two-steps' as there are two steps from semantic to the phonological level under three layers of lexical knowledge. This model is called ‘interactive’ as all the connections are bi-directional with activation spreading both ways. The strength of each connection is assumed to be a product of learning and recent experience.

For example, to produce the target word ‘cat’, the retrieval of word initiates with activation spreading through the semantic network based on the semantic features of intended word and selection of the most active word. In a similar way, phonological retrieval occurs by activation and selection of most activated phonemes. Activation of both target and non-target words / phonemes may result in production of errors (e.g., semantic -“dog”, formal -“mat”, mixed -“rat”, unrelated -“pen”, or non-words -“lat”). Though evidence for this model has
been described in Aphasic population, Levelt (1999) refuted the presence of interaction only for special cases and not during normal processing.

c. Cascaded Models (Caramazza, 1997)

Though discrete models such as Levelt model believe that the stages must complete before moving on, cascaded models believe in the assumption that stages can get started as soon as some amount of information is available. The cascaded model believes that spreading activation is not controlled by selection. Here, the activation flows continuously from lexical to phonological layer.

Hence, for naming the picture of dog, due to spreading activation principle, several lexical nodes are activated (‘cat’ and ‘dog’). Before selection of the target word, activation of phonological segments of both target (/d/, /c/, /g/) and non-target lexical nodes (/k/, /æ/, /t/) get activated. The prediction regarding phonological intrusion (saying ‘cat’ for ‘rat’) is well explained by this model. These errors are considered to occur as a result of failure in the lexical selection mechanism in selecting the word corresponding to selecting semantic representation.

2.3.2 Control Models

Control models focus on the various component of executive functioning. These cognitive processes are important for a variety of functions during verbal fluency including planning, organizing, problem solving, initiation, regulation, strategy generation, sequencing, inhibition of inappropriate responses and termination to reach the desired behaviour.


This model of self-regulation focuses on the control of well-learned habits (routine actions) and willed (non-routine) actions. The routine action selection involves habitual, automatic selection of appropriate behaviour, using contention scheduling system without conscious input. An example of this might be the activity of driving a well-learned route to one’s own office or switching on the light while entering the room.

Contrary to routine actions, the complex, novel behaviours or non-routine action selections involve a supervisory attentional system (SAS), which responds to situations that
are not capable of being handled by habit-based processes, as for example, coping with the closure of a road on one’s normal route. The tasks such as verbal fluency require the use of the attentional system for generating and implementing new schema and are considered as a measure of inhibitory abilities for individuals with executive dysfunction (Burgess, Alderman, Evans, Emslie, & Wilson, 1998).

b. Working Memory Model (Baddeley, 2012)

The multi component model of working memory is comprised of central executive component, phonological loop, visuospatial sketchpad and episodic buffer. The central executive system controls attention and regulates the other three components. The verbal or speech based information is maintained in the phonological loop whereas visuospatial information is temporarily stored and manipulated in visuospatial sketch pad. The episodic buffer integrates short term and long term memory and is involved in retaining and manipulating the limited amount of information.

In relation to verbal fluency, the role of central executive component in rapid initiation of organized retrieval utilizing flexible search processes have been supported by many researchers (Abrahams et al., 2004; Troyer et al., 1997; Troyer, 2000). While the phonological loop is important during phonemic fluency task in short term storage of specified letter and tracking previous responses, the visuospatial sketch pad plays a key role in semantic fluency by providing visual imagery to help in word retrieval. Research has indicated the influence of working memory on verbal fluency performance in individuals with non-brain damage, Parkinson’s disease, Huntington’s disease and Alzheimer’s disease (Azuma, 2004; McDowd et al., 2011; Rosen & Engle, 1997; Unsworth, Spillers, & Brewer, 2011). These studies have revealed the role of working memory in search and word retrieval while monitoring for errors and suppressing previously said responses.

c. Three Component Model (Updating, Inhibition & Switching) (Miyake et al., 2000)

Miyake et al. (2000) proposed a three component model to describe the structure of the executive control system. Updating is one of the executive functions, which involves continuous monitoring and modification of contents within one’s working memory. The second component of inhibition deals with the ability to avoid unwanted responses. The last
component shifting or switching involves an individual’s cognitive flexibility to shift between different tasks and mental states. Authors described these three entities as separable but related processes involved in the executive functioning. Miyake et al. reported that tasks such as verbal fluency are relatively complex involving variety of component processes that may or may not be part of executive function and are used to assess other functions such as semantic memory.

2.3.3 Semantic Memory Models

The verbal fluency can also be explained in terms of semantic memory (modular, context based and exemplar based) models. Semantic memory is considered as a part of human memory systems related to storage of knowledge of concepts or meanings (Goni et al., 2011) with greater role for semantic fluency as compared to letter fluency tasks (Henry & Crawford, 2004a) The models described below explain how semantic memory is organized and processed in the brain.

I. Modular Models: Based on modular model perspective, the semantic memory is viewed as comprising of modules which are interconnected and linked. Hierarchical network model and propositional models are considered as part of modular models.

a. Hierarchical Network Model (Collins & Quillian, 1969)

Collins and Quillian (1969) developed a hierarchical network model of semantic memory which describes how people represent and retrieve semantic information. Based on this model, all concepts are organized in a pyramid of interconnected nodes or lexical entries. For example, different types of food items are clustered together based on the fact that they share similar properties. The most general concepts are found at the upper level of pyramid with specific instances of each concept found one level below it on the pyramid. For instance, dog would be found under the general concept of mammal, which will be under the concept of animal.

Though the model explains the hierarchical organization of natural items in the environment, not all types of semantic knowledge are always structured in a hierarchical manner. It remains still divisive over whether the items appearing closer together is just
related to perceptual similarity of shared features alone or related to the association between items (Goldstone, 1994). Despite the criticisms, the hierarchical nature of semantic memory is employed in clinical population. Bottom up deterioration (hierarchical deterioration of subordinate followed by superordinate—saying fruit rather than apple) of semantic memory has been reported in neuro-degenerative disorders such as fronto-temporal dementia and Alzheimer’s disease (Martin & Fedio, 1983; Troster et al., 1989).

b. Propositional Model (Anderson, 1983)

The propositional model, a model of human cognition, is based on the belief that a unitary production system is the basis for all kinds of human cognition. This production system is made up of three memory parts (production memory, declarative memory & working memory) and a set of possible interactions between these memory parts and outside world. Production memory is the part of the memory that persistently stores sets of productions, whereas the declarative memory represents semantic net linking propositions, images, and sequences by associations. Working memory is the part of long term memory which holds permanent or temporary information and is highly activated.

According to this model, the knowledge begins as declarative information, with the procedural knowledge learned by making inferences from already existing factual knowledge. This kind of knowledge system plays a key role in language learning in terms of generalization of its application, learning new concepts as well as strengthening certain productions.

II. Context-based Models:

The retrieval of semantic information from the mental lexicon is also dependent on the context (linguistic or real-world). The context can act as a prime helping in deriving meaning of words. Spreading activation, typicality and schema models are some of the context based models.

a. Typicality Model (Rosch, 1975)

This model focuses on the typicality of a semantic category, that is, the degree to which category item is a typical and representative member of a particular category. For
example, in the fruit category, apple is usually named as a typical fruit whereas olives are considered as atypical.

It has been believed that all objects in the world can be clustered together based on correlation between attributes, with more typical items accessed easier than less typical items. Possession of one attribute (for example, a creature that has feathers) tends to correlate within the general class of creatures with the possession of other attributes (such as, having wings and flying). This typicality relation may be applied for different types of categories including superordinate and subordinate relationships.

b. Spreading Activation Model (Collins & Loftus, 1975)

This model of semantic memory organization deals with the manner in which words are organized. They assumed that words are represented in the internal lexicon in a network without strict hierarchical organization. The organization is closer to a web of interconnecting nodes, with the concepts stored in terms of attributes or characteristics. For example, a word such as ‘lion’ may get grouped with collection of highly similar words such as tiger, leopard, cheetah to form the semantic network of animal category. Similarly, during the process of semantic activation of farm animals, the concept cow may get more strongly activated than animals belonging to category of wild animals.

Researchers have attributed the organization of words during the tasks of verbal fluency to this spreading activation principle (Schwartz, Baldo, Graves, & Brugger, 2003; Troyer, 2000). It is believed that in the verbal fluency task, participants do not randomly generate some words from semantic memory but rather involve in a systematic and organized semantic search process of related words based on semantic proximity within the rules of the task. In the study by Schwartz et al. (2003), on the semantic fluency task (animal, fruits name), non-brain damaged participant’s (n=40) generated words by grouping words according to size (‘giraffe’, ‘elephant’), domesticity (‘farm animals, wild animals’) and prototypicality (‘cat’, ‘dog’, ‘apple’, ‘orange’, and ‘banana’). Similarly on tasks of phonemic fluency (letter A or F), participants generated words as either animate/living (Example: ‘ant, anteater’) or inanimate/functional (Example: ‘air, airplane’).
c. Schema Model (Mandler, 1979)

Based on this model, the focus of memory organization is on the ordering based on schemas rather than the relationships. Schemas are the cognitive structures which are spatially or temporally organized, formed on the basis of past experiences with objects, scenes or events. For example, a zoo schema would contain information about the animals, types of animals seen, activities involved and so on with mental representation regarding the zoo setting. Mandler (1979) proposed that the schemas provide the most active and constructive set of retrieval cues than a taxonomic sort of categorization of how the world works. These mental representations are reported to be automatically activated by familiar situations regardless of age, culture and schooling.

III. Exemplar Models:

Exemplar models described below explain the nature of category representations in the semantic memory. Contrary to the context based models, the exemplar based models focus on the exemplar view of categorization of relationships. The classification decisions are either based on features of the concepts (feature comparison model) or similarity comparisons with stored exemplars (similarity model).

a. Trait Comparison / Feature Comparison Model (Smith, Shoben, & Rips, 1974)

The computational model developed by Smith et al. (1974) describes the processes that operate in semantic memory and views the concepts as a set of attributes or semantic features. As per this model, it is believed that the members of a particular category share a set of family resemblances / features which are used for feature comparison.

For example, the features such as ‘has wings’, ‘lays eggs’, ‘has feathers’ and ‘can fly’ are the semantic features of the concept - bird. The features may be defining features (essential to define a concept; ‘has feathers’) or characteristic features (features associated with a concept but not essential to define a concept; ‘small’). The authors also suggested that number of defining features will be greater for a subordinate category (pigeon) than the superordinate or larger category (bird). The greater the number of defining features, closer the words get organized in the mental lexicon and are easily retrieved with greater speed and accuracy. This concept of feature comparison, however has been contradicted by researchers
such as McCloskey and Glucksberg (1978) who have supported the presence of ill-defined or fuzzy structure of categories, that is, they have no clear boundaries separating members from non-members.

**b. Similarity Model / Context Theory for Classification (Medin & Schaffer, 1978)**

According to Medin and Schaffer (1978), people represent categories by storing individual exemplars in memory rather than error-driven learning. Based on this exemplar based approach, classification and recognition decisions are made on the basis of similarity comparisons with the stored exemplar information. The highest recognition probabilities are those with highest familiarity scores. Therefore, an item highly similar to one member of category would be retrieved with greater ease than another item which is not highly familiar to that particular category. They reported that the ability to group items into appropriate classes is dependent on the evolution of concepts from the experience with exemplars, rather than the formal learning in school alone, which further enhances the learning experience.

**2.3.4 Lexical Store Models**

Semantic processing requires not only accessing of semantic knowledge but also intact lexical store. Lexical store refers to how words are stored in relation to other words. For example, a word *apple* is stored in relation to words such as *orange, grapes, mango* etc. which are all related to each other in terms of belonging to the same group of *fruit*. Similarly, words such as *fare, pear* and *rare* are linked with respect to the sound /ea/. In the above examples, the relation is made with respect to meaning and form of the words respectively. The integrity of lexical store along with the appropriate retrieval of words is reported to have a crucial role during verbal fluency tasks (Allen, Liddle, & Frith, 1993; Temple, 2002).

**2.3.5 Recent perspectives on Verbal Fluency**

Keeping in consideration the above four models (control models, lexical access, lexical store and semantic memory), contemporary researchers have attempted to explain the cognitive substrates of verbal fluency. The models described below are based on research studies in brain damaged and neuroimaging findings. Though there is no common ground on the exact nature of cognitive correlates of verbal fluency, the role of verbal fluency as a task for assessing language (semantics) and executive functioning has been endorsed by these recent models of verbal fluency.
Chertkow and Bub (1990) hypothesized a two-component model of verbal fluency based on their study in Alzheimer’s type of dementia. They observed marked deterioration on semantic fluency tasks in individuals with dementia of Alzheimer’s type which was related to deterioration in semantic store with an inefficient semantic search. Based on their study findings, they concluded that two components for effective verbal fluency performance required are an intact semantic store for supplying a knowledge base of related words and an effective search process to access and retrieve this information.

In consonance with Chertkow and Bub’s (1990) predictions, Troyer et al. (1997) proposed the much acclaimed and popular, two component processes of verbal fluency. The “store” and “search” processes involved in verbal fluency tasks were operationalized as clustering (associative component) and switching (executive component) processes which were considered as two dissociable components. Troyer et al. described clustering as the process involved in production of successive words or clusters belonging to same subcategories (semantic or letter based) and switching as the process involved in shifting between the clusters. Therefore, a poor performance during word generation task can occur as a result of inability to produce words belonging to a particular subcategory or as a result of an inefficient search strategy within the time limit given.

Contrary to Troyer et al.’s (1997) suggestion, Mayr and Kliegl (2000) proposed another model of semantic verbal fluency involving two additive components, that is, semantic and executive. During the act of word retrieval, the executive component involves updating the current search criterion and stopping or starting retrieval processes. The semantic component reflects the actual semantic search demands, such as spreading of activation in the semantic network. The authors hypothesized that both semantic and executive components play an equal role during semantic fluency retrieval with semantic processing involved being same for between and within cluster retrieval.

In addition to the store and search processes, Rosen and Engle (1997) proposed a four component model of verbal fluency. According to them, verbal fluency involves automatic activation spreading from the cue to related items, monitoring of the generated items to prevent errors such as repetitions, suppression of previously recalled items, and self-
generation of category cues to access new items. Auriacombe et al. (1993) proposed involvement of four cognitive processes during verbal fluency, which were, attention and vigilance, a lexical or semantic store, retrieval mechanism and working memory that monitors item already produced.

Oria et al. (2009) discussed the processes involved in verbal fluency task based on the findings in childhood diarrhea. They reported that though responses are triggered by an auditory stimulus (“name animals or say words starting with letter P”), it requires self-initiation and maintenance of a mental process in the absence of any on-going external cues. The authors described the task as self-driven, requiring motivation and self-control. Snyder and Munakata (2010) considered verbal fluency as a complex and unconstrained task for tapping endogenous flexibility involving self-direction. During the task, the participant needs to detect the need to switch and select what to switch to in order to accomplish the goal of word generation within the time limit. Robinson, Shallice, Bozzali, and Cipolotti (2012) based on their study on sensitivity of verbal fluency on frontal lobe damage, hypothesized three cognitive processes involved during word generation. The three processes involved are sustained activation or energization involving the superior medial region of the frontal lobe, selection involving left inferior frontal gyrus and the creation of novel responses. They described verbal fluency task as involving voluntary generation of non-overlearned responses.

Along with semantic and executive components, the role of metacognitive components has also been reported in literature (Young, 2004). While retrieving information from semantic memory, willingness to continue the search and feeling of knowing also plays an important role. This willingness is important while having difficulty in retrieving newer words with feeling of knowing essential during decision making of when to shift from one semantic sub-category to the next.

2.4 Neuroanatomic and Biochemical correlates of Verbal Fluency

The areas of brain activation and effect of brain pathology during verbal fluency task have been understood using electrical stimulation of cortex over source localization of event related electrical and magnetic cortical activity (Event related potential, Magnetoencephalography), regional Cerebral Blood Flow (rCBF), Positron Emission

The verbal fluency paradigm has been widely used to investigate hemispheric dominance for language among adults and children with and without brain damage (Baldo & Shimamura, 1998; Birn et al., 2010; Gaillard et al., 2003; Robinson et al., 2012; Senhorini et al., 2011; Troyer et al., 1998a). Verbal fluency tasks are also used to explore developmental aspects of language processing and gaining insight into the maturation of language neural networks (Gaillard et al., 2000; Schlaggar et al., 2002). It is therefore essential to understand the specific brain regions that are engaged during verbal fluency tasks.

### 2.4.1 Neuroanatomical correlates of Verbal Fluency - research in Adults

Studies on neuroanatomical correlates of verbal fluency have revealed the role of extensive and sophisticated neuroanatomical network and distinct regions of neuronal activation. Increased activation has been reported in left hemisphere (left dorsolateral prefrontal cortex, left premotor, supplementary motor cortex, left inferolateral temporal lobe, superior-middle temporal gyrus, left posterior inferior parietal lobe, insula, precuneus and anterior cingulate gyrus), right dorso-lateral and medial frontal region, left pre-supplementary motor area-dorsal caudate nucleus–ventral anterior thalamic loop, Basal ganglia (caudate nucleus and putamen), cerebellum and hippocampus (Baldo & Shimamura, 1998; Crosson et al., 2003; Frith, Friston, Liddle, & Frackowiak, 1991; Gleissner & Elger, 2001; Leggio, Silveri, Petrosini, & Molinari, 2000; Robinson et al., 2012; Senhorini et al., 2011; Stuss et al., 1998; Thames et al., 2012; Wagner, Sebastian, Lieb, Tuscher, & Tadi, 2014).

Distinct neural involvement for different tasks of verbal fluency has been explored in literature. Studies have reported distinct anatomical and functional differences between phonemic and semantic fluency with phonemic fluency involving strategic retrieval of word forms being sensitive to frontal lobe damage (Baldo et al., 2001; Baldo et al., 2006; Birn et al., 2010; Stuss et al., 1998; Troyer et al., 1998a) and semantic fluency involving access of lexico-semantic networks, being more sensitive to temporal lobe damage (Baldo et al., 2006;
Rosser & Hodges, 1994; Troyer, 2000). Birn et al. (2010) reported greater activation in left precentral and inferior frontal gyrus, left occipitotemporal sulcus/posterior fusiform gyrus for phonemic fluency task and robust activation in the left middle frontal gyrus and left fusiform gyrus for semantic fluency task. The authors hypothesized the differential involvement to differences in word-form processing demands, which is greater for phonemic fluency as compared to semantic fluency task.

Neuroimaging investigations have also revealed differences in brain activation for different types of semantic fluency. Anterior temporal lobe activation in response to retrieval of names of natural kinds and more pronounced posterior temporal lobe activation for manipulable man-made objects were reported by Mummery et al. (1996). Similarly, Vitali et al. (2005) using fMRI reported enhancement in connectivity within left hemispheric regions, including the inferior prefrontal and premotor cortex, the inferior parietal lobule and the temporo-occipital junction for tool conditions, whereas greater coupling among left visual associative regions was noted in animal conditions. Similarly, in an MRI study in right handed native English speaking individuals, Goldberg, Perfetti, and Schneider (2006) reported representation of semantic category of birds in the left ventral temporal cortex whereas fruits were represented in the bilateral orbitofrontal cortex, left frontal and temporal lobes. These findings suggested task related changes in connectivity and provided evidence for category specific anatomical specialization during word generation task.

Researchers have also studied the neuroanatomical correlates for various strategic components (qualitative aspects of clustering and switching) of verbal fluency. The executive processes regulating semantic retrieval are reported to be located in frontal lobe regions whereas the actual access to semantic memory occurs in temporal lobe region (Troyer & Moscovitch, 2006). Some studies reported that temporal lobe involvement was noted during clustering whereas frontal lobe was involved for switching process based on studies in various clinical population including Alzheimer’s disease, Parkinson’s disease, multiple sclerosis and schizophrenia (Troster et al., 1998; Troyer et al., 1997; Troyer et al., 1998a; Troyer et al., 1998b).
2.4.2 Neuroanatomical correlates of Verbal Fluency - research in Children

Studies have also showed the utility of neuro imaging techniques using verbal fluency tasks in typically developing children and in children with developmental disorders (de Guibert et al., 2011; Gallagher et al., 2007; Hadac, Brozova, Tintera, & Krsek, 2007; Porter, Collins, Muetzel, Lim, & Luciana, 2011). Table 2.1 provides the summary of studies in children describing the neuroanatomical correlates of verbal fluency.

Table 2.1

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Areas of increased activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaillard et al. (2000)</td>
<td>Left inferior frontal cortex (Broca's area); Left MFG (dorsolateral prefrontal cortex); Right IFG</td>
</tr>
<tr>
<td>Holland et al. (2001)</td>
<td>Left IFG (lesser lateralization than adults)</td>
</tr>
<tr>
<td>Schlaggar et al. (2002)</td>
<td>Left inferior and midfrontal gyrus</td>
</tr>
<tr>
<td>Gaillard et al. (2003)</td>
<td>Left IFG, MFG, mesial frontal areas, including SMA, thalamus and left parietal lobe</td>
</tr>
<tr>
<td>Brown et al. (2005)</td>
<td>Age related changes in left frontal and parietal lobe</td>
</tr>
<tr>
<td>Lee et al. (2007)</td>
<td>Inferior parietal lobe, posterior SMG</td>
</tr>
<tr>
<td>Porter et al. (2011)</td>
<td>Changes in cortical thickness by middle childhood</td>
</tr>
<tr>
<td>Tamekuchi, Hashimoto, Honda, Miyamura, &amp; Abo (2011)</td>
<td>Left Prefrontal cortex</td>
</tr>
</tbody>
</table>

IFG=Inferior Frontal Gyrus; MFG=Medial Frontal Gyrus; SMG=Supramarginal Gyrus; SMA = Supplementary Motor Area

Though both children and adults activated similar regions, predominantly in left inferior and middle frontal cortex, differences were noted in regions associated with language including the perisylvian regions surrounding Wernicke's and Broca's areas in left hemisphere (Gaillard et al., 2000; Gaillard et al., 2003; Porter et al., 2011). These findings indicate that word production during verbal fluency task requires an extensive neural network different from adult population with an age related differences in activation patterns in terms of wider cortical activation in children. This greater activation was attributed to developmental plasticity for the ongoing organization of neural networks, which underlie language capacity.
The neuroanatomic correlates of verbal fluency have also been studied among disordered population in children. In a study among 122 children with head injury between 5-15 years of age, Levin et al. (2001) reported that recovery pattern was slower in younger children as compared to older children and that the effect was greater for frontal lesions involving left hemisphere on phonemic fluency. The authors interpreted this as the reflection of the more established functional involvement of the left frontal region to expressive language in older children. In a study among French speaking children (n=21) with Specific Language Impairment, de Guibert et al. (2011) reported smaller activation in left dorsal inferior frontal gyrus with no activation in posterior superior temporal gyrus. Presence of right dominant activation of anterior insula and ventral inferior frontal gyrus in comparison with control group was also reported.

Similarly, Hadac et al. (2007) employed verbal fluency task in Czech language for studying hemispheric dominance for language. fMRI data were obtained on verbal fluency (using letters V, R, S and N) from 34 children aged 7-18 years with pre- and postnatal epileptogenic lesions of left hemisphere. Prominent left hemisphere activation was noted in 56% (19 children) and right hemisphere co-activation / complete shift to the right in 44% (15 children). Atypical language representation was reported in 31.6% of children with developmental pathology and in 60% of children with an acquired epileptogenic lesion. The likelihood of right hemisphere shift was seen more with acquired lesions than developmental lesions. The authors further reported that younger age of epilepsy manifestation and increased persistence of seizures are significant factors for language reorganization.

2.4.3 Biochemical correlates of Verbal Fluency

Along with neuroimaging studies, studies’ focusing on biochemical correlates have also been employed during verbal fluency tasks using techniques such as Proton magnetic resonance spectroscopy. Jung et al. (1999) explored biochemical markers of cognition using proton Magnetic Resonance Spectroscopy ($^1$H-MRS), which measures levels of certain neurometabolites in vivo in normal human brain in the left occipitoparietal white matter. They reported that verbal fluency tasks were closely related to concentrations of neurometabolite N-acetylaspartate (NAA) as compared to other neuropsychological tests. Similarly, though uncorrelated, a lower N-acetyl aspartate/choline ratio (in right frontal cortex and left
hippocampal region) has been reported in children with obstructive sleep apnea (n=19) with associated deficits on verbal fluency (Halbower et al., 2006).

Ferguson et al. (2002) in contrary did not report of any association between NAA concentration and verbal fluency in the parietal cortex among healthy elderly individuals aged 65-70 years. On similar lines, Valenzuela et al. (2000) reported that verbal fluency scores did not correlate with NAA / Creatine levels in the left frontal subcortical white matter region based on their study in 20 elderly participants between 59-85 years.

2.5 Factors influencing Verbal Fluency

Significant moderators of verbal fluency have been studied in literature, with some of the factors showing positive influence on verbal fluency performance. This section focuses on the summary of each variable effect as illustrated by various researchers with specific emphasis on studies pertaining to childhood population.

2.5.1 Impact of Age on Verbal Fluency

Greater word productivity on verbal fluency has been demonstrated in older age group children (Ardila & Rosselli, 1994; Bolla, Lindgren, Bonaccorsy, & Bleecker, 1990; Cohen et al., 1999; Kave, 2006; Regard, Strauss, & Knapp, 1982; Tallberg et al., 2011) with greatest increase seen between ages 10 and 15 years (Matute, Rosselli, Ardila, & Morales, 2004). Sauzeon et al. (2004) in their study of children between 7-16 years found greater differences between 7 to 8 and 9 to 10 year old children on total number of words, clustering and switching, which gradually decreased with age. Brocki and Bohlin (2004) reported a protracted course of development for COWAT (FAS; animals, things to eat) based on a study among 92 children aged 6-13 years. A significant difference was noted at 8 years and 12 years of age with three active stages of maturation observed during early childhood (6-8 years of age), middle childhood (9-12 years of age), and early adolescence.

In terms of qualitative outcome measures, increase in clustering – switching scores with age has been reported by Tallberg et al. (2011) (in number of semantic and phonological clusters, phonological cluster size and number of semantic and phonological switches in letter fluency task; in number of semantic clusters and number of semantic and phonological
switches on animal fluency), Koren et al. (2005) (in number of clusters), Sauzeon et al. (2004) (in number of switches in phonemic fluency; cluster ratio and cluster size in semantic fluency), Kave et al. (2008) (in number of clusters, semantic cluster size and number of switches) and Hurks et al. (2010) (in number of switches/clusters, mean cluster size). Lack of age difference on mean cluster size has also been reported by many researchers including Koren et al. (2005), Tallberg et al. (2011) (in semantic cluster size), Sauzeon et al. (2004) (in cluster size in phonemic fluency) and Kave et al. (2008) (in phonemic cluster size).

The studies in general, have emphasized the fact that performance on verbal fluency continued to develop into adolescence and early adulthood consistent with the continuation in brain maturation. Welsh, Pennington, and Groisser (1991) found word retrieval in 12-year-old children being at a lower level than adult performance. Tallberg et al. (2011) reported that the mean number of words produced during initial letter fluency and animal fluency task by 15-year-old children were lower than a group of young adults aged 16-29 years. Similarly, Kave (2006) indicated a difference in scores between groups of adolescents aged 16-17 years and young adults on animal fluency but not on initial letter fluency. Hurks et al. (2010) reported that the mean cluster size was not established until grade III with number of correct responses, switches and clusters established only by 12-14 years.

On the contrary, some researchers have reported of verbal fluency performance attaining adult levels by adolescence (Anderson et al., 2001; Anderson, 2002; Regard et al., 1982). In the study of Kave (2006), though total number of words was lower in late teens than adulthood, the number of phonemic switches and clusters were similar to adult age group with the authors proposing that executive strategies for phonemic fluency task were already developed by adolescence. Some of the cross sectional studies (Klenberg, Korkman, & Lahti-Nuuttila, 2001; Koren et al., 2005; Levin et al., 2001) have also shown that increase in verbal fluency scores continued until mid-adolescence (till 13 years of age).

2.5.2 Impact of Gender on Verbal Fluency

Research findings on the influence of gender appear to be less consistent. Many researchers have reported of no significant difference between boys and girls on verbal fluency (Ardila & Rosselli, 1994; Brocki & Bohlin, 2004; Charchat-Fichman et al., 2011;
Halperin, Healey, Zeitchik, Ludman, & Weinstein, 1989; Hurks et al., 2010; Koren et al., 2005; Levin et al., 2001; Regard et al., 1982; Riva et al., 2000; Sauzeon et al., 2004; Tallberg et al., 2011). Higher scores on verbal fluency in school-aged girls than boys (Anderson et al., 2001; Barr, 2003; Klenberg et al., 2001; Sincoff & Sternberg, 1988) and girls with ADHD (Reader, Harris, Schuerholz, & Denckla, 1994) have been documented.

Category-specific differential gender effect has also been reported in literature. While females obtained superior scores in vegetables and fruits, no gender effect was reported for animals and clothing (Acevedo et al., 2000; Capitani et al., 1999). Gender influence on verbal fluency performance with more advantage for males in the semantic category of tools and female advantage among fruits has also been documented (Capitani et al., 1999) which was related to different autobiographical experience with each gender group. Gender differences in neural activation during verbal fluency tasks have also been studied and reported in the literature. While some researchers have reported different patterns of brain activation between gender groups (Bell, Willson, Wilman, Dave, & Silverstone, 2006; Schlosser et al., 1998), no significant effect of gender has been reported by others (Sommer, Aleman, Bouma, & Kahn, 2004; Weiss et al., 2003).

A possible effect of gender on qualitative aspects of verbal fluency has also been explored. Troyer et al. (1997) reported minimal effect size for gender as a predictor for the clustering and switching variable. In the study by Weiss et al. (2006), women were observed to be at an advantage on phonemic fluency task with greater switching scores and smaller cluster size resulting in more number of generated words. The authors believed that the gender difference indicated differing use of processing strategies by males and females resulting in varying verbal fluency performance. They recommended consideration of gender as a moderating variable in future clinical studies.

2.5.3 Impact of Literacy and Education on Verbal Fluency

Literature regarding influence of literacy and education indicated significant positive influence (Acevedo et al., 2000; Chan & Poon, 1999; Cohen et al., 1999; Crossley, D'Arcy, & Rawson, 1997; Kempler et al., 1998; Korkman, Kemp, & Kirk, 2001; Mathuranath et al., 2003; Ratcliff et al., 1998; Troyer, 2000) with predominant influence of education on initial
letter fluency than semantic fluency (Ratcliff et al., 1998; Tombaugh et al., 1999). On letter fluency task, among Spanish and Greek population, the number of words generated by illiterate population was listed to be around 3-4 words in a minute (Kosmidis, Vlahou, Panagiotaki, & Kiosseoglou, 2004; Ostrosky-Solis, Ardila, & Rosselli, 1999). Crossley et al. (1997) based on their study among healthy elderly individuals with greater than 13 years of education reported that they were able to generate twice as many words as compared to individuals with educational level of 0-6 years. However, reports of little or no influence of education (Bolla et al., 1990; Harrison et al., 2000) have also been documented.

Across semantic category fluency, better performance on animals, fruits and furniture categories at higher education levels but not on vegetables, food and supermarket categories has been reported (Acevedo et al., 2000; da Silva, Petersson, Faisca, Ingvar, & Reis, 2004). da Silva et al. (2004) reported the use of active search strategy in literate participants with higher number of words and greater number of switches between subcategories for animals and supermarket fluency. The literate participants could generate names such as dinosaurs, camels, kangaroos etc., while in the illiterate group, the responses were restricted to cats, dogs and horses, seen in their day to day environment.

2.5.4 Impact of Psychosocial factors on Verbal Fluency

Influence of psychosocial factors such as socioeconomic status, educational background and profession of the caregiver on verbal fluency performance has been documented (Ardila & Rosselli, 1994; Hurks et al., 2010). Prigatano et al. (2008) studied 213 children in grades I to VIII belonging to minority backgrounds (Hispanic) and low socioeconomic background. The animal fluency scores across age and grade levels were compared and similar performance was noted in comparison with white children from middle socioeconomic status in United States. Contrary to this, Ardila and Rosselli (1994) reported lower performance among children from low socioeconomic status in Columbia. They attributed the low performance to impoverished educational experience children received in school in terms of teachers, teaching facilities and infrastructure. Kishiyama, Boyce, Jimenez, Perry, and Knight (2009) also reported lower performance in children belonging to low socioeconomic status on semantic fluency.
Recently, studies carried out among children have indicated the positive influence of parents and caregiver's educational level on verbal fluency performance (Hurks et al., 2006; Hurks et al., 2010; Kave, Shalmon, & Knafo, 2013; Klenberg et al., 2001) with lower performance in children of parents with lower educational achievement. Hurks et al. (2010) found positive influence of level of parental education on semantic fluency in Dutch speaking school aged children. The significant main effect of the level of parental education (LPE) was seen for the verbal fluency outcome measure of mean cluster size (longer clusters in higher LPE group) but not for number of switches / clusters between lower and higher level of parental education. It was also noted that children of parents of higher scaled education produced more number of words during the first 30 seconds than children of parents of lower scaled education. This differential effect was however not observed during the last 30 seconds of the time frame.

2.5.5 Impact of Cognitive Factors on Verbal Fluency

Studies have investigated the influence of cognitive factors such as verbal intelligence, speed of information processing, word knowledge, verbal long-term memory and attention on verbal fluency measures (Bolla et al., 1990; Bryan, Luszcz, & Crawford, 1997; Dromey & Shim, 2008; Elgamal, Roy, & Sharratt, 2011; McDowd et al., 2011; Ruff et al., 1997; Troyer et al., 1997). A positive influence of intelligence quotient on the semantic category and phonemic fluency performance has been reported in literature (Bolla et al., 1990). In the study by Ardila et al. (2000), a significant correlation (.30 at \( p < .05 \)) was found between verbal fluency and verbal intelligence quotient and Full scale intelligence quotient of Wechsler Intelligence Scale for Children-Revised (WISC-R). Based on their findings, the authors hypothesized that traditional intelligence tests do not appropriately evaluate executive function.

With respect to clustering and switching, only switching was reported to be decreased by an attention demanding secondary task (Troyer et al., 1997). Kraan, Stolwyk, and Testa (2013) suggested that while phonemic fluency is associated with intellectual function and processing speed, the semantic fluency task is associated to working memory and semantic word retrieval.
2.5.6 Impact of other factors on Verbal Fluency

Genetic influence on verbal fluency has been recently addressed in the literature (Hoekstra, Bartels, Van Leeuwen, & Boomsma, 2009; Lee et al., 2012) based on twin studies. Moderate familial resemblance on letter and category fluency (40% and 29% respectively) has been reported by Hoekstra et al. (2009) based on their study among children and adolescents. Lee et al. (2012) based on their Australian twin study reported that genetic factors contributed to 63% variance on the executive functioning task of verbal fluency.

Studies have also addressed the impact of individual difference on verbal fluency. The positive impact of personality traits on verbal fluency has also been documented with higher fluency scores among individuals who are open, extroverted, and emotionally stable. Individuals prone to symptoms of anxiety and depression depicted lower performance scores on category fluency. In a 4,790 community sample aged 14-94 years, the personality-fluency associations were also shown to be consistent across the lifespan and not age-dependent (Sutin et al., 2011).

2.6 Cross-Cultural and Cross-Linguistic aspects of Verbal Fluency

Various studies have addressed the influence of language, ethnicity and culture on verbal fluency. Few studies have reported of positive influence of cultural and ethnic differences (Acevedo et al., 2000; Dick, Teng, Kempler, Davis, & Taussig, 2002; Kempler et al., 1998; Rosselli et al., 2002) warranting the need for norms for different languages or ethnic backgrounds. On the contrary, few studies have not reported of any positive influence of culture on verbal fluency tasks (Agranovich & Puente, 2007; Pekkala et al., 2009).

Significant effects of ethnicity on letter and category fluency have been demonstrated. Better performance on verbal fluency among Caucasians, non-Hispanics and Whites than African American (Gasquoine, 1999; Johnson-Selfridge, Zalewski, & Aboudarham, 1998; Manly et al., 1998) has been demonstrated. Gasquoine (1999) attributed the ethnic difference among Hispanic Americans to English language fluency, length of residency within the United States, years of education, and persistence of poverty.
In terms of **number of words**, significant effects of language on verbal fluency scores have been found. Dick et al. (2002) based on a study among bilingual speakers in New York, reported that the number of words produced by different language speakers varied depending on the length of words in that language. It was noted that on *animal* fluency, while the least number of words was generated by Spanish speakers followed by Chinese and English speakers, the Vietnamese speakers retrieved the maximum number of animal names. It was interesting to note that most of the animal names in Vietnamese were one-syllabic, while they were multisyllabic in Spanish (Kempler et al., 1998). With increase in length of words, the semantic search and retrieval required greater effort and time than retrieving words which are shorter in length. Similarly, Steenhuis and Ostbye (1995) also reported significant difference between French- and English speaking Canadian older population on FAS and *animal* fluency tasks.

Studies have also shown significant cross-linguistic differences in terms of **types of words** retrieved during verbal fluency. Acevedo et al. (2000) studied category fluency among native English speakers and native Spanish-speaking immigrants living in Florida. Though the same number of words were generated by both the groups, English speakers generated greater words in the *vegetable* category than Spanish speakers while Spanish speakers generated more words on the *animal* category than native English speakers. The differences were attributed to differences in exposure to the subcategories of the two tasks, inherent difference between the two languages and divergent early living environments. While in English, the noun ‘*vegetables*’ referred to all herbaceous plants used for food, in Spanish it is a general noun that included all plants.

Similarly, Rosselli et al. (2002) found that during the *animal* fluency task, while English speakers generated more wild animal names, Spanish speakers’ generated names of insects and birds. The increased number of birds and insects among Spanish speakers were related to the fact that the participants were immigrants from tropical countries, where birds and insects were common. The increased number of wild animals was related to experience from school books and television. Further, the frequency of usage of grammatical words (prepositions and conjunctions) was more among English speakers than Spanish speakers.
The impact of geographical region on verbal fluency performance has been broached. In Kempler et al.’s (1998) study among African-American, White, Chinese, Hispanic, and Vietnamese speakers living in southern California on animal fluency, the most frequent animal names produced included words such as ‘dog’, ‘cat’, ‘horse’, and ‘elephant’. However, regional influences were also reported, wherein the common words generated, differed based on the environment and culture, the speakers belonged to. Among the animal names, ‘ox’ and ‘buffalo’ were common for the Vietnamese speakers, ‘donkey’ for the Spanish speakers, ‘rat’ for the Chinese speakers, and ‘giraffe’ for the English speakers. Fillenbaum, Heyman, Huber, Ganguli, and Unverzagt (2001) found that older African Americans living in North Carolina generated lesser animal names as compared to those living in Indianapolis which was related to the quality of education. In a study among Brazilian - Portuguese participants, Brucki and Rocha (2004) found the influence of environment affecting verbal fluency of speakers belonging to different parts of the same country. While city living participants generated words such as ‘horse’ and ‘dog’, those living in rural and rainforest areas generated words such as ‘jaguar’ and ‘monkey’ more frequently.

Ostrosky-Solis et al. (2007) compared the semantic verbal fluency performance (animal fluency) across Spanish speakers from different countries (Mexico, Barcelona, Canary Islands in Spain and Argentina). They found that, despite speaking the same language, statistically significant cultural effect was noted when age and educational effects were not taken into consideration. Differences in scores were attributed to variation in administration and scoring protocol employed in the studies. Similarly, Oberg and Ramirez (2006) in their meta-analysis study (n=926), reported on the influence of language on phonological fluency based on their data from speakers of Danish, English, Spanish and Hebrew language (from Mexico, Argentina, Denmark, USA, and Israel). Regardless of the primary language, the number of words generated was similar across the languages and countries. However, the responses were found to be dependent on level of education and letter frequency in each language. Based on the study findings, authors reported the necessity for culture specific norms based on letter frequency of a particular language.

The influence of cross-language differences in verbal fluency has also been studied in different groups of bilingual population. In Spanish-English studies (Rosselli et al., 2000;
Rosselli et al., 2002), monolinguals were seen to generate a greater number of words than bilinguals on animal fluency but not on FAS task. The difference was attributed to interference between the two languages and weaker connections in a bilingual lexical system for verbal fluency task. Verbal fluency has been also used as a task for assessing a lexical organization among the bilingual population. In a study on 40 French-English bilinguals, Roberts and Le Dorze (1997) found similar performance (in terms of total correct and number of semantic associations) in both the languages for animal and food category. However, the number of subcategory labels, length of the semantic associations and the percentage of words in semantic associations were noted to be greater in French than English for animal category. Similarly, among Russian-English bilinguals, Snodgrass and Tsivkin (1995) reported that on category fluency, more number of Russian words was generated than English with no difference observed for letter fluency.

Contrary to these findings, lack of cultural or linguistic influences on verbal fluency has also been reported in the literature. Pekkala et al. (2009) compared performance of sixty monolingual English speaking and Finnish speaking elderly adults on semantic fluency generation task (animals & clothes). Type/token ratio (number of unique words divided by total number of words) was used to understand the proportion of the most frequently occurring words. Alongside, the number of syllables was calculated in order to find the effect of language on semantic fluency performance. It was noted that there was no difference in the proportions of words produced within the first half (30 seconds) of the semantic verbal fluency tasks, and in the variety of words produced for the categories despite the presence of longer words in Finnish than English. Authors proposed that semantic fluency tasks were relatively culture-free. Similarly, Agranovich and Puente (2007) reported similar performance on category fluency among healthy Russian speakers and American speakers aged 18-44 years.

2.7 Outcome Measures of Verbal Fluency

In order to assess the performance on verbal fluency, there are two kinds of outcome measures employed, that is, quantitative and qualitative measures. The current trend involves assessing semantic organization employing both measures together.
2.7.1 Quantitative measures of Verbal Fluency

In the traditional quantitative measurement of verbal fluency, the total number of correct words produced for the specified letter / category is examined and reported. The total number of correct responses is exclusive of error productions such as perseverations (repeating the correct response: pen, powder, police, *pen*) and intrusions (saying a word that does not belong to a category: pen, powder, police, *spoon*). On F-A-S task, it has been reported that while a healthy old adult generates around 14 correct responses, an older adult with dementia might produce around 10 correct responses (Troyer et al., 1997). Similarly, studies done among healthy children have also indicated that by 9 years, children retrieved $8.48 \pm 3.12$ words whereas by 11 years $8.55 \pm 2.74$ words (Mulenga, Ahonen, & Aro, 2001).

Calculation of total number of correct responses on verbal fluency task has been used in clinical settings, with the objective of assessing performance of a group of subjects in a particular clinical population to another group of control participants or with established normative data. Impairment in terms of total number of correct words produced has been reported by many investigators in different clinical population in both children and adults including dementia, focal cortical lesions, Parkinsons disease, Schizophrenia, Head Injury, Autism, Down’s syndrome, ADHD, epilepsy, PKU and reading disability across both phonemic and semantic fluency (Banerjee, Grange, Steiner, & White, 2011; Cohen et al., 1999; Henry & Crawford, 2004a, 2004b, 2005b; Hurks et al., 2004; McDowd et al., 2011; Nash & Snowling, 2008; Riva et al., 2005; Troyer et al., 1998b; Turner, 1999).

The estimation of the total number of correct responses to the verbal fluency tasks has also been used to compare individual scores to group norms. The group norms for verbal fluency tasks across tasks, age, educational level, language and culture has been established and used widely as a part of many standardized tests including Neurosensory Center Examination for Aphasia, Multilingual Aphasia Examination, Dementia Rating Scale, Delis-Kaplan Executive Function System, Neuropsychological Assessment of Children, CERAD etc. Another utility of estimating the total number of correct responses on verbal fluency task, is to provide client specific interpretation regarding changes in individual performance over time. The verbal fluency performance in terms of total number of correct responses generated
has been documented as a sensitive measure to chart improvement or deterioration in adults as well as in children (Hurks, 2012; Melinder, Barch, Heydebrand, & Csernansky, 2005; Tombaugh et al., 1999; Vlaar & Wade, 2003).

Despite the above mentioned utility of quantitative measurement in the analysis of verbal fluency performance, in order to obtain a better perspective of the task, investigators started looking at the content of the words produced during the task. This shift in interest occurred as a result of the fact that, the number of responses alone cannot always differentiate between disorders, for example, Parkinson’s dementia and Alzheimer’s dementia (Troyer et al., 1998b) or discriminate between dementia and cognitive impairment (Troyer et al., 1997). Moreover, the computation of the total number of responses alone does not provide an in depth knowledge regarding neither cognitive flexibility, efficiency of retrieval from semantic memory (Kosmidis et al., 2004; Troyer et al., 1997) nor does it clarify the nature of impaired performance (Abwender, Swan, Bowerman, & Connolly, 2001).

2.7.2 Qualitative measures of Verbal Fluency

This review provides a summary of various systems of qualitative scoring measures employed by investigators for deeper understanding of verbal fluency performance. There has been no common consensus among researchers regarding the best scoring and interpretation procedure for the verbal fluency task. Some of the qualitative measures include clustering and switching analysis, method of hierarchical exploration, error production analysis and time course analysis.

a. Clustering and switching analysis

One of the qualitative methods gaining wide popularity in verbal fluency outcome research is the understanding of mechanisms involved in the optimal word generation regarding characteristics and pattern of word generation. This endeavour helps in understanding not only how well an examinee performs the task but also regarding how one goes about performing the task. The evidence from lesion studies and brain imaging has also provided evidence for the utility of this qualitative measurement in understanding the precise nature of deficient performance (Abwender et al., 2001; Troyer et al., 1997; Troyer & Moscovitch, 2006).
The earliest analysis of the process of word generation has revealed that words generated during verbal fluency tasks occurred in spurts with some meaningful relation between words rather than evenly in time (Gruenewald & Lockhead, 1980; Wixted & Rohrer, 1994). Individuals need to search for subcategories for the specified letter or category, retrieve the words from the subcategory and then move into next subcategory for retrieval once words have been exhausted for successful word retrieval.

Troyer et al. (1997) proposed that the qualitative aspects of verbal fluency can be described based on two components, viz., clustering and switching. This was employed due to the limitations of quantitative measure of total correct words of not being able to capture entirely all the important aspects of an individual’s performance. The terms clustering and switching were used by Troyer et al. (1997) to operationalize the “store” and “search” processes involved in verbal fluency tasks, respectively. An effective and successful performance on verbal fluency requires an intact ability to produce words related semantically or phonemically (clustering) and an ability to shift efficiently to a new strategy once a category or subcategory is exhausted (switching).

The process of organizing words into semantically or phonemically related subcategories involved the production of clusters. Clusters produced during semantic task involve generation of two or more consecutive words that are related in meaning (e.g., apple, orange in fruits category; car, bus in vehicle category etc.). In the same way, clusters produced during phonemic fluency task involved production of two or more consecutive words that are related based on phonemic characteristics (e.g., words beginning with the same letter [chair, church]; words differing only by vowel [pan, pen] etc.). Clustering can be task-discrepant or task-congruent type. A task congruent clustering involved generation of semantically related words during semantic fluency task and phonemically related words during phonemic fluency task (Raskin, Sliwinski, & Borod, 1992; Troyer et al., 1997). Utility of task-discrepant clustering (Abwender et al., 2001; Tallberg et al., 2011) which is a measure of intentional strategy use may also be present, wherein participants may retrieve phonemic clusters during semantic task or semantic clusters during phonemic fluency task.
Another qualitative measure estimated during word generation task is the *switching* which involved calculation of the number of shifts between subcategories. The clusters produced are separated by gaps with the interval between words within clusters shorter than words between clusters (Gruenwald & Lockhead, 1980; Wixted & Rohrer, 1994). Troyer et al. (1997) postulated that clustering and switching are two dissociable components of verbal fluency with clustering and switching contributing equally to semantic fluency and switching contributing specifically for phonemic fluency. On *animal* fluency task, it was found that in terms of clustering, healthy adults produced clusters of two words per cluster and switched on an average 10.6 ± 3.5 times between the subcategories. Older adult participants tended to switch less as compared to young adults, on average 8.5 ± 2.3 times between the subcategories, with similar cluster size as younger adults (Troyer et al., 1997).

Each of the strategies used to maximize word production involved separate mechanisms involving specific brain areas. Performance on semantic memory processes of clustering (organizing words related to a subgroup) reflects the role of temporal lobe processes such as word storage and verbal memory storage. The executive processes of switching (engaging in strategic search processes) required mediation of frontal and frontal-subcortical area processes such as initiation, cognitive flexibility, and mental shifting. The evidence for these predictions is documented in clinical population with predominant brain damage involving frontal or temporal lesions. Poor performance on clustering has been reported among patients with Alzheimer’s disease (Troyer et al., 1998b), Mild Cognitive Impairment (Price et al., 2012), temporal lobe lesions (Henry & Crawford, 2004a; Troyer et al., 1998a) and temporal lobe epilepsy (Giovannetti, Goldstein, Schullery, Barr, & Bilder, 2003).

Similarly, switching was reported to be impaired among patients with frontal lobe lesions (Troyer et al., 1998a), Parkinson’s disease (Troster et al., 1998; Troyer et al., 1998b), Huntington’s disease (Ho et al., 2002), HIV associated dementia (Woods et al., 2004), multiple sclerosis (Messinis et al., 2013), depression (Henry & Crawford, 2005a), Acquired immunodeficiency syndrome (Iudicello et al., 2007), schizophrenia (Robert et al., 1998) and under conditions of divided attention (Troyer et al., 1997). In conditions involving diffuse brain lesions, investigators have also reported deficits in both clustering and switching with
predominant influence on one. For instance, Troyer et al. (1998b) reported that in dementia of
the Alzheimer’s type, both clustering and switching were impaired, with the severity of
impairment noticed to be more on clustering than switching.

Recently, there has been a shift in focus towards the development of clustering and
switching during verbal fluency in children (Kave et al., 2008; Koren et al., 2005; Hurks et al.,
2010; Sauzeon et al., 2004). Strategic processing during verbal fluency has been examined in
clinical paediatric population including children with PKU (Banerjee et al., 2011), Specific
Language Impairment (Henry et al., 2012), blindness (Wakefield et al., 2006), Turner
syndrome (Temple, 2002) and Down’s syndrome (Nash & Snowling, 2008). As expected,
both of these strategies are positively correlated with the total number of words produced
(Kave et al., 2008; Koren et al., 2005; Troster et al., 1998; Troyer et al., 1997).

Despite the clinical utility and good psychometric property, this qualitative measure is
not without controversy. Abwender et al. (2001) criticized Troyer’s protocol by stating that
there is no adequate evidence for clustering leading to production of more words. They also
stated that the interpretation of switching, whether it is a product of strategic searching and
mental flexibility or lack of ability to cluster is not adequately explained. The consideration of
single words as having cluster size of zero was also criticized by the authors. Epker, Lacritz,
and Cullum (1999) observed that the qualitative measures did not provide any additional
information as compared to the total number of correct words calculation in differentiating
individuals with Alzheimer’s disease, Parkinson’s disease, and healthy older adults.

Similarly, Mayr (2002) criticized Troyer’s scoring system regarding the ambiguous
nature of switching score. They supported the view of difficulty to differentiate whether the
number of switches is associated with difficulties in accessing new clusters or difficulties in
accessing new words within clusters. The more the time an individual spent in one cluster
group; lesser the time will be for the individual to access other clusters. The author suggested
that a reduction in the number of switches may be related to a general reduction in processing
speed or selective switching deficit. Contrary to Troyer’s view of clustering as an automatic
process and switching as an effortful strategic process, Mayr and Kliegl (2000) reported
involvement of the strategic component during both the processes. Demakis et al. (2003)
considered switching component observed during verbal fluency performance as tapping general cognitive ability rather than specific executive processing. Koren et al. (2005) however considered number of clusters rather than number of switches as a measure of executive component.

Reservations about diagnostic utility of clustering-switching measures have been raised by many researchers. From the clinical perspective, lack of consensus is found in terms of use of these measures in differentiating stable and declining individuals with Alzheimer’s disease (Beatty, Salmon, Testa, Hanisch, & Troster, 2000), in individuals with moderate severity (Epker et al., 1999), with lack of differential sensitivity on clustering-switching (Troyer et al., 1998b) and low test–retest reliability (Ross, 2003). The low temporal stability was related by Ross (2003) to lack of providing of explicit instruction to participants.

b. Hierarchical Exploration Analysis

Hierarchical exploration analysis as an outcome measure of semantic retrieval has been employed by many researchers (Beatty et al., 1989; Raboutet et al., 2010; Sauzeon et al., 2004; Troster et al., 1995). The task involved was word generation on supermarket fluency task (generating as many words as possible that can be purchased in a supermarket). The analysis involved a semantic categorical system comprising 10 categories with two hierarchical levels of items (category labels and category exemplars) for each category. The category label corresponds to super and subcategory nouns produced and category exemplars refer to the nouns of category specific items. For example in the category of fruits, the category labels include canned / frozen fruits and category exemplars include lemons, grapes, peaches etc. Based on the word output, a hierarchical ratio score (dividing the number of category labels produced by the number of total words generated) was estimated.

Studies in clinical population have supported the use of hierarchical exploration analysis. For example, a selective decrease in the production of category exemplars has been shown in pathologies with temporal-lobe lesions, such as epilepsy or Alzheimer’s disease (Martin & Fedio, 1983; Troster et al., 1989; Troster et al., 1995). Similarly, in children, Sauzeon et al. (2004) provided scoring for categories sampled, label and exemplar ratio, words per category sampled ratio and category shifts per category sampled ratio among French speaking children between 7 to 16 years of age.
c. Error Analysis

During the task of word generation for verbal fluency, individuals tend to produce erroneous responses such as repeating the words (perseveration error) or coming up with words not starting with a particular letter or belonging to a particular category (rule break errors). From the cognitive perspective, the presence of errors is associated with a less effective control system and reduced executive capacities (Rosen & Engle, 1997) and as a strategic means employed by participants to generate new clusters (Troyer et al., 1997). While the Troyer et al protocol necessitates the inclusion of perseverations and errors in clustering-switching analysis, Haugrud, Lanting, and Crossley (2010) reported that their inclusion inflated the cluster size scores.

The error scores are often calculated as the number of individual error types present or a combined score for all the error types produced. Raboutet et al. (2010) calculated error score as the number of intrusions and perseverations produced. Roberts and Le Dorze (1997) calculated the following five error types: (1) repetition errors, that is, repeating an item previously given as a correct response within the current test; (2) outside category errors, a word that did not belong to the category currently being tested; for example, saying “veal” in animals or “pills” in foods. (3) non-word or unintelligible errors; (4) wrong language errors, a word belonging to the appropriate category but not in the language currently being tested; and (5) other, any error not meeting one of the above definitions.

Researchers have attempted to understand the error response pattern in disordered population in both adults and children which provided important information in clinical practice (Hurks et al., 2004; Hurks et al., 2006; March & Pattison, 2006; Martin & Fedio, 1983; Raboutet et al., 2010; Raskin et al., 1992; Rosen & Engle, 1997; Troster et al., 1995). Compared to healthy adults, perseveration errors were frequent in individuals with Alzheimer’s disease, aphasia, frontal lobe damage, Parkinson’s disease, Huntington’s disease, and traumatic brain injury (Azuma, 2004). Pekkala, Albert, Spiro, and Erkinjuntti (2008) reported presence of recurring perseverations (e.g., fan, fried, friend, fan), continuous perseverations (e.g., fan, fan, fan) and stuck-in-set (e.g., continuing to name words starting with letter ‘F’ after a new letter has been presented) perseverations in Alzheimer’s disease.
Error analysis has also gained popularity in childhood verbal fluency research. The presence of more number of intrusion errors has been reported in children with ADHD (Mahone et al., 2001). More perseveration errors have been reported in preschool children with early treated Phenylketonuria (Welsh et al., 1990) than control group. Similarly, error analysis has been studied in typically developing children also (Charchat-Fichman et al., 2011; Hurks et al., 2004; Hurks et al., 2006; Tallberg et al., 2011).

d. Time course analysis

The organization of words during verbal fluency production has also been examined as a function of time (Crowe, 1998; Hurks et al., 2010; Raboutet et al., 2010). Crowe (1998) proposed a model of lexical organization emphasizing the role of analysing verbal fluency performance as a function of time, focusing on two types of store for retrieval of words. During the initial time frame (first 15-20 seconds) of verbal fluency task, participants generated words from a long term store called topicon which contained easily accessible common words. Once the topicon is exhausted, effortful search occurred in the store of extensive lexicon. Bousfield (1953) and Gruenewald and Lockhead (1980) showed that the time interval required to access new subcategories is long and increased during the production, whereas the time required to produce items within semantic clusters was short and tended to remain constant.

In children, studies (Hurks et al., 2006; Raboutet et al., 2010) have illustrated that the word frequency and number of words produced decreased with time with the greater score observed during 0-30 seconds as compared to 31-60 seconds. It was also noticed that the efficiency to avoid perseveration errors decreased with time, along with decrease in intercategorical process of hard switching. An increase has been reported in ratio of number of clusters produced, the number of category exemplars and in the mean cluster size score. The varied performance across time was attributed to higher attention load and more effortful and extensive semantic search during the last time frame.

e. Other Measures

Automated approaches using clustering algorithms to scoring, consistent with Troyer and Mayr theories of verbal fluency have also been reported. These techniques focused on co-
occurrence frequencies and amount of competition between exemplars (items generated) for given category. Some of the computational methods included latent semantic analysis, correspondence analysis and hierarchical clustering and network theory (Goni et al., 2011; Kenett et al., 2013; Schwartz et al., 2003; Snyder & Munakata, 2010).

2.7.3 Standard scoring protocols

Various scoring protocols for verbal fluency performance have been described in literature. One of the most common and widely used protocols was given by Troyer et al. (1997). Troyer et al. focused on the analysis of number of words generated excluding errors and repetitions, clustering (number of clusters; cluster size; mean cluster size) and switching (number of switches). Cluster was operationally defined as production of successively generated words belonging to same subcategory (either phonemic or semantic subcategory). For the sequence cat-dog-lion-elephant-zebra, pet animals and African animals were considered as the two clusters produced by the individual. The cluster size, which is the number of words in a cluster, was counted beginning with the second word in each cluster (e.g., a 2-word cluster was counted as having a cluster size of 1). Single or non-clustered words were designated as having a cluster size of 0. The mean cluster size was calculated by adding up the size of each cluster and dividing by the number of clusters produced. For example, the sequence “lemons, chicken, meat, fruit, banana, apple, corn flakes, salt, pepper, cheese, milk, yogurt” contains 6 clusters, with respective cluster sizes of 0, 1, 2, 0, 1, 2 and a mean cluster size of 1.

With respect to definition of clusters, other researchers have attempted to refine Troyer and colleagues’ protocol. Raskin et al. (1992) defined clusters as comprising of pair of words belonging to same subcategory without consideration for longer clusters or cluster size. Based on this, authors emphasized the role of number of clusters as a measure of cognitive flexibility rather than number of switches. Contrary to Troyer protocol, the ratio of total words to number of clusters was considered rather than the single word productions. Robert et al. (1998) considered three consecutive associated words in semantic fluency task and two consecutive associated words in phonemic fluency task as a cluster. In another protocol developed by Abwender et al. (2001), clusters were defined as two or more associated words. The authors did not consider single words as a cluster and hypothesized that
single words suggest a failure to retrieve other words from that particular category. In Kosmidis et al. (2004) scoring protocol, three or more consecutive words were grouped as a cluster for semantic and phonemic fluency tasks.

With respect to switching, Troyer et al. (1997) defined number of switches as transition between clusters including single words. Abwender et al. (2001) described two types of switches, that is, cluster switch and hard switch, which reflected speeded nature of the task. Cluster switch involves transition from one cluster to next cluster and hard switch involves transition between two single words (banana, cheese) or between a cluster and a single word (fruit, banana, cheese). Abwender et al. provided an example for clustering-switching for word generation on food fluency. For the sequence of “banana, orange, milk, cheese”, the number of clusters was considered as two (fruits; dairy products) with one cluster switch and no hard switch.

Other researchers have also attempted to extend the protocol. March and Pattison (2006) along with Troyer system, provided scores for raw number of subcategories produced and number of errors (repetitions and categorical error types) in their study of individuals with Alzheimer’s disease. The number of semantic subcategories as an indicator of semantic memory organization was also reported by da Silva et al. (2004) in their study on impact of literacy and education in semantic fluency. Sauzeon et al. (2004) calculated ratio of total number of switches and mean cluster size to total number of words produced. In Koren et al’s (2005) study, instead of the number of switches, only number of clusters was analysed. Lanting, Haugrud, and Crossley (2009) explored the number of novel and repeated clusters and percentage of clustered words in healthy and older adults. Kosmidis et al. (2004) also provided a specific scoring protocol for animals, fruits and objects based on the data from Greek population.

Roberts and Le Dorze (1997) reported use of scoring protocol consisting of total correct words (subcategory labels as in ‘fruits’ and category members as in ‘apple’), number of errors. The analysis also involved analysing of number of comments (such as swearing, self-talk (‘that’s all I know’), and questions about the task - ‘can I say that?’). Scoring of number of semantic associations (three or more words belonging to same category), mean
Carneiro et al. (2008) in their study on Portugese category norms for children, reported the scoring of various measures including number of responses and exemplars, responses which are idiosyncratic and inappropriate and commonality and diversity indexes for the categories tested in children. Recently, Raboutet et al. (2010) provided a scoring system involving evaluation of five scores (general scores, inter categorical or switch scores, intra categorical or cluster scores, semantic hierarchical exploration scores and error scores) for each time interval involving supermarket fluency task. The protocols mentioned above, varied in terms of the testing measures employed for analysis purposes. It is however to be kept in mind that a lot of disparity and disagreement existed between researchers on interpretation and utility of the protocol employed.

2.8 Normal and abnormal aspects of Verbal Fluency

The utility of verbal fluency has been researched in various population including healthy individuals as well as disordered population. The research findings expanded below illustrate the extent of utility of verbal fluency tasks as a screening, diagnostic and treatment measure in various domains in both adult and childhood population.

2.8.1 Verbal Fluency in Adult population

The clinical and research utility of verbal fluency has been extensively researched and well established among adult clinical population. It continues to be one of the important assessment tools for assessing language and neuropsychological functioning.

Verbal fluency task is considered as a sensitive tool for examining language related and executive changes related to word retrieval with healthy adults (Tombaugh et al., 1999; Troyer et al., 1997), Aging (McDowd et al., 2011; Troyer, 2000), Focal cortical lesions (Baldo & Shimamura, 1998; Henry & Crawford 2004a; Troyer et al., 1998a), Parkinson's disease (McDowd et al., 2011; Piatt et al., 1999; Raskin et al., 1992; Troyer et al., 1998b), Schizophrenia (Allen et al., 1993; Henry & Crawford, 2005b; Robert et al., 1998), Epilepsy (Giovannetti et al., 2003), Cerebellar diseases (Leggio et al., 2000), Traumatic Brain Injury
Verbal fluency tasks are part of dementia battery and have been considered useful in Alzheimer’s disease (Martin & Fedio, 1983; McDowd et al., 2011; Troyer et al., 1998b), Huntington’s disease (Ho et al., 2002; Rosser & Hodges, 1994; Troster et al., 1989), Dementia with Lewy bodies (Lambon Ralph et al., 2001), Vascular dementia (Jones, Laukka, & Backman, 2006), HIV associated dementia (Woods et al., 2004), Fronto-temporal lobar degeneration (Catani et al., 2013), Progressive supranuclear palsy (Rosser & Hodges, 1994). It has also gained popularity in disorders such as Klinefelter Syndrome (Boone et al., 2001), adults with Autism Spectrum Disorders (Beacher et al., 2012; Spek, Schatorje, Scholte, & Van Berckelaer-Onnes, 2009) and bilingual population (Luo, Luk, & Bialystok, 2010; Roberts & Le Dorze, 1997; Roberts & Le Dorze, 1998; Rosselli et al., 2000).

### 2.8.2 Verbal Fluency in typically developing Children

The earliest norms on verbal fluency in healthy school children had been provided for phonemic fluency (FAS) task by Gaddes and Crockett (1975); Sincoff and Sternberg (1988) in 135 children belonging to grades III and VI task; Anderson et al., 1997 as cited in Strauss et al. (2006) in 390 children between the age range of 7-13 years from primary and secondary schools in Melbourne, Australia and Anderson et al. (2001) in 32 adolescents between ages of 14-15 years. Similarly, Schum et al., 1989 as cited in Strauss et al. (2006) provided data on CFL and PRW phoneme fluency task across both males and females (98:131) between 6-12 (n=229) years of age and Barr (2003) investigated verbal fluency using CFL version among 100 high school athlete children (60 males and 40 females) between 13-17 years. Halperin et al. (1989) also investigated performance in 204 children between 6-12 years of age on phoneme fluency (‘sh’). Cohen et al. (1999) studied the maximum number of words retrieved by typically developing children on verbal fluency. The letter fluency tasks (letters C, P, B, R) in a thirty second time frame for each letter was used for normal children aged 6.0 to 12.11 years divided into seven age bands. Statistically
significant difference was noted between 6 years and 8-12 years, however, 6 years were not significantly different from 7-year-old children. This pattern of nearer age bands not showing significant differences was noted even in higher age groups.

Performance on semantic category fluency had also been reported by Nelson (1974) on nine natural language categories in five and eight year old children; Posnansky (1978) on 25 categories in children between grades 2 and 6; Storm (1980) in children (6 years, 9 years, teenagers) on animal fluency task; Halperin et al. (1989) on animal and food fluency; Lucariello et al. (1992) on tasks of clothes, animals, food, furniture and tools among four and seven year old children; Grube and Hasselhorn (1996) in eight-year-olds and older children on animal fluency and Crowe and Prescott (2003) for the categories of animal, body parts, food, clothes, vehicles and plants in 155 children between 5-10 years of age.

Studies on verbal fluency had also been carried out among healthy children in various languages other than English including Chinese (Chan & Poon, 1999), Cantonese-speaking Hongkong Chinese adolescents (Lee et al., 2002 as cited in Mitrushina et al., 2005), Italian (Riva et al., 2000), French (Sauzeon et al., 2004), Spanish speaking children (Ardila & Rosselli, 1994; Matute et al., 2004; Nieto, Galtier, Barroso, & Espinosa, 2008; Filippetti & Allegri, 2011), Brazilian population (Dellatolas et al., 2003; Charchat-Fichman et al., 2011), Portuguese (Carneiro et al., 2008), Dutch (Hurks et al., 2006; Hurks et al., 2010; Hurks, 2012; Van der Elst, Hurks, Wassenberg, Meijs, & Jolles, 2011), Hebrew language (Koren et al., 2005; Kave, 2006; Kave et al., 2008; Kave, Kukulansky-Segal, Avraham, Herzberg, & Landa, 2010) and Swedish language (Tallberg et al., 2011). Similar studies have been carried out among Spanish-English bilingual children (Rosselli, Ardila, Navarrete, & Matute, 2010) where they have reported of reduced performance on verbal fluency tasks with a predominant bilingual disadvantage for semantic fluency task in bilingual speakers as compared to monolingual speakers.

An increase in the number of research carried out in typically developing children was noted from early 2000 onwards using variations in type of tasks, procedure and analysis protocol employed in numerous languages. Developmental changes in semantic and phonemic fluency in 153 Italian school children between 5 years 11months to 11 years 4 months
(classified into five groups depending on the grade) was reported by Riva et al. (2000). Total number of words retrieved on the phonemic fluency tasks ($B$ and $S$) and semantic fluency ($animals$ and $food$) were calculated. Significant age related differences were noticed only on semantic fluency task with phonemic fluency tasks considerably difficult compared to semantic fluency tasks. The difficulty on phonemic fluency task was attributed to the task dependency on frontal lobe maturation and requirement of greater organizational and strategic capabilities. Linear increase in fluency scores especially in semantic fluency tasks was noted with an increase in age with a significant increase between Group I and Group II. The findings were related to cognitive development, formal instructions and enrichment in linguistic knowledge between the ages of 5 and 7 years.

Sauzeon et al. (2004) studied five groups of children ($n=140$) between the age range of 7-16 years (second grade to tenth grade) on their performance on verbal fluency of three letter fluency tasks ($F$, $A$ and $S$), two semantic fluency tasks ($fruit$ and $supermarket$ fluency), two sound fluency tasks ($/ma/$, $/o/$) and one free fluency task. The influence of age on verbal fluency was assessed in French in terms of total number of words, clustering and switching and semantic network exploration. Findings revealed a greater difference between 7-8- and 9-10- year old children which gradually decreased with age. These differences were noted more on semantic fluency as compared to letter fluency tasks which showed improvement with age, attributing to dependency on late developing cognitive strategies and late brain maturation. Similarly, greater changes with age in switches and cluster measure except for cluster size were evident in the letter fluency task. Proficient semantic network exploration was reported only after 13-14 years of age. The authors concluded that semantic knowledge enrichment was associated with semantic fluency while, strategic switching is associated with letter fluency. They suggested the use of verbal fluency task as an early indicator for strategic or semantic deficits in childhood developmental disorders.

Matute et al. (2004) studied verbal fluency among Spanish speaking children attending public and private schools in Guadalajara and Tijuana, Mexico. 171 children (81 boys, 90 girls) between ages 6 and 15 years performed semantic ($fruits$) and phonologic fluency task ($letter M$). Their study findings revealed significant age effect and authors supported the need for norm based cross-language studies. Nieto et al. (2008) provided
normative data for Spanish speaking children on phonemic (letters FAM) and semantic (animals) fluency tasks. Verbal fluency performance (number of words, number of clusters, switches and mean cluster size) in 79 school aged children were investigated. Developmental changes in terms of number of words, clusters and switches generated were observed with older group performing better than the younger age group. On phonemic fluency task, there was a significant difference noted between older children and 6-7 year old children, whereas on semantic fluency, the significant difference was noted only between 10-11 years and younger children. These developmental differences were related to frontal lobe maturation and development of cognitive flexibility.

Koren et al. (2005) conducted a study comparing third (8-9 years) and fifth grade (10-11 years) children on development of clustering abilities (number of clusters and mean cluster size) on 5 phonological fluency tasks (letters g, d, p, r, sh) and 4 semantic fluency tasks (‘animals’, ‘food’, ‘clothes’ and ‘streets’) in Hebrew. The authors reported an increased number of clusters in the higher age group; though mean cluster size did not show any age effect which had been attributed to the development of cognitive flexibility and change in organization of output with age.

The development of verbal fluency as a function of age has been studied in one hundred and fifty Hebrew-speaking children by Kave (2006) between the age range of 8 and 17 years on three phonemic fluency (bet /b/, gimel /g/, and shin /š/) and three semantic fluency (animals, fruits and vegetables, vehicles) tasks. A steady increase in number of words with age was reported with 16-17 year old adolescents reaching adult level only on phonemic fluency task. The findings were attributed to vocabulary enrichment and due to the improvement in ability to retrieve stored vocabulary efficiently with age.

In a later study in 2008, Kave et al. compared clustering and switching measures on phonemic and semantic task across 8-29 years. Improvement in verbal fluency measures was reported to increase with age except for mean cluster size measure. Comparison of adolescents and adult performance revealed no significant difference in phonemic fluency task; however, on semantic fluency task, adults were found to perform better than adolescents on switching scores. Significant correlations were noted between total number of words and
clustering measures (number of clusters, mean cluster size) and switching measures (number of switches) on both tasks except no significant correlation between the total number of words and mean cluster size. The authors attributed study results towards development in executive search strategies and shifting than maturation in word retrieval. Recently in 2010, Kave et al. studied phonemic and semantic fluency in 207 Hebrew speaking children between 8-17 years. This study also provided evidence of a positive correlation between age and test scores.

Hurks et al. (2006) compared verbal fluency performance (semantic category versus initial letter fluency) in 91 healthy school going Dutch speaking children (8.4-9.7 years) from Netherlands using an alternative scoring protocol of verbal fluency focusing on the word production as a function of time. The two aspects taken into consideration for verbal fluency scoring were automatic information processing (word production during first 15 seconds of verbal fluency task) and controlled information processing (word production during the next 45 seconds). It was observed that the word production was greater with less error production during semantic category fluency as compared to initial letter fluency task. As a function of time, a decrease in performance was noted during controlled processing. Hurks et al. (2010) provided a detailed investigation report of developmental changes in semantic verbal fluency among 309 native Dutch children attending first to ninth grade. The authors reported that the controlled information processing was observed to be established by grades 7-8 only. With respect to demographic variable of gender, no positive influence was noted in both the studies. However, the performance was found to be influenced by the level of occupational achievement of caregiver and parental education.

Recently, Hurks (2012) did a comparative study on effects of brief training on strategy use during verbal fluency task in 81 children between grades 3-6. The influence of instruction was observed only in older children, whereas the younger population continued to use cognitive capacity to increase the semantic clustering scores. In 294 healthy Dutch speaking children between 6.56-15.85 years, Van der Elst et al. (2011) also studied animal fluency performance and provided the norm based findings. The research outcome indicated a linear pattern in productivity (on total number of correct unrepeated animals) as a function of age with positive influence of parental education and lack of gender effect.
**Carneiro et al. (2008)** investigated 300 Portuguese speaking children including preschoolers between 3-4 years (M:F-54:46), second grade children between 7-8 years (M:F-49:51) and preadolescents (M:F-49:51) between 11-12 years. The category fluency was tested using 13 categories in preschool group, 17 categories in the second grade group and 21 categories in preadolescents group. The authors provided norms with findings regarding the frequency of sub category production, number of responses, inappropriate and idiosyncratic responses and commonality (calculated by adding the frequency of the three first exemplars and then dividing by the total frequency production) and diversity indexes (the degree to which the exemplars are distinct).

Recently, **Charchat-Fichman et al. (2011)** studied phonemic and semantic fluency in one hundred and nineteen Brazilian children between the age range of 7-10 years (male: female- 59:60). Phonemic fluency was tested using $F, A, M$ letters and semantic fluency using *animals, clothes* and *fruits* category. The total number of correct words produced during each task was computed along with rate of error production. Total number of words generated was greater for semantic fluency task as compared to phonemic fluency tasks. The authors related the findings to greater requirements of executive function and strategic retrieval in phonemic fluency and semantic network activation during semantic fluency task. Significant difference was noted among the three semantic tasks but not during phonemic fluency task. Though no effect of gender was noted, significant age difference was noted with lesser number of words in younger age group than older children. Total number of errors during semantic fluency task correlated with phonemic fluency task though no significant correlation was noted with age. The authors reported that the number of errors was very small for the age range taken for the study. Similarly, **Dellatolas et al. (2003)** studied semantic fluency (*animals, clothes*) and phonemic fluency (letters $P, F, M$) in 41 school children (7-8 years) from Brazilian population. On comparison of the performance with 97 illiterate normal Brazilian adults, lower performance was reported for semantic fluency in school children.

**Tallberg et al. (2011)** studied strategies employed by 130 children speaking Swedish language between 6 to 15 years of age. $FAS$ and *animal* fluency task was used to analyze the mean scores, clustering, switching and error production in these children. Effective switching and clustering strategies were reported in higher age children along with better mean scores.
for both the tasks. The authors suggested that verbal fluency continued to develop into early adulthood. It was also reported that gender did not have an influence on verbal fluency performance. The detailed error production analysis revealed predominantly perseveration especially on letter fluency task. The study also provided support for semantic facilitation not only during semantic fluency but also during the phonological fluency task.

Based on the verbal fluency study among Spanish speaking children between 8-11 years (n=120), Filippetti and Allegri (2011) reported the role of the task in measuring executive functioning in children. In consonance with previous literature, greater verbal output (total score) was noted for semantic as compared to phonological fluency especially in older children with a decrease in scores over time. The authors also reported correlations between qualitative strategies (clustering & switching) and total score as well as with cognitive executive functions. On the verbal fluency subtest of NEPSY, a score of 8.48 (3.12) in 9-year-olds (n=25) and 8.55 (2.74) in 11-year olds (n=20) were reported in Zambian school children (Mulenga et al., 2001). The study compared the performance of 45 literate Zambian children according to age-equivalent norms for U.S. children. Similarly, Korkman et al. (2001) reported significant age effects especially for 5-8 year age range than 9-12 year age band in a study on 800 children from the United States between 5-12 years of age.

2.8.3 Verbal Fluency in Disordered population in Children

The utility of verbal fluency in childhood population is gaining widespread importance. The tests are part of the various assessment protocols focusing on investigation of both semantic and executive functioning. There is a wealth of literature documenting the impact of childhood disorders on verbal fluency. Table 2.2 focuses on the summary of research studies and their findings in these clinical childhood conditions.
<table>
<thead>
<tr>
<th>Study population</th>
<th>Authors</th>
<th>Research findings</th>
</tr>
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</table>
| Attention Deficit Hyperactivity Disorder (ADHD) | Abreu et al. (2013); Cohen et al. (1999); Hurks et al. (2004); Takacs, Kobor, Tarnok, & Csepe (2013) | ▪ Lower correct word production, increased errors, poor strategy use
▪ Difficulty with word retrieval especially during first 15 seconds
▪ Utility in differential diagnosis of subtypes & VF deficits considered as a characteristic of attentional & executive dysfunction |
| Autism spectrum disorders (ASD)   | Begeer et al. (2013); Inokuchi & Kamio (2013); Kilincaslan et al. (2010); Turner (1999) | ▪ Reduced performance with increased error production in Asperger syndrome, High functioning autism and in autism with co-morbid conditions
▪ Atypical production with less frequent switching & larger clusters |
| Blindness                        | Wakefield et al. (2006)                                                | ▪ Differential pattern of deficits - more number of switches & number of words on letter fluency |
| Cerebellar damage                | Riva & Giorgi (2000); Vaquero, Gomez, Quintero, Gonzalez-Rosa, & Marquez (2008) | ▪ Differential deficits on semantic and phonemic fluency tasks, based on the kind of tumour, post-surgical treatment modalities and the influence of frontal cortical connections
▪ Utility in differentiating clinical subtypes in cerebellar lesion |
| Childhood diarrhea               | Oria et al. (2009); Patrick et al. (2005)                              | ▪ Sensitive cognitive biomarker in children with early childhood diarrhea
▪ Greater deficits on semantic fluency than letter fluency |
<p>| Childhood Stroke                 | Max (2004); Max, Bruce, Keatley, &amp; Delis (2010)                       | ▪ Reduced VF performance with greater deficits among older children |
| Depression                       | Beers &amp; De Bellis (2002)                                               | ▪ Reduced scores in maltreatment-related post-traumatic stress disorder |
| Developmental Stuttering         | Bahrami et al. (2014)                                                 | ▪ Poor performance noted for phonemic fluency in comparison to control group children; Deficits related to executive function deficits |</p>
<table>
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<tr>
<th>Study population</th>
<th>Authors</th>
<th>Research findings</th>
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<tbody>
<tr>
<td>Down’s syndrome</td>
<td>Nash &amp; Snowling (2008); Pennington, Moon, Edgin, Stedron, &amp; Nadel (2003)</td>
<td>- Reduced productivity and number of clusters with spared cluster size score</td>
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<tr>
<td></td>
<td></td>
<td>- Indicative of less efficient retrieval strategies with age related improvement</td>
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<tr>
<td>Dyslexia</td>
<td>Cohen et al. (1999); Marzocchi et al. (2008); Nation &amp; Snowling (1998); Lipowska et al. (2008)</td>
<td>- Lesser number of words (lower performance on letter fluency predominantly); In differential diagnosis of dyslexic subgroups (language disorder/dysphonetic and visual-spatial/dyseidetic dyslexic sub group)</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>Croona, Kihlgren, Lundberg, Eeg-Olofsson, &amp; Eeg-Olofsson (1999); Gallagher et al. (2007); Henkin et al. (2005); Neri et al. (2012); Riva et al. (2005)</td>
<td>- More difficulty on letter fluency in frontal lobe epilepsy as compared to the temporal lobe epilepsy group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Lower scores reported in children with idiopathic generalized epilepsy, rolandic epilepsy; Greater impact in epilepsy of earlier onset &amp; left sided involvement</td>
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<tr>
<td></td>
<td></td>
<td>- Difficulty in verbal organization (attending to task, creating novel responses and avoiding irrelevant stimuli) during VF</td>
</tr>
<tr>
<td>Fetal alcohol syndrome (FAS)</td>
<td>Kodituwakku et al. (2006); Schonfeld, Mattson, Lang, Delis, &amp; Riley (2001)</td>
<td>- VF deficits common (letter fluency more impaired than semantic fluency; Age related improvement in scores noted</td>
</tr>
<tr>
<td>Head Injury</td>
<td>Braga, Souza, Najjar, &amp; Dellatolas (2007); Levin et al. (2001); Slomine et al. (2002); Yeates et al. (2002)</td>
<td>- Performance dependent on severity of disease, age of injury, extent of lesion and time post onset; Poorer in younger children with severe injury than older children</td>
</tr>
<tr>
<td>Hearing Loss</td>
<td>Kenett et al. (2013); Lofkvist et al. (2012); Marshall, Rowley, Mason, Herman, &amp; Morgan (2012)</td>
<td>- Under-developed semantic network in children using hearing devices; Better scores for cochlear implant users as compared to hearing aid users</td>
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<tr>
<td></td>
<td></td>
<td>- Children with hearing loss using British sign language have similar lexical organization as those using spoken language</td>
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<tr>
<td>Infections</td>
<td>Ezeamama et al. (2005); Nazel, el-Morshed, Farghaly, Shatat, &amp; Barakat (1999)</td>
<td>- Poor performance on VF in Helminth infection</td>
</tr>
<tr>
<td>Study population</td>
<td>Authors</td>
<td>Research findings</td>
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<tr>
<td>Intellectual Disability</td>
<td>Henry (2010)</td>
<td>Performance on VF task at mental age level with scores indicative of delay than deviant development</td>
</tr>
<tr>
<td>Klinefelter Syndrome (KS)</td>
<td>Bender et al. (1993)</td>
<td>Reduced scores in adolescents with KS than matched controls</td>
</tr>
<tr>
<td>Malnutrition</td>
<td>Chandler et al. (1995); Kar, Rao, &amp; Chandramouli (2008); Simeon (1998)</td>
<td>Reduced scores with age related improvement; Short term positive effects of breakfast &amp; school feeding programs on VF performance</td>
</tr>
<tr>
<td>Phenylketonuria (PKU)</td>
<td>Banerjee et al. (2011); VanZutphen et al. (2007); Welsh et al. (1990)</td>
<td>Detrimental effects on VF with increased error production; Correlation between phenylalanine levels and VF parameters; Impaired switching with clustering measures similar to the control group</td>
</tr>
<tr>
<td>Prematurity</td>
<td>Allin et al. (2008); Luu, Ment, Allan, Schneider, &amp; Vohr (2011)</td>
<td>Lower scores with effects persisting into adulthood related to less developed linguistic skills, mental flexibility and response inhibition; VF task useful as an early predictor of executive dysfunction</td>
</tr>
<tr>
<td>Specific Language Impairment</td>
<td>de Guibert et al. (2011); Henry et al. (2012); Weckerly et al. (2001)</td>
<td>Weaker performance (predominantly on letter fluency); Few authors support similar performance as control group</td>
</tr>
<tr>
<td>Tourette Syndrome (TS)</td>
<td>Mahone et al. (2001); Verte, Geurts, Roeyers, Oosterlaan, &amp; Sergeant (2005)</td>
<td>Useful in differential diagnosis in ADHD, ADHD + TS, TS alone group and High functioning autism; Deficits based on severity of TS symptoms</td>
</tr>
<tr>
<td>Turner Syndrome</td>
<td>Romans, Roeltgen, Kushner, &amp; Ross (1997); Temple (2002)</td>
<td>VF deficits with significant age effect; Unusual, low frequency words (Example: fahrenheit, facetious, antediluvian, alimony, assyrian); No common consensus regarding presence of limited lexical access or poor development of lexical store</td>
</tr>
<tr>
<td>William Syndrome</td>
<td>Bellugi, Bihrl, Jernigan, Trauner, &amp; Doherty (1990); Jarrold et al. (2000)</td>
<td>Similar performance as age matched peers on number of items retrieved; Less sophisticated semantic structure as indicated by ordering of items</td>
</tr>
</tbody>
</table>
2.9 Research on Verbal Fluency in Indian Languages

Research in the area of verbal fluency has emerged in India from the late nineties with greater understanding of its usefulness in clinical diagnosis and in community research. The studies done were predominantly focusing on epidemiological research on the elderly population to identify various neurological disorders including dementia. Studies have also been done in order to examine the influence of demographic variables on verbal fluency performance.

Ganguli et al. (1996) explored verbal fluency in non-demented elderly population (n=374) from the rural area of Ballabgarh in northern India as part of Indo - U.S Cross-National Dementia Epidemiology Study. The participants were stratified based on age into three age bands: 55-64, 65-74, and 75+ years and tested on category fluency. The mean scores for fruits and animals subtests were 8.2 (2.8) and 11.7 (3.7) respectively. The authors provided overall distribution scores on verbal fluency subtests for each of the study group. Chandra et al. (1998) had reported the use of verbal fluency tasks (‘fruits’; ‘animals’) as part of a cognitive screening battery in their prevalence study of Alzheimer’s disease and other dementias. The scores from this task were used to identify cognitively impaired population among Hindi-speaking population in the Ballabgarh district in northern India.

Ratcliff et al. (1998) studied the influence of literacy and education on verbal fluency in 90 young and elderly individuals (Male: Female- 48:42) between 34-55 years from rural northern India as part of a cross-national study of dementia epidemiology. The participants were stratified based on education into 0, 5 and 10 years of formal education. The total number of words produced on semantic fluency (animals, fruits) and initial sound/phonemic fluency (/p/, /s/) in the Haryanvi dialect of Hindi was estimated. The study findings indicated that education had greater effect on initial sound fluency than semantic fluency. The authors concluded that initial sound fluency was influenced by the knowledge of written language and therefore not useful in illiterate population. The authors suggested the need for examining factors affecting verbal fluency in different population through cross national comparisons.

Das, Biswas et al. (2006) analysed the reliability of verbal fluency test, a part of “Cognitive test battery” in the Kolkata Municipal Corporation (in Bengali & Hindi). The
study was part of a survey for major neurological disorders (epilepsy, stroke, dementia and Parkinsonism) in Kolkata. The inter-rater variation was determined by applying the cognitive tests on 24 randomly selected subjects in the community and intra-rater variation on 50 subjects at one month interval using Spearman’s rank correlation coefficient $P$. A value of 0.986 was obtained on intra-rater validation whereas 0.980-0.987 was obtained as inter-rater scores. In the same year, Das, Banerjee et al. studied 745 non-demented individuals between 50-95 years (male:female-363:376) on the total number of words produced in category-based verbal fluency tests of fruits and animals. The authors reported better scores in the higher education group with age related cognitive decline. Gender effects were reported with men scoring better on both animal and fruits naming task. The performance on animal naming was better among urban as compared to rural population. Based on the findings, authors’ called for population derived normative data, specific in each vernacular language.

Kar et al. (2008) investigated cognitive development in twenty children with chronic protein energy malnutrition (PEM) in comparison with adequately nourished group (n=20) between 5-10 years taken from a corporation school in Bangalore, Karnataka (Kannada Language). On FAS phonemic fluency task, the malnourished group differed significantly from adequately nourished children. Age related improvement across 5-7 years and 8-10 years was noted to be similar in both malnourished and adequately nourished children. The authors attributed this difference to the effect of PEM on the ongoing development of higher cognitive processes.

Sosa et al. (2009) reported findings of 10/66 Dementia Research Group's cross-sectional surveys of older people carried out in seven urban and four rural sites in five Latin American countries, China and India. In India, the study was conducted in both rural and urban sites among Tamil speaking Indians (65-80+ years) in Tamil Nadu. Along with other neuropsychological tests, animal fluency (from CERAD as part of the Community Screening Instrument for Dementia - CSI ’D’) was tested. The study findings indicated that the Indian participants generated nearly six fewer animals on verbal fluency than participants in China and Latin America. The authors further provided normative data by age group, sex and educational level for the task of verbal fluency. The authors also suggested that the study findings clearly cannot be generalized to the vast and diverse populations of India and China.
as a whole. Similarly, Saldanha, Mani, Srivastava, Goyal, and Bhattacharya (2010) in their epidemiological study conducted in Pune and Kirkee cantonments, employed *animal* naming from CERAD to determine prevalence of dementia among the elderly population (> 65 years).

**J. P. John, Halahalli, Vasudev, Jayakumar, and Jain (2011)** explored the pattern of functional magnetic resonance imaging blood oxygen level dependent activations and deactivations during semantic word generation in individuals with schizophrenia (n=24) and a control group (n=24) between 19-44 years. The participants were instructed to overtly produce an exemplar of the category word-cue that was displayed on the screen during the experiment. The performance on total number of words (correct & incorrect) and repetitive responses on six verbal fluency tasks (‘animals’, ‘vegetables’, ‘birds’, ‘fruits’, ‘flowers’ and ‘trees’) were investigated in south Indian Dravidian languages. The study findings revealed poorer performance in schizophrenics in terms of total responses and correct responses. The study also provided data regarding regional activations and deficient deactivations during verbal fluency task in schizophrenia.

**Bhattacharyya, Guha, Ghosal, and Barman (2012)** compared 47 patients with chronic schizophrenia and 29 healthy controls on verbal fluency. The mean age of cases and controls were 35.70 years and 38.10 years respectively. The verbal fluency subtest of KCSB (Kolkata Cognitive Screening Battery) for category fluency was used for testing speed of processing. The authors reported that age was associated with better performance in verbal fluency with poorer performance in subjects with schizophrenia on speed of processing tasks. The utility of verbal fluency task among schizophrenia has also been reported by Adarsh (2013).

The task of verbal fluency was also employed by Nagendar and Swathi Ravindra (2012) in their study on adaptation of Mississippi Aphasia Screening Test in Telugu language. The task of verbal fluency has also been employed by Adhikari, Basu, Das, and Misra (2012), among patients with idiopathic parkinsonism (n=51). Similarly, D’Cruz, Rajaratnam, and Kumar (2013) reported effects of age, gender and education on semantic verbal fluency (*animal* and *first names* categories) in their study among cognitively unimpaired aged population. In a
study by Hariprasad et al. (2013), improvement following yoga-based intervention among elderly population was also reported.

Recently, Krishnan and Karanth (2013) investigated verbal fluency performance in 22 individuals with right hemisphere damage. Clustering, switching and time course analysis of verbal fluency task was done using eight semantic fluency categories (animals, vegetable, birds, fruits, vehicle, clothes, furniture, & verbs) and three phonemic categories (letters p, a & s). The authors reported impaired lexical retrieval with lower scores on semantic and phonemic tasks with reduced number of clusters (in semantic task) and smaller mean cluster size. The persons with right hemisphere damage exhibited similar temporal pattern of retrieval with performance on number of switches similar to control group.

### 2.9.1 Research on Verbal Fluency in Malayalam

Owing to the fact that in the present study, verbal fluency was tested using Malayalam letters among Malayalam speaking children, it is apt to describe briefly some linguistic features of Malayalam language. Malayalam is one of the four major Dravidian languages of Southern India (along with Kannada, Telugu and Tamil) which was given the classical language status recently in the year 2013.² It is one of the 22 scheduled languages of India spoken by 34,713,130 people (Census of India, 2011). It has an official language status in the state of Kerala, Union Territories of Lakshadweep and Puducherry.³ This language is also spoken in many other parts of South India including Tamilnadu (Nilgris, Kanyakumari & Coimbatore districts) and Karnataka (Dakshina Kannada & Kodagu districts). Overseas, it is used by many Indians living in Middle East, North America, New Zealand, Malaysia, Singapore, Fiji, Australia, and Europe.⁴

In Malayalam, the consonant inventory consists of 38 phonemes and the vowel inventory of seven phonemes, making a large set of distinctive phonemes as compared to other Dravidian languages.⁵ Unlike English, which is considered an isolating language (with little to no morphology), Malayalam exhibits characteristics of an agglutinative language.

³ http://www.ethnologue.com/language/ml
⁴ https://en.wikipedia.org/wiki/Malayalam
⁵ http://www.lmp.ucla.edu/Profile.aspx?LangID=92&menu=004
wherein most of the words are formed by joining morphemes together making it a morphologically rich language. The syllable structure in Malayalam language is (C)(C)(C)V(V)(C) (parenthesis indicating optionality). The average number of syllables in a word is more in Malayalam (4.44) as compared to other Dravidian languages, viz. Telugu (3.55), Kannada (3.83) or Tamil (3.87); further, the average word length is also maximum in Malayalam (10.255) as compared to Kannada (8.68), Tamil (8.67) and Telugu (7.76) due to the post positional markers being attached to the word itself (Bharati, Rao, Sangal, & Bendre, 2002). Another striking feature present to a lesser degree in other Dravidian languages is the close blend of Dravidian and Sanskrit elements in the language. It is a common sight to see Malayalam speaking individuals using a lot of loan words from English, Sanskrit, Tamil, Latin, Portuguese, and Arabic in their day to day conversation.

Among Malayalam speaking urban cognitively unimpaired older adults (n=153) between 55-84 years (62 males & 91 females), Mathuranath et al. (2003) studied the effect of age, gender and education on verbal fluency. Based on the years of education, each subject was categorized into any of the four education groups: illiterate (0 years of formal education), primary education (1–3 years), upper primary and secondary (4–12 years) and university (>12 years). The verbal fluency was tested using category fluency (animal) and letter fluency (/pa/). Based on the total number of words, it was reported that the level of education and age had significant influence on letter fluency and category fluency respectively with no significant difference in performance between gender groups. The authors also cautioned against the use of data for younger population or individuals belonging to rural population.

Mathuranath et al. (2007) conducted a study to obtain population norms on Malayalam adaptation of Addenbrooke’s Cognitive Examination (M-ACE) among cognitively unimpaired older adults (n=488) stratified based on education. For testing verbal fluency which was a sub test in M-ACE, participants were instructed to produce words beginning with initial letter /pa/ and on animal category in Malayalam. The authors provided education stratified normative scores for verbal fluency.

de Jager et al. (2008) studied 282 young controls (20-29 years) and literate adults (55-92 years) on animal fluency, which was part of 7- minute screening test for detecting high
risk of Alzheimer’s disease in Malayalam. Based on the study results, the authors concluded, significant differences between controls, high and low risk groups with poorer performance on category fluency with increased age. The authors also reported 88% discrimination between high and low risk groups using verbal fluency task.

S. John, Jose, and Rajashankar (2011) analysed the total number of words and clustering measures on phonemic (/pa/) and semantic (animal) fluency tasks in 30 healthy Malayalam speaking adults (18-25 years) recruited from a University-based participant pool. The results revealed that semantic fluency scores were better than phonemic fluency with no variation across gender. In addition, a positive correlation was observed between the total number of words generated and two of the clustering measures, that is, number of clusters and cluster size. The results indicated that across both types of fluency, significantly fewer words, cluster size and mean cluster size were produced in phoneme fluency as compared to semantic fluency; however, there was no significant difference between the tasks on number of clusters.

2.10 Psychometric properties of Verbal Fluency tasks

Psychometric properties of a test refer to the measurement characteristics of a test. A test is considered as having good psychometric properties, if it measures the construct it is designed to measure, as accurately as possible. Reliability (the extent to which the measurement procedure produces the same results on repeated trials) and validity (the extent to which the measurement procedure measures what it purports to measure) are two of the most important psychometric properties of a good test. The following pages briefly summarize the literature review on reliability and validity of verbal fluency task.

**Psychometric properties with reference to Internal Reliability:** A high degree of internal consistency (r = 0.83) for FAS tasks and COWA has been reported by many researchers (Tombaugh et al., 1999; Ruff et al., 1996). Based on the data presented from two studies on verbal fluency tasks in participants with schizophrenia, Melinder et al. (2005) reported relatively similar internal consistency for category (0.70) and phonological (0.78) fluency. For the Japanese version of verbal fluency task (Emi, Emi, & Takeshi, 2006), a cronbach’s alpha of 0.818 was reported for both letter and category fluency based on their study in 1903 residents.
Psychometric properties with reference to Test-retest Reliability: One of the important psychometric considerations is the measure of test-retest reliability, the measure of test score stability over time. It refers to the extent to which subjects produce similar scores on the same measure administered on two different occasions. In general, the study findings are indicative of significant increase of scores on re-testing with good reliability score. Significant test-retest reliability has been reported by many researchers (0.88 - DesRosiers & Kavanagh, 1987; 0.74 - Ruff et al., 1996; 0.68-.82 - Harrison et al., 2000; 0.79 - Cohen & Stanczak, 2000; 0.77 - 0.87 - Emi et al., 2006) with practice effect ranging from one to eight words. However, no considerable changes on retesting after one year has been reported by Basso, Bornstein, and Lang (1999) and Tombaugh et al. (1999).

In terms of qualitative aspects of verbal fluency, Ross (2003) reported poor to modest \( (r = 0.47 \text{ for clusters}, r = 0.58 \text{ for switches}, \text{and } r = 0.70 \text{ for total words}) \) test–retest reliability coefficients in 55 healthy participants for ratings by seven judges after 22-34 days (6-7 weeks) re-testing. Similarly, Ross et al. (2005) reported improved temporal stability for cluster and switch scores on instructional modification on the COWAT procedure to test-retest after 29-47 days. The stability coefficients for the cluster and switch scores were higher in undergraduates in the experimental group \( (n=60) \) who received clustering instructional strategies than the control group \( (n=60) \) who received only original instructions.

Test-retest reliability has also been studied in children. Brown, Rourke, and Cicchetti (1989) reported 0.54 in 8-year-old children on a test-retest after 2.5 years. Hurks (2012) studied the test-retest reliabilities of verbal fluency measures in forty children between grades three and six. While the test-retest reliability coefficient was substantial for word productivity \( (\text{riccs} = 0.45-0.64) \), it was moderate for both clustering and switching \( (\text{riccs} = 0.31) \). Similarly, Barr (2003) reported marginal \( (r = 0.68) \) test-retest reliability with practice effect of three words among 48 adolescents (aged 13-17 years) who were retested after 8 weeks with no gender difference.

Psychometric properties with reference to Inter-rater Reliability: The psychometric property of inter-rater reliability refers to the extent to which the raters or judges are in agreement with respect to the similarity of the scores when applying the same scoring system. In terms of
inter-rater reliability, studies have reported near perfect scores (0.99 - Ross, 2003; 0.98 - Cohen & Stanczak, 2000; Das, Biswas et al., 2006; 0.90 - Vlaar & Wade, 2003). For qualitative measures of clustering and switching, Troyer et al. (1997) and Ross (2003) have reported excellent inter-rater reliability. In children, Kave et al. (2008) and Tallberg et al. (2011) reported high reliability scores for phonemic and semantic fluency.

The reliability coefficients for the different versions of standardized verbal fluency tests have been also tested and reported. The internal reliability and the test-retest stability coefficient of verbal fluency subtest of NEPSY was <0.59 (low) for ages 3-4 and 0.70 - 0.70 (adequate) for ages 5-12 years (Strauss et al., 2006). For the D-KEFS verbal fluency test, for ages 8-89 years, the internal consistency and test-retest reliability coefficient has been reported by Strauss et al. (2006). In terms of internal consistency and test-retest reliability, the magnitude of reliability coefficient was high (0.80 - 0.89) for letter fluency, marginal (0.60 - 0.69) for category fluency and low (< 0.59) for category switching subtest.

**Psychometric properties with reference to Validity**

Studies have attempted to explore the validity of Verbal Fluency tasks in terms of correlation, concurrent and construct validity.

**Correlation between Verbal Fluency tasks:** Among phonemic fluency tasks, high correlations have been reported by many researchers. The correlation has been reported to range from 0.85 - 0.94 for letters FAS and CFL (Cohen & Stanczak, 2000; Lacy et al., 1996; Troyer, 2000); 0.81 between Thurstone word fluency and FAS (Cohen & Stanczak, 2000) and 0.72 between Thurstone word fluency and CFL/PRW (Cohen & Stanczak, 2000). Among semantic fluency task, moderately high correlations (0.66 - 0.71) have been reported across various semantic categories used. Between phonemic and semantic fluency tasks, a moderate correlation (0. 34 - 0. 64) has been reported in both adults and children (Kave, 2005; Matute et al., 2004; Tombaugh et al., 1999).

**Concurrent Validity:** Correlation of letter fluency with Wechsler Adult Intelligence Scale has been reported by Tombaugh et al. (1999) and Crawford, Moore, and Cameron (1992). Ardila et al. (2000) reported a significant correlation (0. 30) between verbal fluency and VIQ and Full scale intelligence quotient among fifty 13-16 year old typically developing children.
While Crawford et al. (1992) found a correlation of .67 between FAS and National Adult Reading Test, a moderately high correlation (0.41 - 0.46) was reported by Ross (2003) and Harvey and Seigert (1999). Riva et al. (2000) reported a closer relationship between naming and animal fluency (0.57 - 0.68) as compared to phonemic fluency (0.43 - 0.50).

_Construct validity:_ With respect to construct validity (the ability to actually identify or measure the psychological construct studied), studies have found loading of verbal fluency on various constructs. Verbal fluency loading on verbal knowledge, reading, writing and sentence construction has been reported by Crockett (1974) and DesRosiers and Kavanagh (1987). Salthouse, Atkinson, and Berish (2003) examined construct validity of executive function (EF) in 261 adults (18-84 years) and reported verbal fluency as the “best” neuropsychological measure of executive function based on factor loadings. Similar findings have been reported by other researchers also (Hughes & Bryan, 2002; Unsworth et al., 2011). Studies among clinical populations (Fossati et al., 2003; Troyer et al., 1998a; Troyer et al., 1998b) have also provided substantial evidence of good construct validity for verbal fluency task.

2.11 Summary

Based on the above literature review, it is evident that verbal fluency is a quick and efficient task with good psychometric properties requiring effective word retrieval process without errors within the limited time frame. Various researchers have attempted to explain the mechanism of verbal fluency from different perspectives. Despite its extensive utility in disordered adult population, there is a paucity of research among healthy typically developing children belonging to different culture and languages. It is still unclear how children of different age groups and gender performed in terms of how many words are retrieved for different tasks of verbal fluency. The question remains unanswered on whether children employed similar or distinct word retrieval strategies as adults during verbal fluency task. The lack of demographically adjusted norms had been a major obstacle for childhood research using verbal fluency. In children, the evaluation of verbal fluency performance needs to be understood from a developmental and linguistic perspective as these factors influence performance. Clearly, there is a need for deeper understanding of the elusive nature of verbal fluency in typically developing children for enhancing its utility to a greater extent in paediatric disorders. This study attempts to address these issues within the stipulated aim and objectives.