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Semantic-category processing in bilingual individuals with aphasia

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ABSTRACT

Anomia or word retrieval difficulties are the most commonly observed symptoms in individuals with aphasia and often severely affect the communication abilities in their every day life. There are reports of word retrieval difficulties demarcated to different domains or categories. The most frequently reported form is that of deficits affecting the ability to name objects in the living domain as opposed to the nonliving. However, research regarding semantic-category processing has so far focused on monolingual individual, as language organization may differ in bilingual individuals. In order to advance the treatment of these symptoms, semantically guided treatment methods for category-specific deficits need to be designed. The aim of this study is to give a foundation for further research towards understanding the semantic-category organization and processing of bilingual individuals with stroke-induced aphasia. Three bilingual individuals with aphasia have been tested with an extensive neuropsychological test battery. The tests are designed for comparison between different semantic categories and feature cues such as living versus nonliving, animate versus inanimate, and perceptual versus functional. All participants showed subtle patterns in their abilities to process living and nonliving objects, with one having a more intact ability of processing living than nonliving objects, whereas the other two participants had a more intact ability in naming nonliving objects. The latter two also displayed the expected correspondent difficulty in processing perceptual more than functional information types. The participant with a favor in processing living objects did not perform any different on perceptual than functional cues. These results indicate that semantic-category processing theories regarding monolingual speakers also seem to hold true for bilingual speakers.

Keywords: *bilingual, aphasia, semantic organization, lesion location, category-specific*

ARTICLE OUTLINE

1. Introduction

In 2001 it was estimated that there are 45 000 new cases of bilingual aphasia every year in the US. These numbers were expected to grow rapidly both in the US and western Europe (Green & Abutalebi, 2008). With this in mind, bilingual and multilingual individuals with aphasia are an increasingly common group of patients Speech-Language Pathologists encounter in their clinical work. The most common symptom observed in aphasia is word retrieval difficulty (also known as anomia), which has significant impact on a person's communication abilities. However, as of yet it is unknown how deficient processing of semantic knowledge influences the word retrieval difficulties that are observed in aphasia in monolingual and bilingual speakers. In order to design efficient semantically based treatments for facilitating word retrieval, one needs to understand the relationships among semantic feature knowledge, word retrieval deficits, and lesion location in individuals with aphasia. This project is meant as a pilot study of how semantic categories are organized in bilingual individuals with aphasia.

1.1 Background

1.1.1 Semantic organization and memory

Semantic memory is the dynamic system that coordinates concentrated knowledge spread out across different cortical regions. Semantic memory also gives us the ability to have long-term knowledge of word and object meaning (Antonucci & Reilly, 2008). A semantic representation is a stored world knowledge, which is shared by the speakers of a language. This includes understanding the meanings of words, objects, or actions and can be accessed from any input modality (for example, by reading, hearing or viewing objects or gestures), as well as output mode (such as writing, speech, or gestures) (Raymer & Gonzalez Rothi, 2001). The semantic representations likely engage networks of information about words, objects, and ideas, which include relationships such as superordinate, coordinate, associate, and subordinate information (Raymer & Gonzalez Rothi, 2001). Damage to one or more of the components in the network can give impairments typically associated with aphasia and dementia. Depending on which component has been impaired, the semantic memory and word retrieval ability are affected differently, thereby making different therapeutic approaches appropriate in terms of behavioral treatment (Antonucci & Reilly, 2008). Individuals with semantic impairments have difficulties with all tasks requiring a semantic mediation, such as written and spoken word comprehension and/or spoken and written picture naming (Raymer & Gonzalez Rothi, 2001). Furthermore, Lambon Ralph, Moriarty, and Sage (2002) point out that most cases of anomia (word retrieval difficulties) can be traced to impairments to the semantic and/or phonological representations.

Research today is more or less homogeneous in viewing lexical processing as a multimodal system that requires several functioning units in order to comprehend and/or say words. There is, however, no consensus regarding exactly which units or components are critical, and the terminology differs even though most models seem to describe similar abilities and functions.

Although details may vary, studies on both neurologically intact as well as brain-injured individuals have given us models of lexical processing in which the general features are reoccurring. The lexical process is a complex system where a multimodal network with different types of lexical stimuli is processed (Raymer & Gonzalez Rothi, 2001).

Sensory input, such as written or spoken words, or viewed objects and gestures activate peripheral sensory structures in the brain, which triggers processing and reaction. These inputs are managed by cognitive mechanisms in the central nervous system. In early sensory processing, stimulus recognition processes can activate representations that closely resemble the input. When a stimulus becomes "uniquely distinguishable and familiar compared to all other physically similar stimuli" that is the point of recognition (Raymer & Gonzalez Rothi, 2001, p. 525). Hence, recognition is not when a stimulus is understood or comprehended, but when it is identified as previously experienced and familiar, not necessarily that one understands the meaning of the word or object. Furthermore, Raymer and Gonzalez Rothi (2001) review research proposing that recognition level processes are modality specific, meaning that knowledge of each different type of familiar sensory stimuli has its own module. As soon as the recognition-level representation is fully activated, this will trigger the semantic system. The knowledge stored in the semantic system is the semantic representations that contain meanings for words, objects, and actions, which are likely included in a network of information, such as superordinate, coordinate, associated, and subordinate relationships. These can be accessed from any input modality and lead to whichever output modality seems fit. Some of the research reviewed by Raymer and Gonzalez Rothi (2001) indicated that the semantic representations are modality independent - a single unitary semantic system give meaning to stimuli independently of input or output modality. A reaction to this view is that the semantic system itself is divided into subsystems for each input sensory or output mode (Raymer & Gonzalez Rothi, 2001).

Once a cognitive mechanism has been activated by a sensory input, this leads to peripheral motor processes that activate a response, whether it may be in writing, speech, or gesture. This ability can be disrupted in any of the modules or communications between the modules, and can lead to word retrieval difficulties (the output) either separately or along with comprehension impairments (the input) (Raymer & Gonzalez Rothi, 2001).

Depending on the type of input, there are different stores; familiar spoken and written words are organized in the phonological and graphemic input lexicons, familiar objects are stored as visual object representations, whereas the action input lexicon is responsible for the storing of familiar viewed actions. There might also be separate stores for olfactory and tactile stimuli, respectively. It is therefore important to know which store or module that is tested in clinic or in research, in order for treatments to be tailored as efficiently as possible (Raymer & Gonzalez Rothi, 2001).

The semantic memory, as is the case with all human memory, is divided into several subsystems, which more or less overlap one another. A number of components need to function in order for a person to access and pronounce a word. For example, in a modality-independent system model, one looks at a sun and thereby initiates visual/perceptual processes. These mechanisms start a chain of events, each one leading on to the next; visual object recognition, which turns into semantic analysis, which then turns into phonological output lexicon, proceeding into phonological buffer and finally accesses the speech initiation and articulation, see Figure 1 (Antonucci & Reilly, 2008).

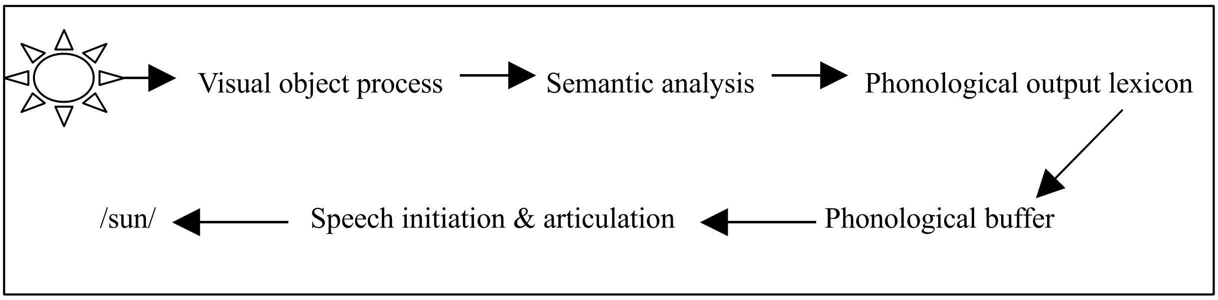

Figure 1. The chain of subsystems in the process of word retrieval.

In order to understand semantic organization one needs to entertain different theoretical models. Firstly, it is unknown whether there is one semantic system for processing all information, independent of modality, or if there are different routes specifically for processing information depending on the in- or output modality. Furthermore, we do not yet know exactly how semantic knowledge itself is organized. In order to understand semantic organization some research has focused on interpreting category-specific deficits in brain-damaged individuals (Antonucci & Reilly, 2008). That is, many individuals with acquired brain injury demonstrate a disproportionate difficulty in naming living objects, but less is known about the reverse impairment difficulty naming objects within the nonliving domain. Impairments within the living domain as well as impaired processing of visual-perceptual semantic features have been associated with the inferior temporal cortex. Impairments within the nonliving domain have on the other hand been associated with the dorsolateral network in the left parietal and posterior middle temporal cortices (Antonucci & Reilly, 2008).

A disturbance in any of the leads in the chain would prevent correct spoken word retrieval (Antonucci & Reilly, 2008). Yet another possibility is that there are different semantic systems depending on whether the stimuli are presented visually or verbally. These systems could be independently damaged, which would lead to impairment to either name objects presented visually or difficulty naming objects primed verbally. An alternative to these linear models is the multimodal model that considers the semantic system a network where concepts emerge from an interaction between modality-specific sensory perceptions. This hypothesis can be explained by thinking of the relation between a library and a librarian. The content and format can be represented differently; both amodal as well as modality-specific models believe that the semantic system can be compared to a library, as a storage area of facts. Multimodal theories, however, suggest that the semantic system functions more like a librarian - the semantic system does not hold any information per se, but know where to locate the information necessary (Antonucci & Reilly, 2008).

When hearing a word, neuronal assemblies that represent lexical forms in the perisylvian cortex activates. This cortex is also associated with neuronal assemblies in the visual cortices of the occipital and inferior temporal lobes, where object and sensory properties are associated. However, an activation of the visual cortex may not be a sign of a complete mental image of the word whenever said word is uttered, but merely that subsets of neuronal assemblies in the cortex commonly associated with the word, has been triggered (Schrauf, 2009). The medial temporal lobes, which are related to the explicit memory system, are responsible for tying information into events when the events are encoded into the memory system, as well as the search-and-retrieval system, which is related to the frontal areas of the brain. The frontal areas are responsible for the selection and temporary storage of information during the retrieval processes. This is the result of the individual beginning a mental search for personal memories associated with the spoken word.

Damage that has made an impact independently on the phonological input lexicon leads to difficulties in all tasks that require processing speech, such as word-to-picture naming, and naming to spoken definition. Even with such impairment, comprehension of written words may still be intact. Individuals described to have pure word deafness often have damage either affecting bilateral temporal or subcortical left hemisphere. This affects input to Wernicke's area, which is therefore believed to be crucial for prelexical stages of phonological processing. Some individuals with Wernicke's aphasia have been reported to have lesions affecting the left posterior perisylvian area, including Wernicke's area, and thereby could be characterized by impairment of the phonological input lexicon. Taking this into account, it is plausible that a neurologically critical area for phonological lexical input knowledge is the posterior part of the left superior temporal cortex (Raymer & Gonzalez Rothi, 2001).

Studies have described individuals with aphasia having lesions affecting their naming and comprehension in fractionate ways, with selective impairments within specific semantic categories. These categories could be living and nonliving, fruits and vegetables, animals, tools, or medical terminology. This, however, does not necessarily implicate that the semantic system is structured in these categories, but rather by the characteristics that each category possess. If a neurological disease damages a neural region, in which crucial shared properties are located, all concepts with those properties will be affected. Categories such as animals and plants (natural categories) likely have a large amount of interconnected properties. As an example, many animals are mammals, have four legs, have fur, or many plants grow, need water, need sunshine, are green making all exemplars within a category vulnerable to neurological injuries (Raymer & Gonzalez Rothi, 2001). As a result, since the semantic system is likely structured in different textures, lesions may result in impairments for selective categories. Detailed lesion analysis combined with assessment of semantic abilities therefore provides valuable information regarding the neural instantiation of semantic knowledge. Both individuals with acute vascular lesions affecting the left posterior regions, and individuals with degenerative dementia affecting the left postero-lateral cortex have demonstrated those regions to be highly significant for semantic knowledge (Raymer & Gonzalez Rothi, 2001).

Damage to the left posterior temporal/inferior parietal cortex, have been reported to affect the input to the semantic processing, resulting in a comprehension impairment leaving word retrieval abilities intact. There are also reports suggesting that individuals with damage to the left inferior temporal/occipital cortex junction (Brodmann’s Area 37) have impairments to the semantic output stage. This indicates that the left posterior perisylvian regions are critical in terms of semantic processing, although individuals with more semantic impairments often have damage to larger parts of their left hemisphere. Also, the left thalamic nuclei seem to be critical for the semantic network due to many individuals with transcortical sensory aphasia having a vascular lesion affecting that area (Raymer & Gonzalez Rothi, 2001).

1.1.2 Semantic knowledge in patients with aphasia

Naming impairment is the single most commonly observed symptom in aphasia (Antonucci, Beeson, Labiner, & Rapcsak, 2008). Antonucci et al. (2008) reported that there may be two different underlying mechanisms with distinct neural substrates necessary for accurate word retrieval. Naming impairments or word retrieval difficulties are commonly noted after damage to posterior regions of the left inferior temporal lobe (Brodmann Area 37). It has been suggested that anomia is the result of a disconnection between preserved semantic knowledge and phonological word forms (known as pure anomia), whereas damage to the anterior temporal regions (BA 38,20/21) can lead to anomia-symptoms that are the result of degraded semantic representations (semantic anomia). There is, however, not sufficient evidence to suggest that individuals with pure anomia actually have intact semantic knowledge. Also, the lesions in those individuals were not necessarily restricted to BA 37 and the evidence of semantic anomia is often derived from patients with bilateral temporal lobe damages. It is therefore unknown if a unilateral temporal lobe lesion is sufficient to produce any significant semantic impairments. Furthermore, Antonucci et al. (2008) showed that pure anomia and semantic anomia are two endpoints along a continuum of semantic impairment. Other studies incorporating neuropsychological testing with lesion analysis support the theory that left inferior temporal lobe is critical for semantically guided lexical retrieval, and that there may be variations in the nature of a naming impairment depending on the exact lesion location (Antonucci et al., 2008). For example, there are case reports of lesions to left posterior inferior temporal cortex (BA 37) that have led to intact semantic knowledge even though anomia was present. In addition, individuals with that type of damage often produce naming errors that are semantically appropriate circumlocutions, and thereby display a somewhat preserved conceptual knowledge as well as phonological word form (Antonucci et al., 2008). An increasing amount of evidence supports the importance of the extrasylvian regions of the left temporal lobe for semantically guided lexical retrieval. Functional neuroimaging studies (fMRI) on non-brain damaged, neurologically intact participants have demonstrated activation in left posterior inferior temporal cortex (BA 37) during picture-naming as well as verbal fluency tasks (Mummery, Patterson, Hodges, & Wise, 1996; Price, Moore, Humphreys, Frackowiak, & Friston, 1996).

In a review by Gainotti (2006), he highlights the categorical organization of semantic memory from the perspective of a number of authors' theories. The semantic memory seems to be organized in many different categories - not only by grammatical subsets such as nouns and verbs. Lesion studies have shown that damage to different brain locations can lead to impairments solely affecting abstract words, biological entities, and/or manmade artifacts. Discussions have focused on the contrasts between category-specific impairments within the living and the nonliving domains. Its most frequently reported form is an inability to name living things, while the ability to name nonliving and manmade artifacts is intact. This manifests in an impairment to identify animals, fruits, flowers, and vegetables (Gainotti, 2006). Individuals can also have a disproportionate impairment between living animate (animals) and living inanimate (plants, fruits, vegetables) objects. It has been proposed that word retrieval of living animate and living inanimate objects also is affected by type of visual/ perceptual stimuli. For example, information regarding color is more useful in terms of naming vegetables and fruits than when naming animals and biological motion information is more helpful in naming animals than plants (Caramazza & Mahon, 2006).

There have been theories regarding the discrimination between living and nonliving items simply being the result of living things being of lower frequency and greater visual complexity than nonliving objects. Furthermore, some authors have proposed that if living and nonliving objects are carefully matched for frequency, familiarity, and visual complexity, the effect disappears. Others claim that even when carefully matched, many patients still display a significant difference between the two categories. Also, some patients display an impairment on the other way around; inability to identify objects within the supposedly easier nonliving category, with an intact ability to identify living items. Due to these arguments, although still somewhat controversial, it is more commonly accepted that brain lesions at certain locations affect the semantic knowledge within specific categories, such as biological entities (Gainotti, 2006).

The so called sensory-functional theory explains the distinction between living/nonliving as a "by-product of a more basic dichotomy, concerning the differential weighting of visual-perceptual and functional attributes in identifying members of biological and, respectively, of artifacts categories" (Gainotti, p. 586, 2006). This implies that identifying a living object is heavily dependent on visual features, whereas nonliving objects are reliant on functional attributes. Using computer simulation, it has also been shown that one can create category-specific deficits by damaging the sensory input (Gainotti, 2006). However, as mentioned above, there are also reports of impairments within the living categories, such as inability to name objects within categories such as animals and plants. This has resulted in the domain specific knowledge systems' hypothesis. This hypothesis suggests that the impairment could be due to a disruption of different evolutionary-adapted dedicated neural mechanisms for the domain of "animals" (potential predators), "plant life" (possible food or medicine), and "artifacts" (Gainotti, 2006). Yet another theory is the intercorrelations among semantic features' hypothesis, in which it is believed that different levels of interconnections could exist within the semantic structure between shared perceptual and functional attributes of living and nonliving objects. For example, living beings often have eyes and ears, which correlate with seeing and hearing. Interconnections in artifacts, however, do not have the same significance. Some authors believe this to be more important than the distinction between perceptual and functional in terms of explaining category-specific semantic disorders (Gainotti, 2006).

Even though all of the above hypotheses predict specific lesion patterns in connection to the category-specific deficits, not many have entertained the neuroanatomical correlates of those semantic impairments. It has been suggested that the temporal pole functions as a convergence zone (top of a cascade) of closely interconnected cortical processors that connect the different components of a concept's various representations (Gainotti, 2006). The convergence zone supports a continuum between perceptual information and conceptual representations (Gainotti, 2011). This results in the inferior temporal lobe, the temporo-limbic structures, and the temporal pole being critical not only in processing, but also in storing and retrieving representations of objects, which are mainly based on sensory, mostly visual, attributes. On the other hand, the dorsolateral locations (especially the fronto-parietal) of the left hemisphere are important for action planning as well as advanced somatosensory processing. These areas are also part of the dorsal stream of visual processing used for spatial and action functions (Gainotti, 2006).

It has been widely reported that living stimuli activates either the antero-infero-medial parts of the temporal lobes, mainly the infero-temporal cortex, or the antero-medial parts of the temporal cortex (Gainotti, 2006).

1.1.3 The bilingual brain

There is no consensus regarding who should be considered bilingual. Generally, it is defined as a person who "has a choice of two available languages for conversation" (De Bleser, Dupont, Postler, Bormans, Speelman, Mortelmans, & Debrock, p. 440, 2003). Neither is there a consensus regarding the neural organization of languages in bilingual/ multilingual speakers, or semantic-category organization in particular. Hernández, Costa, Sebastián-Gallés, Juncadella and Reñe (2007) bring attention to some general hypotheses regarding the cortical organization of the two languages of a bilingual. One of those is the "linguistic-domain principle" hypothesis. According to this hypothesis, the second language (L2) representations are organized following the exact same principles (when possible) as those that are used in first language (L1's) organization. This means that on a macroscopic level, the same brain tissue sustains both L1 and L2. Different factors such as grammatical class and semantic category are here considered to govern the lexical representations in the cortical organization independent of language membership. For example, a living animate noun such as /dog/ and its Swedish correspondent /hund/, would be stored in the same place for a bilingual English and Swedish speaker. Supporters of this hypothesis emphasize that this view does not preclude that a bilingual person with aphasia may recover in one language but not the other (Hernández et al., 2007). In accordance with this hypothesis, it is expected that the results for monolingual individuals with aphasia would be the same as for the bilinguals that are tested in this project.

In terms of recovery, researchers have entertained two different "rules" or "laws". The first being Pitres' rule (recovery of the mostly used acquired language), which mainly applies to younger patients, whereas older patients are affected by Ribot's law (recovery of the native language) (Pearce, 2005; Javier, 2007). These rules suggest that older patients will have greater difficulties in their later-learned languages than younger patients. This is explained by age affecting the declarative memory, which is expected to subserve the L2 more than the procedural memory (Javier, 2007).

Green and Abutalebi (2007) emphasize that one cannot consider a bilingual speaker the sum of two monolingual speakers. Therefore, the monolingual language production models are generally not sufficient to explain bilingual language production. As an example, bilinguals tend to be slower at naming in picture-naming tasks than monolingual speakers, as well as experience more tip-of-the-tongue states. This could be due to bilingual speakers not using every word as often as a monolingual speaker since a bilingual person divides their lexical production between two languages. Another explanation could be that bilinguals have their conceptual representations linked to two different lexical representations that are used by different grammatical systems. When presented with a picture, the bilingual individual faces a conflict in terms of which of the two lexical representations should be used (Green & Abutalebi, 2007).

However, recent research using fMRI (functional Magnetic Resonance Imaging) suggests that, on a lexical level, the neural substrates are shared for L1 and L2, although some populations of neurons within the shared areas do have language-specific responses (Klein, Zatorre, Chen, Mihner, Crane, Belin, & Bouffard, 2006). The same article states that the patterns of brain activity for semantic judgments largely depend on proficiency. Cortical representations of grammatical processing are also dependent on the age of acquisition of the language in question. Furthermore, Hull and Vaid (2007) showed that individuals who acquired their second language after the age of six are more lateralized to the left hemisphere in both languages than speakers who acquire their L2 before six years of age. The left hemisphere's dominance was also greater the less proficient the speaker was in L2. This was even more prominent when it came to single word processing. According to the so called Age hypothesis, language lateralization is dependent on the temporal proximity of acquisition, meaning that an early, near simultaneous, acquisition of two languages leads to a different lateralization pattern than a late, successive acquisition of L2 in relation to L1. However, there is a debate regarding these activation patterns, as De Bleser et al. (2003) points out. There have been studies stating that a low proficiency language speaker is accompanied by less activation of language relevant areas of the left temporal lobe, but with a more widespread participation of other areas across the brain. Furthermore, De Bleser et al. (2003) also emphasize that the studies citing different activation patterns often have participants with different language history in terms of age of acquisition and proficiency. In support of the Age hypothesis, Hull and Vaid (2007) further describe that the cerebral cortex as well as corpus callosum are not fully developed until approximately ages five or six years, or possibly even later. Also, the myelination of neural pathways is not completed until earliest that age. One must also not forget that the age of acquisition may result in socio-cognitive differences, which may cause a structural difference (Hull & Vaid, 2007).

Some authors suggest that depending on the various ways a second language may be acquired, these reflect on the linguistic organization. Some bilinguals may develop and maintain two more or less independent linguistic schemes, whilst others have a much closer interaction between the different languages' lexical organization (Javier, 2007). This is feasible considering that brain functioning is often considered to be sensitive to variations in early sensory experience. Studying bilingual individuals with different language experiences can therefore also give valuable information regarding the brain functions and structure shaping, and its plasticity. As an alternative to the Age hypothesis, we find the Stage hypothesis. This theory claims that the critical factor for language laterality is not that of age of acquisition, but the relative proficiency of the acquired second language. It is believed that the more proficient one is in one’s L2, the more automatic will the grammatical and phonological processes be, and one will be less dependent on pragmatic cues, which are mediated by the right hemisphere, thereby causing a left hemisphere dominance for language usage and processing (Hull & Vail, 2007). Furthermore, fMRI studies have shown that picture-naming in L2 acquired in late teenage-years, display increased brain activation in the right insula, anterior cingulate gyrus, dorsolateral prefrontal cortex, and the left fusiform gyrus in comparison to picture-naming in L1. This suggests that word retrieval and production is more demanding in L2 than in L1 (Altarriba & Basnight-Brown, 2009; Hernandez & Meschyan, 2006).

Plenty of bilingual processing and representation models presume that even though the phonological and morphosyntactic forms differ between languages, the meanings and concepts are for the most part shared. This is believed due to multilingual individuals usually being able to translate most words from one language into another, whether it be voluntary or not. This has led mapping of form to meaning to be a central part of theories regarding the bilingual lexicon. Research has often focused on links between word forms and meanings as well as examined factors for conceptual representation (Pavlenko, 2009).

A main issue in describing the lexical organization of the bilingual brain is the numerous reports of different recovery patterns post-stroke (Meuter, 2009). Some patients show a so called selective recovery; only one of the languages (in some cases L1, in other L2) improved, whereas some demonstrate a pathological (involuntary) switching back and forth between L1 and L2. A third recovery pattern is that of both languages having a parallel improvement. However, in these reports usually little is known about the patients' language history. It is seldom reported when the L2 was acquired or how the patient value his or her own proficiency in the languages. Due to this information commonly being unknown, retrospective comparisons between patients cannot be thoroughly made (Meuter, 2009).

Paradis (2004) explained the phenomena of selective or parallel recovery with an analogy of hands clasped with the fingers intertwined. Although forming a unit, both hands fingers can still be wiggled independently. Still, if someone were to hit the fingers with a hammer, both left and right hands fingers would get smashed. Each hand stands for a subsystem, and like the intertwined fingers, circuits subserving the two cognitive subsystems, L1 and L2, can be affected by damage either independently or together.

There has, however, not yet been any research conducted that focus on category-specific semantic processing in bilingual individuals with aphasia, in the same way as it has for monolinguals.

1.2 Aims and Hypotheses

This study was outlined under the hypothesis that deficient processing of specific semantic feature cues will impact word retrieval differently for concepts whose meanings are weighted in favor of those features.

The hypothesis is tested by pursuing the specific aim of determining the association between semantic feature cues and word retrieval for different types of object concept. This approach will be implemented by testing proficient bilingual individuals with aphasia using a neuropsychological battery specifically designed to provide for direct comparison between feature types within the same living and nonliving objects. The test battery was also balanced between functional and visual-perceptual information as well as shared and distinct features. A longterm goal is that in addition to the behavioral data, high-resolution magnetic resonance imaging (MRI) scans will be collected for the participants in order for lesion location to be related with their behavioral performance. It will then be possible to differentiate the patterns of performance and discern the extent to which semantic feature treatments may be tailored to meet the individual needs for word retrieval therapy.

The identification of the interaction between semantic feature and object-concept processing for bilingual individuals with aphasia will contribute to the discussion regarding whether the impairment to process different types of object concepts is an emergency property of feature-processing deficits that might be linked to lesion location.

2. METHOD

2.1 Participants

This thesis was done under the auspices of ongoing work at New York University, by the approval of the IRB (Institutional Review Board). Three bilingual individuals participated in the study. Two are right handed (as language organization and processing may differ in left-handed individuals and the reaction-time based task may be influenced). English needed to be one of their proficient languages considering that being the language that is tested. Each participant had experienced a single, unilateral cerebral vascular accident. The participants all signed an informed consent form prior to the testing.

All testing was done ≥ 6 months post-stroke. One of the inclusion criteria was that participants needed to be medically and neurologically stable at the time of testing. This in order for them to be able to participate in testing sessions lasting 2 – 3 hou rs once per week for approximately 4 weeks. Although the participants were fairly proficient communicators, they displayed evident anomic difficulties in their spontaneous speech. The participants were screened with a medical history/demographic questionnaire, with inclusion criteria covering negative history of psychiatric disorders, substance abuse disorders, or concomitant conditions, which result in progressive, degenerative neurological impairments. Participants may however have concomitant medical conditions such as heart disease or diabetes. Due to a pending MRI scanning, participants must also pass an MRI metal safety screening.

Screening tests

The participants also had their hearing screened at 40 dB at 500, 1000, 2000, 4000, and 8000 Hz binaurally (hearing aid acceptable), to ensure that their hearing would not affect results on tasks including phonological foils. The screenings were not conducted in soundproof rooms. None of the participants passed 8000 Hz binaurally at 40 dB. However, all participants self-rated their hearing as adequate and performed well on the tasks that depended on phonological discrimination. None of the participants used hearing aid.

Participants also had to get a minimum score of 4/10 in the *Western Aphasia Battery- Revised* auditory comprehension composite score in order to take part in the study. This was done in order to assure that test results were not affected by poor auditory comprehension. There was no minimum inclusion criteria set for other characteristics tested with the *WAB-R*. The test assesses those linguistic skills that are most frequently affected by aphasia. The *WAB-R* consists of two parts, of which only part one was used in this project. Part one consists of subtests of content, fluency, auditory comprehension, repetition, naming, and word finding. The maximum score is 100, with a cut-off limit to be considered normal or non-aphasic at 93.8. Part two, which was not used in this project, includes reading and writing as well as testing of nonlinguistic skills such as drawing, block design, calculation, and praxis.

Participants were also tested with the *Pyramids and Palm Trees Test* (*P&PTT*), which is a standardized test used to assess a person's semantic ability to access meaning from pictures and/or words by testing the ability to access semantic and conceptual information. There are different versions of this test - incorporating words, pictures, or words and pictures together. In this project, only the picture-version was used. The test is organized as a forced-choice format test, where the person being tested is presented with three pictures at a time, two at the bottom and one on the top. The participant has to decide which one of the pictures at the bottom goes with the one on the top (for example, the top picture being a pyramid and the two at the bottom being a fir tree and a palm tree, the correct answer would be palm tree since they usually go together with a pyramid).

Furthermore, the participants were tested with the *Raven's Coloured Progressive Matrices* (*RCPM*) as a method of screening to ensure that participants had an intact ability of logical thinking as well as visual-perceptual ability, which rules out visual agnosia that could affect the picture-based tasks. *RCPM* is a standardized test that consists of 36 items in 3 sets (A, Ab, B), with 12 items per set. The items are arranged to test the chief cognitive processes up to the difficulty level that is considered to be one of the first to decline as a result of an organic dysfunction of the intellectual maturation. All participants considered English their first language but had an early exposure to another language. The participants in this study are referred to as Bilx 1, 2, and 3.

Bilx 1

Bilx 1 is male who at the time of testing was 60 years old. He had experienced a stroke 3 years before testing. Bilx 1 was left handed and spoke Chinese until approximately three years of age. He also studied Chinese in school. However, he rates his proficiency very low. According to Bilx 1 he spoke Chinese at the level of a first grader when he was at his best. He seldom uses his Chinese (only when ordering food) and has therefore not noticed any difference pre- and post-stroke regarding his Chinese language skills or recovery. Bilx 1 has an education level of 16 years. He scored a *WAB Average Quotient* (*AQ)* of 95.2/100. Due to the cut-off limit to be considered normal or non-aphasic is 93.8, this means that according to the *WAB-R*, Bilx 1 does not have aphasia. However, the *WAB-R* only provides a brief overview of a persons language abilities and does not capture all language processing impairments. Furthermore, he scored 49/52 on the *P&PTT*, which is average. Lastly, Bilx 1 scored 31/36 on the *RCPM*. 34.5 is considered average for men with the same age and education level as Bilx 1.

Bilx 2

The second participant, Bilx 2, is a 58 years old male who experienced a stroke 22-23 months prior to testing. He grew up speaking Spanish. He considers himself fluent, however, as an adult he does not use his Spanish frequently. He has not noted any difference in recovery between his English and his Spanish. He has an education level of 16 years. Bilx 2 got a *WAB AQ* of 87.6/100 and was tested to have anomic aphasia. He got all the items on the *P&PTT* correct, scoring 52/52. Finally, Bilx 2 scored 33/36 on the *RCPM*. For men of his age and education level demography, average is 27.4.

Bilx 3

Bilx 3 is an 80 year old female who experienced a stroke 7 years prior to testing. She grew up speaking Italian with her grandmother and other relatives in her everyday setting. She spoke Italian on a daily basis until 17 years of age. However, she has not had anyone to speak Italian to in many years and has not spoken it since her stroke. Bilx 3 does not consider herself fluent in Italian, but self-rates that she is able to make herself understood and that she does understand Italian, at least when spoken in the same dialect that her grandmother spoke. Bilx 3 has an education level of 12 years. She tested to have anomic aphasia with a *WAB AQ* of 93.4/100 with the cut-off limit for what is being considered aphasia at 93.8. Bilx 3 scored

44/52 on the *P&PTT*, which is below the average score of 49. She got a total score of 24/36 on the *RCPM*. There is no normative data for participants over the age of 79 years. However, for women between ages 70-79 years, with the same education level as Bilx 3, the average score is 28.3.

2.2 Tests

All data were collected over three to four testing sessions. The participants completed a battery of experimental tasks that were created to access category-specific differences between living and nonliving items. The items in these tasks were considered to have both functional as well as perceptual distinguished features. Information such as function, action, or context was considered as functional, whereas information about color, shape, size, part/whole description, or component property was considered perceptual (Antonucci et al., 2008).

Spoken and written confrontation naming
In the confrontation naming, consisting of 60 pictures from the Rossion & Pourtois (2004) set presented on a computer, participants were asked to name presented items first verbally, then in writing. This task was administered at the final day of testing, so not to prime any responses in the other experimental tasks using the same stimuli. Confrontation naming was scored for accuracy and error type to examine the quality of the responses, meaning if they were semantically appropriate (airplane = "something to travel in") or if they were semantically empty (airplane = "yeah, I know what that is") or due to sound or word errors (airplane = "airpane", "car"). The writing was not conducted to look at spelling per se, but to give the possibility to see if sound errors would be eliminated and any if there were differences between semantic domains.

Word-picture Verification
This task was created to assess recognition and comprehension of colored pictured items. Participants were presented with a picture of an item and asked to verify its name ("Is this a plane?") verbally answering /yes/ or /no/. In total, the participants were presented with three statements/possible names regarding each picture throughout the testing sessions. For example, at the first testing session, the participant would be presented to the correct name ("Is this a plane?"), the second testing session the same picture would be presented with a semantic foil ("is this a helicopter?"), and the third session with a phonological foil ("is this a plate?"). In order to score correctly on an item, the participant had to answer correctly for the true statement and the semantic and phonological foils. The task consisted of 20 items. The pictures are part of the Snodgrass and Vanderwart set revised by Rossion & Pourtois (2004) and were presented on a computer.

Verbal Fluency
Verbal fluency was tested in both category fluency and letter fluency (FAS). Four semantic categories were assessed - two living categories, one being animate and one inanimate (animals and plants) and two nonliving categories also animate and inanimate (vehicles and tools) for one minute each. The FAS letter fluency task (Borkowski, Benton, & Spreen, 1967) was also administered. The verbal fluency task was administered before other tasks that could potentially prime words applicable to the fluency tasks. This test was administered in order to assess to which extent each semantic domain was affected by lesion location.

Naming-to-Definition

18 items derived from the large normative feature production database published by McRae, Cree, Seidenberg, & McNorgan, 2005) were used in order to differentiate how participants respond to visual-perceptual and function/action definitions. The visual-perceptual and functional definitions were balanced for level of superordinate information, length, and amount of information provided to insure that differences in response accuracy were not due to differences in linguistic complexity or the amount of information provided. The participants were presented with the definitions and then asked to verbally name the object being described. Each item had one functional and one visual-perceptual description. For example, the target word "pencil" was described in one of the sessions as "an object used to write and erase" and "a yellow object with a lead point", with the first description being functional and the latter visual-perceptual. The functional and visual-perceptual definitions for a particular item were not administered during the same testing sessions.

Verbal Description

18 items that were not used for the naming-to-definition task, was presented for verbal description to test usage of perceptual versus functional words to describe living and nonliving objects. Participants were orally presented a name of an item and prompted to tell the examiner "about a(n)____, pretend I don't know anything about it". Due to this being a fairly fatiguing task, it was divided between the different sessions. The participants' answer was audio-recorded for later transcription, which allowed an inter-rater reliability (IRR) to guess which target word, that had been censured, was described. Answers were deemed correct if an uninformed listener could identify the correct item from the description. Responses were also analyzed for types of information provided (visual-perceptual, functional, shared, or distinct).

Reaction Time Feature-Concept Verification

Participants were verbally presented with true and false visual-perceptual and functional features associated with 30 items and asked to verify (yes or no) whether there is a relationship between the feature cue and the object-name. Each item was presented eight times in different statements regarding if the statement was true or false, used functional or perceptual information, and if that information was shared or distinct. For example, one of the times the item "candle" was presented, the statement given was "does a candle have doors?", which is a false, perceptually shared statement. Yet another example is "can a clock be used for telling time?", which is a true functional distinct statement. The task was conducted on a Dell laptop computer via Empirisoft Direct RT software (http://www.empirisoft.com/directrt). The participants responded via button-press ("Y"/green button for yes and "N"/red button for no) on Empirisoft Direct In High Speed Button Box. The pre-recorded spoken feature cues were presented following an inter-stimulus interval of 200 ms. Before each testing, which was divided over three sessions, the participants completed a practice round in order to get used to the button box and task setup. Most of the features came from the McRae et al., 2005 database. For each item, features were presented that are shared among many objects as well as features that are distinctive for that particular object.

3. RESULTS

The results in this case series will be presented case-by-case for intra-subject comparison. Exploratory statistics using ANOVA and Fisher Exact Test did not show any statistical difference among the various categories between the participants or, in the Feature Verification, within the results for each participant. The abbreviations that will be used are presented in Table 1.

Table 1. Abbreviations used.

Living	L	**True**	T
Nonliving	NL	**False**	F
Functional	F/Func	**Shared**	S
Perceptual	P/Perc	**Distinct**	D

3.1 Bilx 1

Confrontation Naming
Presented with 60 items, half living and half nonliving, Bilx 1 could name all items but one both verbally and in writing. The item scored incorrect was nonliving.

Word-picture Verification
Bilx 1 answered all but one of the statements correctly. The error that was made was a phonological foil on a living inanimate object and hence not related to the semantic category.

Verbal Fluency
Bilx 1 retrieved fewer nonliving (3.5 words/minute) than living objects (6.5 words/minute) and scored generally higher on the category rather than the letter fluency (3 words/minute). In total Bilx 1 could mobilize a total of 13 living objects (animals and plants) and 7 nonliving objects (vehicles and tools). He performed slightly better on the category fluency tasks targeting animate words as oppose to inanimate words, see Figure 2a-b.

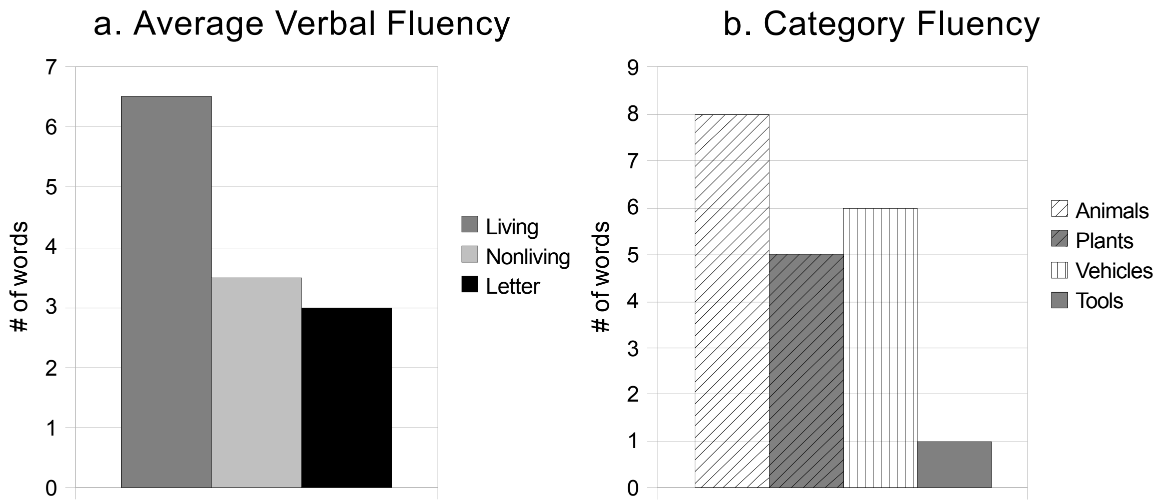

Figure 2. a: Bilx 1's average number of words retrieved in living categories, nonliving categories and letter fluency. b: Bilx 1's average number of words mobilized in Category Fluency.

Naming-to-Definition

With a possible high score of 9, Bilx 1 displayed a fairly even profile across the different categories, with a slight advantage in favor of living in comparison to nonliving items. There was no difference between functional and perceptual descriptions, as shown in Figure 3.

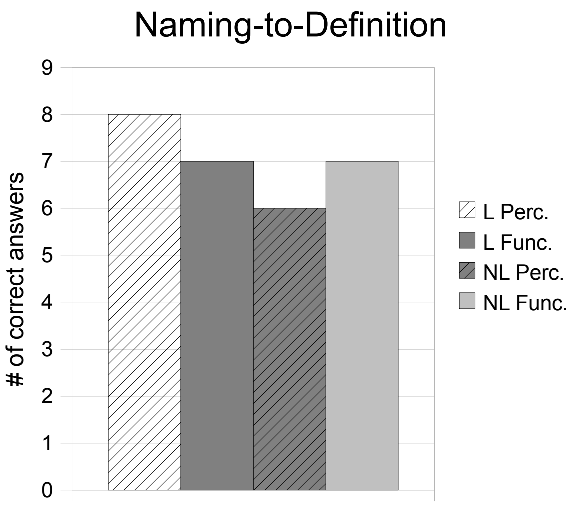

Figure 3. Bilx 1's result on Naming-to-Definition.

Verbal Description

The verbal description task was scored for accuracy as well as an analysis of the information types provided. The inter-rater reliability between the PI and two independent raters was 94.4 % and 100 %, respectively. As shown in Figure 4, Bilx 1 had 17/18 descriptions deemed correct, the only error being a nonliving inanimate object. He mainly used perceptual information for all descriptions and more information was given when describing living than nonliving items. Bilx 1 also used encyclopaedic information on average 0.72 times per item. He used mostly shared information when describing living items. Perceptually shared information was most commonly used with an average of 4 perceptually shared informations given per word. Information types in nonliving showed the same pattern as in living objects, but with fewer perceptually shared types. Perceptually shared information was here used on average 2.5 times per word (see Figure 5a-b).

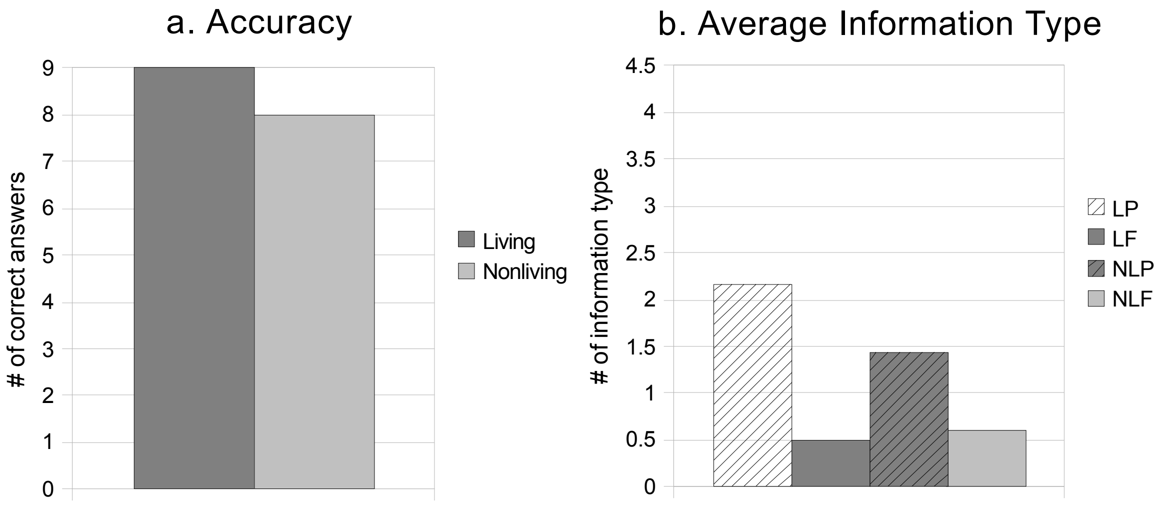

Figure 4. a: Total correct in Verbal Description for Bilx 1. b: Information types used on average for every item in Bilx 1's descriptions.

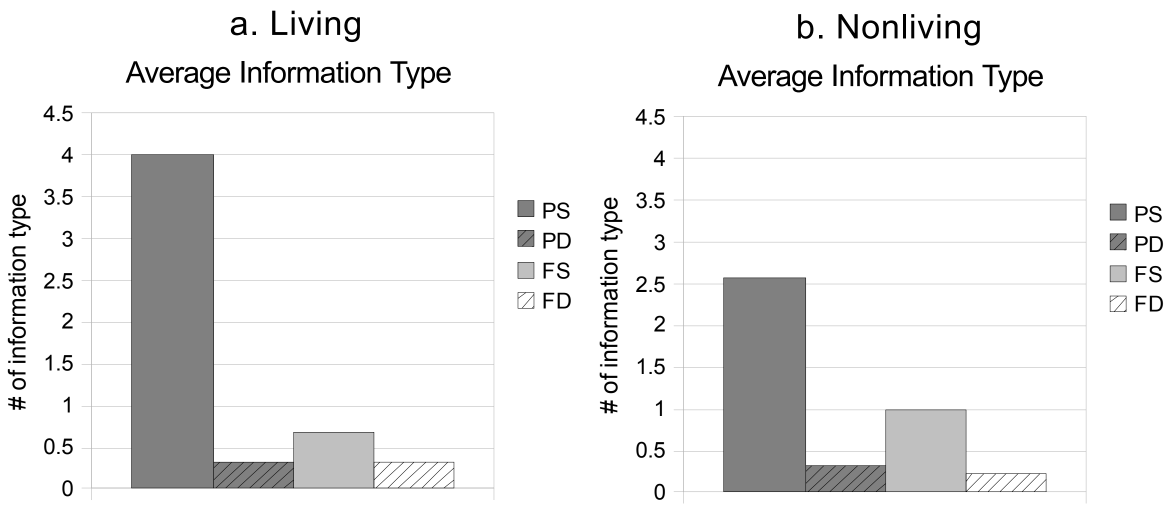

Figure 5. a: Average information types used by Bilx 1 for living objects. b: Average information types used for nonliving objects by Bilx 1.

Feature Verification

Bilx 1 made a total of 9 errors on the feature verification task. These errors, although fairly evenly distributed, again showed slightly better performance on living than nonliving tasks, scoring 117/120 on living and 114/120 on nonliving statements. However, all functional items were answered accurately, with the exception of nonliving functional distinct where Bilx 1 made 4 errors. The remaining 5 errors made were on living perceptual shared and distinct, as well as nonliving perceptual shared information types. This is in contrast to the idea of performance within the living and nonliving domains being in close relation to one's ability to process perceptual and functional stimuli respectively. In total, Bilx 1 answered 118 false and 113 true statements correctly. All living functional items were answered correctly. Regarding the nonliving functional items, shared information types were answered correctly more frequently. For both living- and nonliving perceptual statements, the distinct information types scored higher (see Figure 6a)

As shown in Figure 6b, Bilx 1 had very little differences in reaction time across the different domains. His average reaction time for living items (4150.25 ms) was slightly slower than for nonliving items (3982.77 ms). Across all categories he also responded quicker to the shared than the distinct statements. This was also the greatest difference observed between the different categories. The difference between his average reaction time for perceptual/functional information as well as true/false (4065.03 ms/4067.99 ms and 4069.7 ms/4063.3 ms, respectively) was close to inexistent.

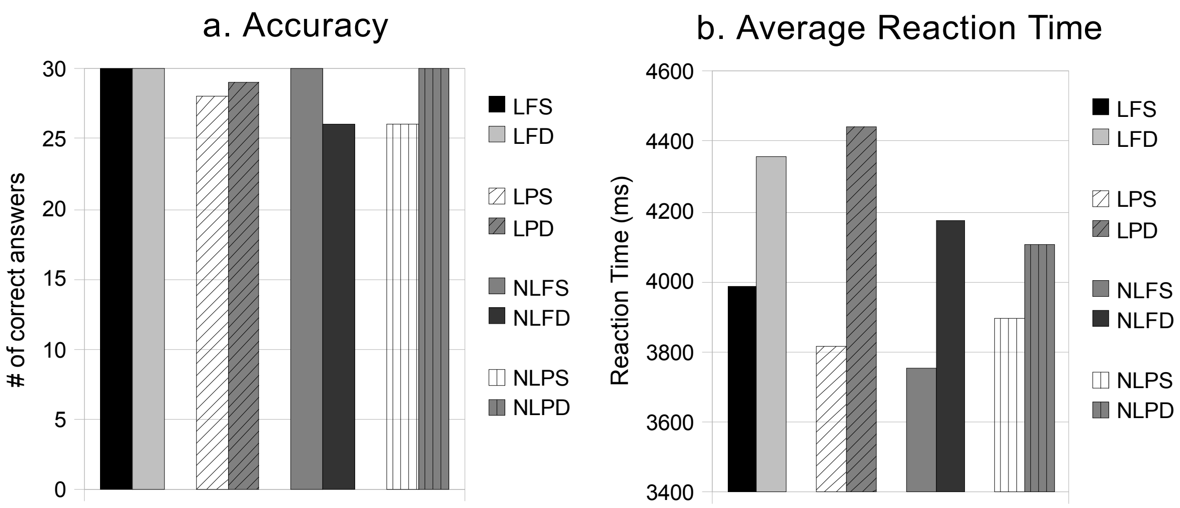

Figure 6. a: Total score on Feature Verification for Bilx 1. b: The average reaction time for items accurately answered on Feature Verification by Bilx 1.

Summary

All in all, Bilx 1 showed an even profile and scored higher for living items than nonliving in all tasks. The only exception was in the Word-picture Verification task, but as discussed above that error was due to a phonological foil and therefore cannot be attributed to its semantic category. Bilx 1 did perform slightly better on comprehension tasks targeting functional rather than perceptual words. However, there was no difference in reaction time or in the Naming-to-Definition task. In terms of language production, Bilx 1 did use more perceptual than functional information types in the Verbal Description task.

3.2 Bilx 2

Confrontation Naming
There were in total 2 errors made - both in the living domain with one being animate and the other inanimate.

Word-picture Verification
Bilx 2 made one error on the word-picture verification. He scored incorrectly on a living inanimate object due to a phonological foil and his error can thereby not be coded as domain specific.

Verbal Fluency
Bilx 2 could generally retrieve more words for living than nonliving objects in one minute. He mobilized twice as many living animate as living inanimate and nonliving animate words. The participant also performed significantly better on the category than the letter fluency task, as shown in Figure 7a-b.

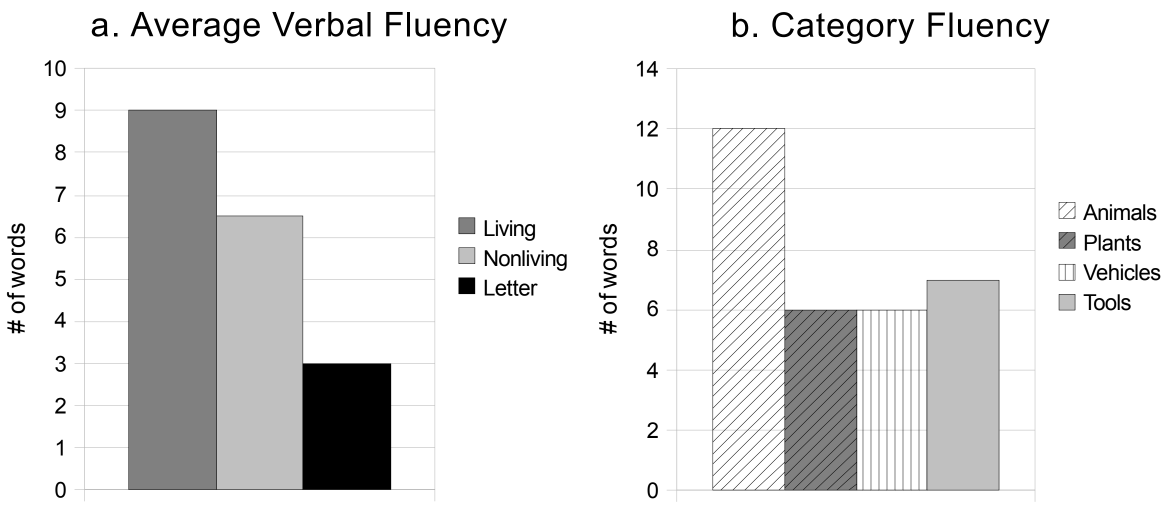

Figure 7. a: Bilx 2's average number of words retrieved in living categories, nonliving categories and letter fluency. b: Bilx 2's average number of words mobilized in Category Fluency.

Naming-to-Definition
Bilx 2 answered more definitions correctly within nonliving than living domains. He also answered more accurately to the definitions using functional information type, see Figure 8.

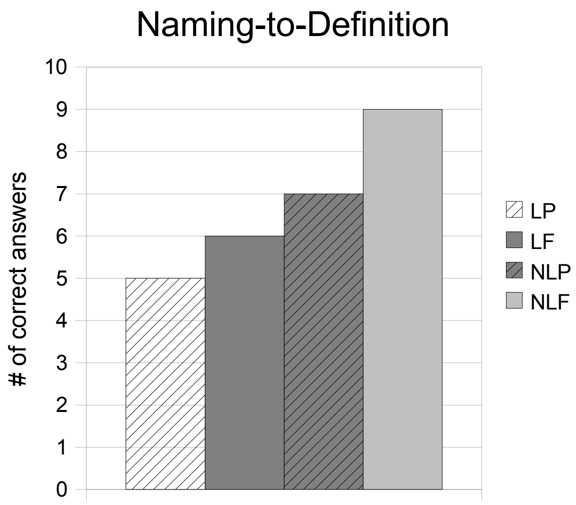

Figure 8. Bilx 2's result on Naming-to-Definition.

Verbal Description

All Bilx 2's verbal descriptions were scored as correct. The inter-rater reliability between the PI and one independent rater was 100 %. For living objects he used more functional than perceptual words, see Figure 9a-b. This relation was opposite to the nonliving objects, for which he had a clear preference to use perceptual information in order to describe the target words. On average, Bilx 2 used far more shared information than distinct both along perceptual and functional descriptions for living objects. The same also held true for nonliving words. Here were, however, the perceptually shared informations in far majority , see Figure 10a-b. Bilx 2 also used on average 1.83 encyclopaedic units of information per described word.

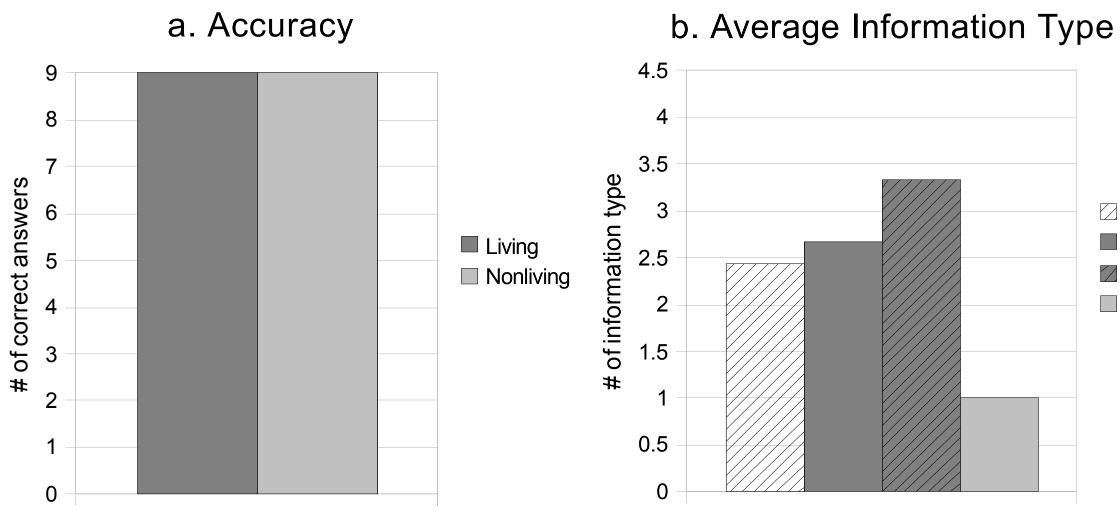

Figure 9. a: Total correct in Verbal Description for Bilx 2. b: Information types used on average for every item in Bilx 2's descriptions.

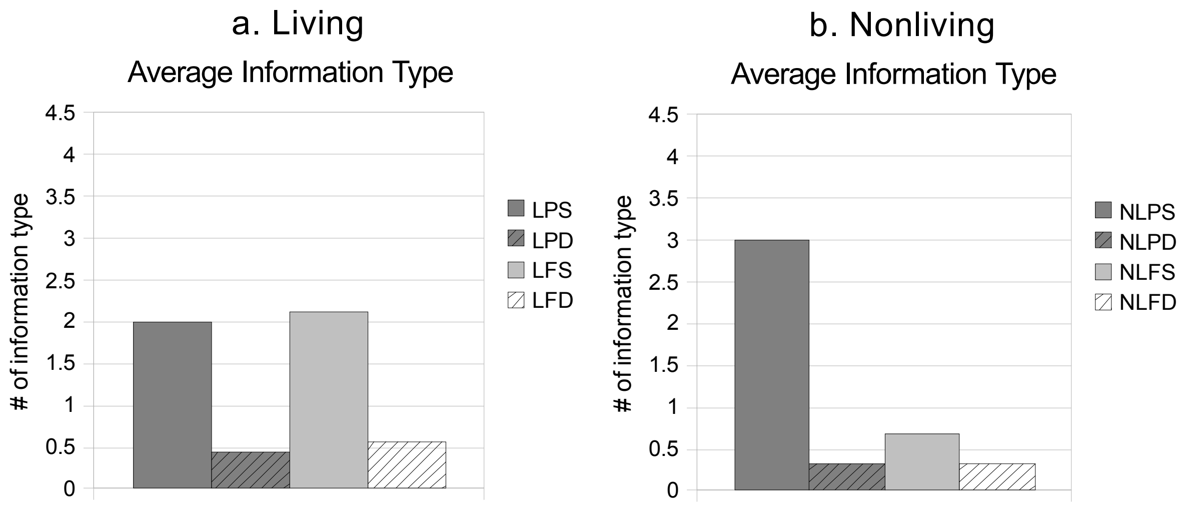

Figure 10. a: Average information types used by Bilx 2 for living objects. b: Average information types used for nonliving objects by Bilx 2.

Feature Verification

Bilx 2 had a fairly even profile across the different domains. Bilx 2 scored correct on all living statements with distinct functional and perceptual information and had two errors each in the living functional and perceptual shared information statements. Within the nonliving domain, Bilx 2 scored all correct with perceptually distinct information and made one error in each of the other three categories, see Figure 11a.

He did not have a substantial difference among the domains in terms of average reaction time. Bilx 2 was slightly slower at responding to living than nonliving (5262.72 ms/4980.03 ms) and false than true (5366.9 ms/4875.86 ms) statements. He was slower to answer perceptual than functional statements for both living and nonliving concepts. With the exception of the living functional statements, Bilx 2 had a longer reaction time for distinct than shared information types. One can see a pattern between accuracy and reaction time in all domains but the living and nonliving. Bilx 2 had a longer reaction time for those domains that he most frequently answered accurately (see Figure 11b)

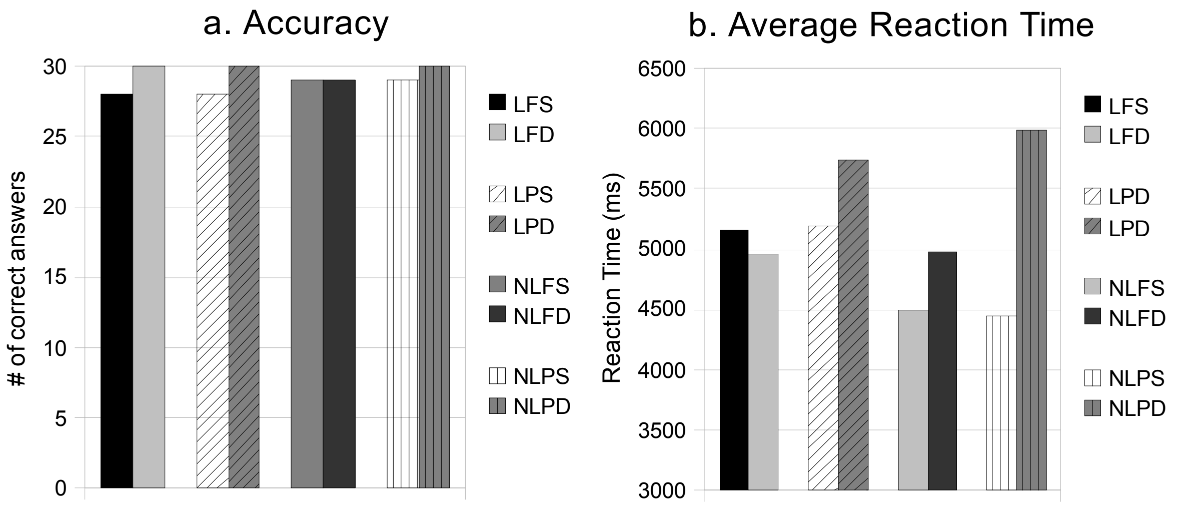

Figure 11. a: Total score on Feature Verification for Bilx 2. b: The average reaction time for items accurately answered on Feature Verification by Bilx 2.

Summary
Bilx 2 performed better within the nonliving than the living domain in all tasks but the Verbal Fluency. He also performed slightly better within the functional than the perceptual domain.

3.3. Bilx 3

Confrontation Naming
For the confrontation naming, Bilx 3 got 27/30 correct within the living and 30/30 within the nonliving domain. Two of the errors were animate living objects whereas the third error was an inanimate living object.

Word-picture Verification
As the other participants, Bilx 3 got one item incorrect on the Word-picture verification and this being due to a phonological foil on a living inanimate object. Again, since it was a phonological error, it can not be attributed to the semantic category of the item.

Verbal Fluency
Bilx 3 mobilized more living than nonliving items but showed no difference between animate and inanimate objects. The living domain being in majority is due to the living animate category “animals” priming significantly more words than do other categories. As shown in Figure 12a-b, this also influences the average number of words retrieved for category fluency being greater than that of letter fluency.

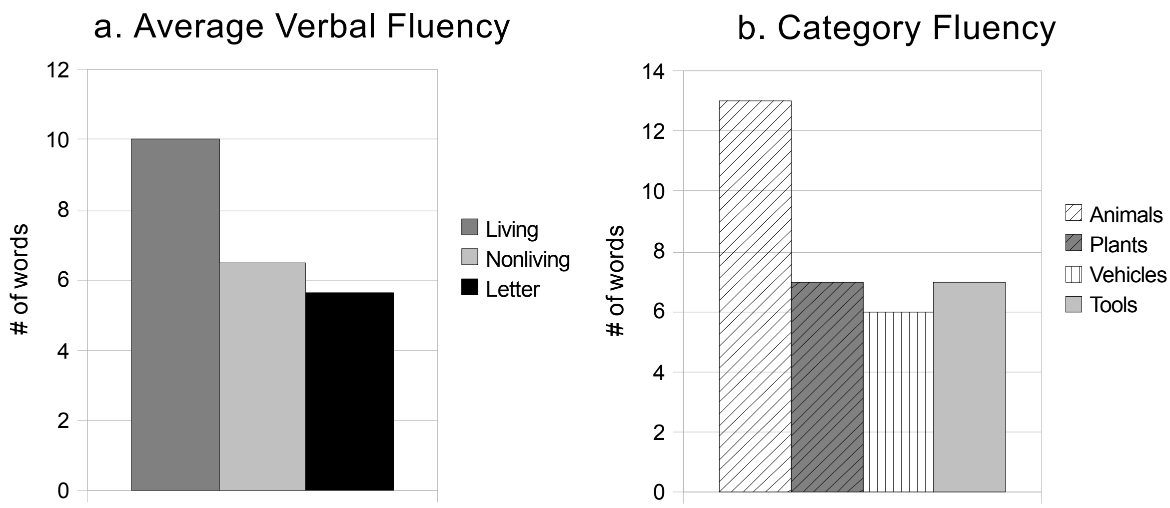

Figure 12. a: Bilx 3's average number of words retrieved in living categories, nonliving categories and letter fluency. b: Bilx 3's average number of words mobilized in Category Fluency.

Naming-to-Definition

Bilx 3 performed significantly better on the nonliving, especially the nonliving functional, statements than on the living. Across domains she performed better on functional than perceptual descriptions, see Figure 13.

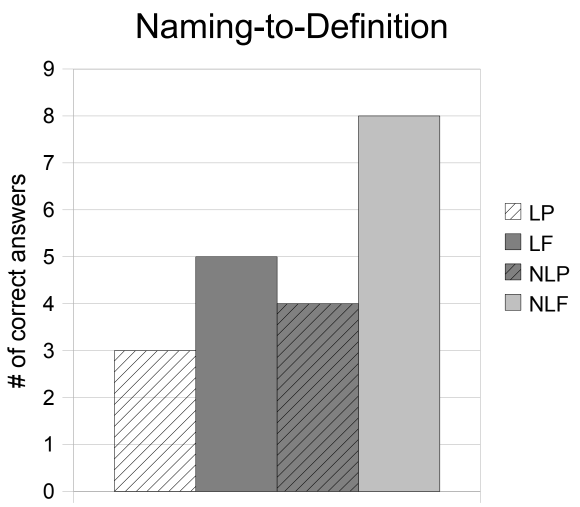

Figure 13. Bilx 3's result on Naming-to-Definition.

Verbal Description

One of the items on this task, a living animate object, was scored as incorrect (see Figure 14a). The inter-rater reliability between the PI and one independent rater was 94.44%. As shown in Figure 14b, the majority of given information was perceptual. Bilx 3 gave more information for describing nonliving than living objects. Shared features were used more than distinct, see Figure 15a-b. She also provided 1.89 units of encyclopaedic information in average per item.

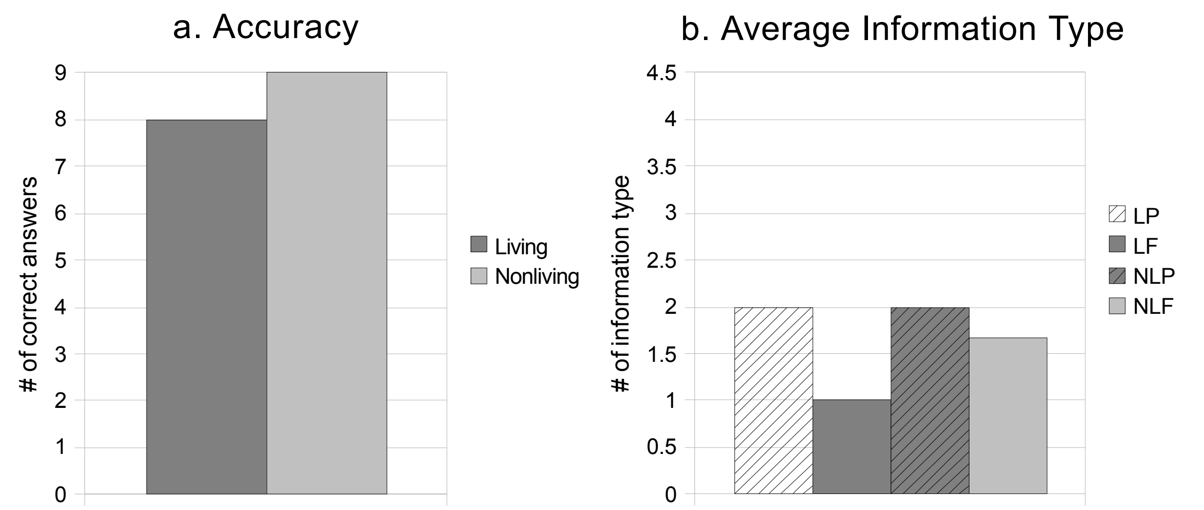

Figure 14. a: Total correct in Verbal Description for Bilx 3. b: Information types used on average for every item in Bilx 3's descriptions.

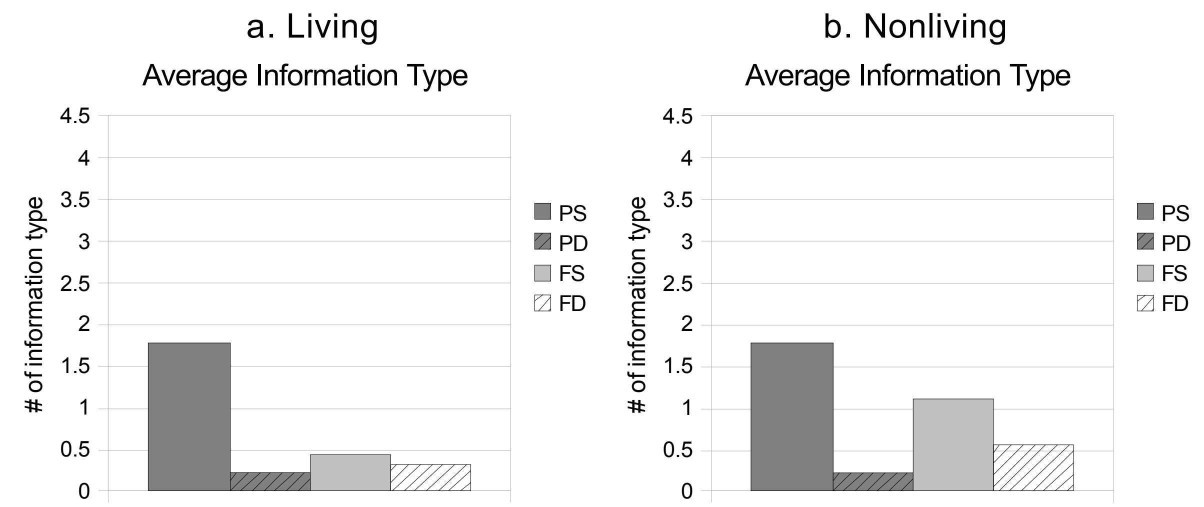

Figure 15. a: Average information types used by Bilx 3 for living objects. b: Average information types used for nonliving objects by Bilx 3.

Feature Verification

For the Feature Verification, she answered more correctly on the nonliving than the living items. She also scored slightly higher on function than perception and shared than distinct, although the difference consisted of only one item for those four categories. Bilx 3 made three errors each for both the living perceptual distinct and living functional shared categories, although getting maximum score on living functional distinct as well as living perceptual shared. All nonliving functional statements were answered accurately. Also, all the nonliving perceptual shared statements were answered correctly whereas one error was made in the nonliving perceptual distinct domain. All errors that were made were for true statements, see Figure 16a.

There was no correlation between accuracy and average reaction time. The reaction times were very similar for the categories living/nonliving (5084.13 ms/5020.34 ms). There was almost a second in difference between the faster reaction times for function (4588.54 ms) than perception (5515.92 ms) even though function statements were answered correctly more often. All shared information statements were answered faster than distinct information across all categories, as was functional information answered faster than perceptual. Average reaction time for true/false (5092.26 ms/5012.21 ms) was also next to identical, see Figure 16b.

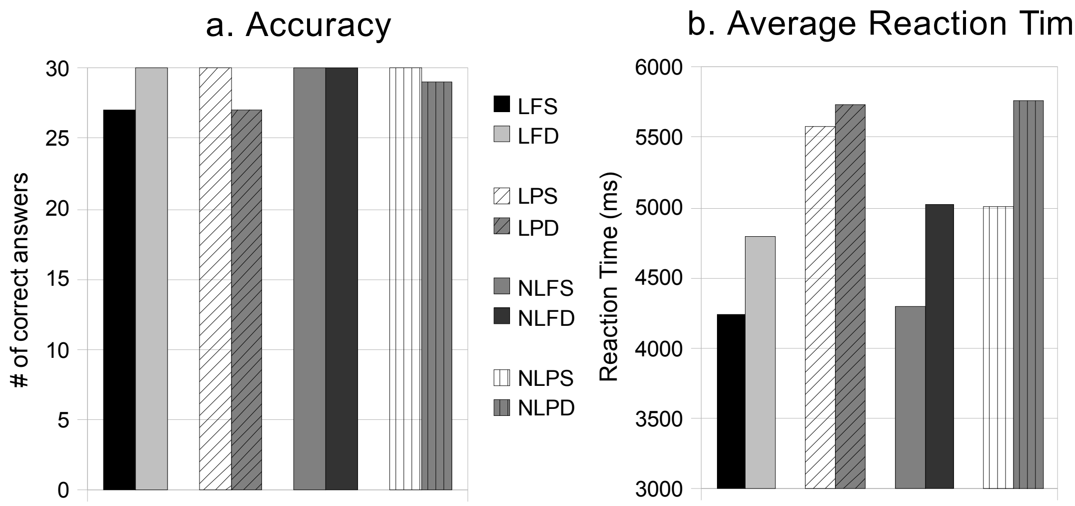

Figure 16. a: Total score on Feature Verification for Bilx 3. b: The average reaction time for items accurately answered on Feature Verification by Bilx 3.

Summary

Throughout the tasks, Bilx 3 scored higher within the nonliving domain than the living, again with the exception being the Verbal Fluency task. She also scored generally higher, and responded faster, to functional than perceptual information.

4. DISCUSSION

In the following, the results will be discussed in relation to the hypothesis that deficient processing of specific semantic feature cues will impact word retrieval differently for concepts whose meanings are weighted in favor of those features.

The hypothesis holds true in regards of Bilx 2 and Bilx 3. Both these participants had the more frequently occurring pattern of a more impaired ability to process both living objects and perceptual cues, whereas processing of nonliving and functional cues were less impaired. Bilx 1, on the other hand, had a more impaired ability in processing nonliving than living concepts. He did not show any pattern regarding his ability to process perceptual and functional cues. He did, however, have a less impaired ability to process animate than inanimate features, which are weighted in favor to living concepts.

The specific aim of determining the association between semantic feature cues and word retrieval for different types of object concepts to be investigated by testing proficient bilingual individuals with aphasia using a neuropsychological test battery, has been completed in terms of defining the associations. Additionally, it has provided a base for this study to be expanded into determining the extent to which semantic feature/concept processing is associated with lesion location in aphasia. Future MRI scans can also be lesion mapped in order for behavioral data to be related to the lesion location.

In this initial study investigating word retrieval deficits, three bilingual individuals with aphasia have been tested. The investigation, which consisted of standardized tests as well as experimental tasks created specifically to capture differences between semantic categories and feature cues, have given a first insight into the bilingual brain's category-specific semantic processing. To further our knowledge about the semantic processing in bilingual aphasia in future studies, a number of aspects may be addressed.

Regarding the stimuli for the verbal fluency task, having “animals” as the living animate category stimuli seems to favor the living domain across participants even though two of them have an impairment affecting the living domain more than the nonliving in other tasks. However, this task can prove to be more valuable when comparing brain damaged individuals with a control group. This is in accordance with findings by Antonucci et al. (2008), where both the participants with a brain damage as well as the neurologically intact controls performed better in the living category. This was explained by the fact that the living categories (animals and plants) are broader and therefore prime more words than the nonliving categories (vehicles and tools). Nonetheless, the relative difference between the controls' scores and the patients' scores on the living items showed to be relevant, as it was in relation to the results of other tasks such as the Confrontation Naming and the Naming-to-Definition.

In accordance with Hull and Vaid's (2007) results regarding hemisphere lateralization in relation to language proficiency, it was expected that all participants would have a left hemisphere dominance considering their early language exposure before six years of age. However, for processing in their L2 it is probable that the right hemisphere would be more activated than when processing their L1. This is done in order to take advantage of pragmatic cues, which are mediated by the right hemisphere, when one is less proficient in a language. With that said, Bilx 2 is likely to be more left hemisphere dominant than the other participants when speaking his L2, since Bilx 2 although considering English his first language, self-rates himself as fluent in his L2, which Bilx 1 and 3 do not.

Due to the three participants all being high-functioning individuals with aphasia, they scored high on the majority of the tests. As a result of the errors being few, all patterns and differences shown are subtle. Nonetheless, there are patterns within the subjects.

Bilx 1's ability to process items within the living domain was greater than within the nonliving. This correlates well with higher scores on animate items than inanimate. However, he did not show any difference in processing perceptual and functional information. Bilx 1 may have a more intact ability to process false statements rather than true ones, but the data was inconsistent and therefore a definite conclusion is not possible. Even though Bilx 1 turned out to be left handed pre-stroke as well as post-stroke, this does not seem to have affected his results on the reaction-time based task. However, in future studies, it would be desired to have all participants being right handed.

In general, Bilx 2 had a more intact processing of nonliving than living objects, which correlates with his ability to process functional information. He used function features more in his production and could also better comprehend these more than perception features. Shared features scored higher than distinct, however at the cost of reaction time. Furthermore, Bilx 2 had no difference between animate and inanimate items but the accuracy level on true/false was to some extent affected by the reaction time.

Just as Bilx 2, Bilx 3 had a more intact ability to name and process nonliving stimuli. She also scored higher on functional information types than perceptual information types. There were no consequent differences between the other categories such as animate versus inanimate or shared versus distinct.

This study has shown that theories regarding semantic-category processing in monolinguals seem to be applicable for bilingual speakers with a clear language dominance as well, when tested in their L1.

The continuation after this pilot study will be expanded to increase the number of bilingual participants, having bilinguals with different language backgrounds (including a more balanced proficiency between L1 and L2), testing in both L1 and L2, MRI scans for lesion mapping, and matched controls for age, education, and language history. It will then be possible to state with greater confidence whether there is a correlation between semantic-category specific deficits and lesion location.

5. ACKNOWLEDGMENTS

Foremost, I wish to express my sincere gratitude to my thesis advisor Dr. Sharon M. Antonucci, who has provided me with much assistance and encouragement. I am very glad for the opportunity to be part of Dr. Antonucci's lab and participate in her interesting research.

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