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## **Morpho-syntactic processing of Arabic plurals after aphasia: Dissecting lexical meaning from morpho-syntax within word boundaries**

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### **Abstract**

Within the domain of inflectional morpho-syntax, differential processing of regular and irregular forms has been found in healthy speakers and in aphasia. One view assumes that irregular forms are retrieved as full entities while regular forms are compiled on-line. An alternative view holds that a single mechanism oversees regular and irregular forms. Arabic offers an opportunity to study this phenomenon as Arabic nouns contain a consonantal root, delivering lexical meaning, and a vocalic pattern, delivering syntactic information, such as gender and number. The aim of this study is to investigate morpho-syntactic processing of regular (sound) and irregular (broken) Arabic plurals in patients with morpho-syntactic impairment. Three participants with acquired agrammatic aphasia produced plural forms in a picture naming task. We measured overall response accuracy, then analyzed lexical errors and morpho-syntactic errors, separately. Error analysis revealed different patterns of morpho-syntactic errors dependent on the type of pluralisation (sound vs broken). Omissions formed the vast majority of errors in sound plurals, while substitution was the only error mechanism that occurred in broken plurals. The dissociation was statistically significant for retrieval of morpho-syntactic information (vocalic pattern) but not for lexical meaning (consonantal root), suggesting that the participants' selective impairment was an effect of the morpho-syntax of plurals. These results suggest that irregular plurals forms are stored while regular forms are derived. The current findings support the findings from other languages, and provide a new analysis technique for data from languages with non-concatenative morpho-syntax.

**Key word forms: Aphasia, agrammatism, inflection, morphology, syntax, morpho-syntax, Arabic, regular, irregular, lexical retrieval, plural, dual, sound, broken, non-concatenative, language processing**

### **1. Background**

Regular and irregular forms are morpho-syntactic structures that belong to the same grammatical category but differ in terms of their formation processes. While regular forms follow one canonical rule in their construction, irregular forms are idiosyncratic. This

phenomenon can be found in both nouns and verbs. For example, English regular verb tenses inflect via suffixation (talk; talked), while most irregular forms are formed by changing the vocalic pattern of the verb (sing; sung) or no change (put; put). English also has more complex forms such as 'teach, taught' and 'bring, brought' (Bybee and Slobin, 1982).

This phenomenon has been of interest to researchers within the domains of inflectional morpho-syntax, and its breakdown. In languages other than Arabic, people with aphasia have been found to show single and double dissociations between regular and irregular forms in word form production (e.g. Bird, Lambon Ralph, Seidenberg, McClelland and Patterson, 2003; Braber, Patterson, Ellis and Lambon Ralph, 2005; Lambon Ralph, Braber, McClelland and Patterson, 2005; Miozzo, 2003; Patterson, Lambon Ralph, Hodges and McClelland, 2001; Penke, Janssen and Krause, 1999; Ullman et al., 1997). Numerous theories have been proposed to account for this pattern of performance (e.g. Pinker and Ullman, 2002; Joanisse and Seidenberg, 1999; Rumelhart and McClelland, 1986; Sereno and Jongman, 1997; Ullman et al., 1997). Theories proposed to account for regular and irregular inflectional processing can be classified into two major frameworks i.e. the dual (e.g. Pinker and Ullman, 2002; Ullman et al., 1997) and single mechanism accounts (e.g. Joanisse and Seidenberg, 1999; Rumelhart and McClelland, 1986; Sereno and Jongman, 1997). The current study does not aim to test all existing models/theories, but focuses on the general principles of two views on regular and irregular processing (Joanisse and Seidenberg, 1999; and Ullman et al., 1997).

### **1.1 The dual mechanism account**

The dual mechanism account has been defined as “a family of psycholinguistic models which hold that morphologically complex word forms can be processed through stored full-form representations and by rules that decompose or parse inflected or derived word forms into morphological constituents” (Clahsen, 2006; p. 2). It also postulates that word forms can be processed associatively (stored) and through rule-based (computed) mechanisms (Clahsen, 1999; 2006; Pinker, 1999; Pinker and Ullman, 2002).

Dual mechanism advocates agree on the presence of these two routes. However, there is disagreement concerning the types of word forms processed within each route. Chialant and Caramazza (1995) suggest that high frequency word forms are processed via the stored full-form route, while the rule-based route (online computation) is responsible for production of novel or low frequency word forms. Chialant and Caramazza's (1995) proposal does not differentiate between word forms based on their morphological features, but merely on their psycholinguistic features e.g. frequency of occurrence. Caramazza et al., (1995)'s AAM theory suggests that whole word form representations may be available for all word forms regardless of frequency. More recently, Cholin, Rapp and Miozzo (2010) propose the stem-based assembly model (SAM), suggesting that affixation processes apply more broadly, without limitation to the productive or default affixes. In their proposal, they maintain that combinatorial affixation is available to all stems, and that the lexicon contains an entry for each word form that includes the basic stem.

An alternative view differentiates between processing routes on the basis of word form morphology (Pinker, 1999; Pinker & Ullman, 2002; Ullman, 2001; Ullman et al., 1997). This view maintains that regular inflection is the predictable form, which can be applied to novel word forms and invokes a combinatory rule (e.g. English past tense regular form rule: stem + -ed; e.g. print-ed). Conversely, irregular inflections are stored forms that cannot be predicted by the form of the stem, and cannot be applied to novel word forms (e.g. meet; met). This view assumes that the dual model uses an associative system which depends on declarative memory. It also includes a combinatorial system that depends on rules to formulate multi-morphemic word forms. It maintains that the lexicon is a subdivision of memory and that irregular forms are stored in memory. However, grammar is a productive and combinatorial system that carries out operations that assemble morphemes into word forms. The associative system generalizes on the basis of resemblance to stored examples, while the combinatorial system suppresses differences between items, and treats members of a morpho-syntactic category equally. According to this model, word forms with regular inflection are composed using the combinatorial system in which relevant affixes are combined with stems in line with pre-defined rules forming a given morphological unit from its basic components (morphemes). Word forms with irregular morpho-syntax are retrieved from declarative memory. Full-form representations for morphologically complex word forms are also retrieved from declarative memory.

### **1.2 The single mechanism account**

The single mechanism account maintains that one mechanism governs production of both regular and irregular forms (Bird et al., 2003; Braber et al., 2005; Bybee, 1995; Joanisse and Seidenberg, 1999; Juola and Plunkett, 2000; Lambon Ralph et al., 2005; Marchman, 1993; Patterson et al., 2001; Rumelhart and McClelland, 1986; Stockall, & Marantz, 2006; Yang, 2000). While there are a number of different views within this family of models, our focus will be on Joanisse and Seidenberg (1999) who proposed a connectionist account based on computerized simulations of regular and irregular processing. This view is based on the Parallel Distributed Processing (PDP) model (Rumelhart and McClelland, 1986). The connectionist perspective maintains that both forms are computed by a single mechanism, which is not rule-based as this is not necessary for formulation of regular forms. Instead, the processing of regular and irregular forms is governed by two types of lexical information i.e. semantic and phonological. According to Joanisse and Seidenberg (1999), an impairment in production of regular forms results from a phonological deficit but a deficit in irregular forms results from a semantic deficit. They assume that semantic knowledge has an impact on irregular word forms. They stipulate that the semantic system retrieves specific idiosyncratic forms of verbs. For example generating the past tense of the English verb 'take' is an idiosyncratic property of this verb which requires specifically identifying 'took' as its past tense. Damage to the semantic representation of this verb will necessarily result in deficient production of its past tense 'took'. Therefore phonologically similar word forms such as 'fake; faked' can be used as analogies which will result in production of errors such as 'take, \*tak-ed'. Phonology has an impact on regular and novel word forms. It applies analogies to word forms which undergo similar phonological processes

(such as adding the English past tense verb suffix -ed). For example, a novel word form such as 'yug' has no meaning (thus no semantic reference) but its past tense can be generated using a phonological analogy. A deficit in phonology affects such processes.

Advocates of this account maintain that it is not necessary to propose differential processing of regular and irregular forms even though double dissociations between regular and irregular have been reported (e.g. Miozzo, 2003; Ullman et al., 1997). They maintain that dissociations could be a result of phonological similarities and differences rather than morphological features. They argue that the two types of inflectional morpho-syntax i.e. regular and irregular, are not categorically different; they have a common structure in two respects. Firstly, there are systematic phonological similarities between, for example, regular and irregular English verbs. Both present and past tense verbs like 'take; took' maintain the onset and coda. Second, there are similarities in patterns of the irregular past tense forms 'slept' /slɛpt/ and 'crept' /krɛpt/. These are similar to the regular past tense forms of verbs like 'stepped' /stɛpt/ and 'cropped' /krɒpt/ (Bird et al., 2003). It is argued that the English regular past tense verbs have similar phonological endings while irregulars do not. Therefore, a phonological effect could result in dropping the -ed in regular past tense suggesting that dissociation between regular and irregular is present.

Various studies have investigated different aspects of the dual and single mechanism frameworks (English: Braber, Patterson, Ellis and Lambon Ralph, 2005; Lambon Ralph, Braber, McClelland and Patterson, 2005; Miozzo, 2003; Patterson et al., 2001; German: Penke, Janssen and Krause, 1999; Hebrew: Berent, Pinker and Shimron, 1999; Italian: Walenski, Katiuscia, Cappa and Ullman, 2009; Spanish and Catalan: Rodriguez-Fornells, Munte, and Clahsen 2002). Support for both theoretical frameworks has been found. While findings from these studies have confirmed certain aspects of a given model, they were inconsistent with other assumptions of the same model. For example, deficient irregular inflections in agrammatic aphasia (reported in De Deigo Bulaguer et al. 2004) indicated that the dual mechanism approach does not account for all patterns of performance. Moreover, irregular impairment in the presence of phonological deficit and absence of semantic deficit in, for example, AW (Miozzo, 2003) is problematic for Joanisse and Seidenberg's (1999) single mechanism model.

Spanish and Catalan have regular and irregular verb forms. Furthermore, some regular verbs in Spanish are irregular in Catalan and vice versa. De Deigo Bulaguer, Costa, Sebastian-Galles, Juncadella and Caramazza (2004) investigated the processing of regular and irregular verb forms in JM and MP (bilingual speakers of Spanish and Catalan) through a morphological transformation task in which the participants were asked to provide appropriate verb forms in sentence frames (e.g. 'Ayer yo comía, Hoy yo \_\_\_\_': yesterday I ate, today I \_\_\_\_). Both JM and MP had Broca's aphasia with agrammatism following cerebrovascular accident. According to the dual mechanism account, agrammatic participants should process irregulars more successfully than regular (Pinker and Ullman, 2002; Ullman et al., 1997). The dual mechanism account assumes that the breakdown of regular forms is due to impaired rule-based processes linked to a general syntactic processing impairment underlying agrammatism. De Deigo Bulaguer et al.

(2004) reported that both JM and MP showed poorer performance of irregular than regular forms in both Spanish and Catalan. This finding is contradictory to the prediction of the dual mechanism and is consistent with results reported in the literature (e.g. MR: Laiacina and Caramazza, 2004; Penke et al., 1999; RC: Shapiro and Caramazza, 2003). De Deigo Bulaguer et al. (2004) conclude that certain aspects of the dual mechanism account need to be reconsidered and revised, such as the claim that agrammatic participants process irregular forms better than regular ones.

Regular and irregular forms are present in the Italian verb system i.e. past-participle and present-tense. Studies have examined the production of these two verb aspects in brain-damaged participants (Say and Clahsen, 2002; Walenski, Katiusia, Cappa and Ullman, 2009). Walenski et al. (2009) explored regular and irregular production in Italian verb tenses (past participle and present tense) in 12 participants with Alzheimer's Disease. Participants were asked to read sentences aloud filling in the appropriate form of the verb. All the participants showed impaired irregular production, while the production of regular forms was spared. These findings replicate findings from studies in English (Miozzo, 2003; Pinker and Ullman, 2002; Ullman et al., 1997). Walenski et al. (2009) interpreted their findings within the dual mechanism account.

Only one study investigated regular and irregular forms in Arabic after aphasia (Mimouni et al., 1998). However, the authors used a theoretical linguistic approach (prosodic nonconcatenative morphology developed by McCarthy (1975)) rather than models of processing to account for their data. In their study on Algerian Arabic, Mimouni et al. (1998) investigated the process of word form recognition of singular and plural nouns in 24 healthy speakers and two participants with aphasia. The aim was to examine the lexical representation of plurals in Algerian Arabic. They used an auditory lexical decision task within a morphological priming paradigm. They presented participants with different sets of word forms in their singular and plural forms. The stimuli were selected according to plural type (sound vs. broken) and length. Frequency values for Arabic are not readily available; therefore they asked healthy participants to rate the frequency of their stimuli prior to conducting the experiment. They did not control for any other psycholinguistic factors. Mimouni et al. (1998) found that broken plurals were produced faster than sound plurals in healthy speakers and participants with aphasia. This was the case for singular forms of different types of plurals i.e. singulars of broken plurals were responded to faster than singulars of sound plurals. They claimed that Arabic plural forms have differential processing routes: broken plurals are accessed as whole word forms, but sound plurals are decomposed into word form + suffix.

## **2. The current study**

The failure for any model to account for all the data, and the fact that most of investigations have been done on English and other Indo-European warrant further investigation in Arabic

which is of different morpho-syntax. Arabic offers the opportunity to study the phenomenon in question due to its morpho-syntactic features. According to McCarthy, (1975; 1981) and Prunet et al. (2000), Arabic word forms are composed of two morphemes: a consonantal root (delivering lexical meaning) and a vocalic pattern (delivering syntactic information, i.e. gender and number). This feature could enable morphological detachment of the root and pattern, hence separating lexical meaning from syntactic information at word form level.

This study investigates morpho-syntactic processing of regular and irregular inflected formations of Arabic plurals through qualitative and quantitative analysis, in which vocalic patterns are isolated from consonantal roots. To the best of the researchers' knowledge, it is the first investigation of regular and irregular processing that attempts to detach lexical meaning from morpho-syntactic information at a surface level, using a data analysis method developed for non-concatenative morphology.

The primary aim of the study is to test whether Arabic sound and broken plurals are processed differentially, or equally. Furthermore, the study has two secondary aims; whether Arabic data fulfills the assumption of linking agrammatism to regular inflection impairment, and whether the proposed models (Joanisse and Seidenberg, 1999; Ullman et al., 1997) withstand language specific features generated by Arabic data.

The dialect in question in the current study is urban Jordanian Arabic (hereafter, Arabic) which is a sub variety of Levantine Arabic. Arabic has two plural types. Duals refer to two items only. Plurals that refer to three or more items are divided into sound and broken plurals. Duals and sound plurals are formed through

-inflected suffixation of the singular form of a given noun, and are deemed the regular form. Broken plurals are formed through changing the vocalic pattern of the noun, and are deemed the irregular form. Examples 1 and 2 present feminine duals and masculine duals, respectively.

(1) /wəɾəg-tein/ [FEMININE DUAL NOUN] 'two papers'

(2) /gələm-ein/ [MASCULINE DUAL NOUN] 'two pens'

Sound plurals are largely confined to nouns that indicate profession and habit. Nouns such as 'engineer', 'teacher' and 'liar' are pluralised in this way. Examples of sound plurals are provided in (3) and (4), below.

(3) /mɔɖɑɾis/ [MASCULINE SINGULAR NOUN] 'instructor'; / mɔɖɑɾis-i:n/ [MASCULINE PLURAL NOUN] 'instructors'

(4) /mɔhəndis/ [MASCULINE SINGULAR NOUN] 'engineer'; /mɔhəndis-ɔn/ [MASCULINE PLURAL NOUN] 'engineers'

Broken plurals are formed by stem change in the vocalic pattern of the noun. This process is dependent on two morphological phenomena: the vocalic patterns of broken plurals and the consonantal roots. Lexical items of Arabic origin consist of a consonantal root which is a string of consonants. Most roots in Arabic are made up of three consonants which are referred to as trilateral roots or consonantal roots (Zabbal, 2002; Prunet, 2006). A root can be notated as C1 C2 C3. Roots are combined with vowels that embed themselves between root consonants to form a lexical item. The meaning of a given lexical item can be changed by changing the vowel pattern within the word form. For example, the word form /kətəbə/ meaning 'he wrote' is derived from the consonantal root /ktb/ which is the trilateral root for word forms derived from these three consonants. The same trilateral root /ktb/ is used with a change of vowels for the word form /kitəbə/ meaning 'writing'. Previous literature (Soudi et al., 2002; Zabbal, 2002; Prunet, 2006) has stated that broken plurals are formed in a three stage process. For the sake of describing this process, the singular noun /rəðʒəl/ 'man' will be used as an example through the three stages of broken pluralisation process. Stage one: the root from the underlying singular noun is selected. Stage two: the broken plural pattern i.e. vocalic pattern is selected. Stage three: the selected root is merged with the selected vocalic pattern to form the broken plural of the singular noun /rəðʒəl/ 'man', to become /rɪðʒɑ:l/ 'men'.

### **3. Methods**

#### **3.1 Participants**

Participants were recruited from two hospitals in two major cities in Jordan. They were first contacted through their speech and language therapists, then they received an information sheet about the project. Prior to entering the study they signed a consent form. A confidentiality form was signed by the researcher. Recruitment and participation procedures were approved within the research ethics processes of both hospitals and the University of Sheffield, UK.

Participants were literate native speakers of urban Jordanian Arabic, over the age of 18 years and right handed, and had normal development of speech and language prior to their injury. Their aphasia was a result of a single left cerebrovascular accident (CVA), at least six months prior to their involvement in this study. They presented with anomia, and no dysarthria or apraxia of speech, and no homonymous hemianopia. They had adequate auditory and visual comprehension to enable them follow test instructions, and normal or adjusted to normal vision and hearing. They did not show signs of other significant neurological or psychiatric disorders. Since the focus of our investigation is on a morpho-syntax, all participants had varying degrees of agrammatism and word form finding difficulties.

Three participants (P1, P2 and P3) with aphasia were recruited to the study, two females and one male. Background information including initial diagnosis and medical history were provided by participants' speech and language therapists and neurologists. Table 1 summarises their profiles.

**Table 1: about here**

### **3.2 Materials and experimental procedure**

Two sets of materials were used to collect data. The first set consisted of a number of aphasia assessment subtests, the aim of which was to establish a profile of each participant's aphasia and identify the functional locus/loci of the anomia. The second was an Arabic naming test aimed at assessing the production of regular and irregular plurals in Arabic. The researcher administered all assessments.

Participants were assessed individually in speech and language therapy clinic rooms. Prior to each subtest, participants were informed about the subtest procedure. All instructions were presented in spoken and written Arabic. Participants were also presented with practice items prior to each subtest in order to ensure that they understood what was required of them. If a participant did not understand what was required, further instructions and practice items were given. Participants were informed that they could ask for a break or end their participation at any time.

#### **3.2.1 Aphasia assessment subtests and neuropsychological profiles**

The selection of these tests was constrained by the materials available for assessment in Jordanian Arabic in clinics in Jordan at the time of assessment. These subtests were taken from two sources: translated subtests of the Comprehensive Aphasia Test (CAT) (Swinburn, Porter & Howard, 2004) and subtests that have been developed in speech and language clinics in Jordan. The CAT subtests had been translated by clinicians and were in use in Jordan. They were modified to suit local cultural and linguistic criteria. In addition, a connected speech sample was recorded from each participant. The sample served as a measure of lexical retrieval and grammatical construction in connected speech. Transcription, coding and analysis of the output was conducted in line with recommendations suggested by Herbert, Best, Hickin, Howard and Osborne (2008; p. 200-202).

The assessment results in tables 2 and 3 show the neuropsychological profiles for participants. All three participants had anomia and agrammatism.

**Table 2: about here**

Table 3: about here

### P1's neuropsychological profile

P1 is a right-handed female who is a native speaker of Jordanian Arabic and literate, she also speaks English as a second language. She was 22 years old at the time of the study. She was educated in Arabic at school. Prior to her injury, P1 was a final-year undergraduate student of information technology. She suffered a single left cerebrovascular accident (CVA) 12 months prior to her participation in this study, as a complication of surgery for resection of a carotid body tumour. Her most recent computerized tomography (CT) scan, conducted four months post-onset, showed a large area of low attenuation involving left anterior and middle cerebral artery territories. In addition, P1's CVA resulted in encephalomalacia involving the above arterial distributions. This encephalomalacia was the result of the CVA and was not degenerative, as reported by her neurologist. Her speech and language therapist described a right-sided hemiplegia and Broca's aphasia.

P1's picture naming was outside the normal range. Her semantic errors included one semantic-coordinate (/sɪkɪnə/ 'knife' → /məlʃəqə/ 'spoon'), two semantic-associate (e.g. /sɪgərə/ 'cigarette' → /dʊxɑ:n/ 'smoke') and one semantic-visual (/dʒrəbə/ 'sock' → /rɪdʒl/ 'foot'). All phonological errors were phonological-related non-word forms (e.g. /ʔnənɑ:s/ 'pineapple' → /ʔnɑ:s/ 'non-word form'). P1's lexical retrieval in the middle 5 minutes of the conversation was analyzed in line with guidelines from Herbert et al. (2008). A sample of this interview is presented in extract 2.

#### Extract 2: A sample of P1's conversation with the researcher (TK)

TK: /ʒɪf btʒɪməlɪ ləmə btrɔ:hi əl beɪt/?

'What do you do when get back home?'

P1: /ʒr (13.8) əʃæɡ (2.5) əʃrəb (3.0) kɔljə (6.4) ah/

[er - phonological paraphasia - simple present verb - feminine singular noun - ah]

'er (13.8) [phonological paraphasia] (2.5) drink (3.0) college (6.4) ah'

TK: /ʃʊ kəmə:n/?

'what else?'

P1: /əʃhɑ:b(4.3) jəʃnɪ/

[masculine broken plural noun - first person pronoun - simple present verb]

'friends (4.3) I mean'

**TK:** /ʒɪf bɪtʒɪmælʊ mɑː bəʃð/?

'what do you do together'

**P1:** /məjə (5.2) əfrəb (2.8) ənæ məjə (3.7) kɔːl əfrəb (3.5)/

[noun - simple present verb - first person pronoun - noun - expletive speech filler - simple present verb]

'water (5.2) drink (2.8) I water (3.7) everything drink (3.5)

P1's expressive language was non-fluent and effortful. She could correctly produce single word forms with pauses in between. P1 did not produce well-formed syntactic structures. Phrases were not grammatical as they lacked agreement. Her language did not include subject-verb-object sentences and complex sentences. She produced a total of 24 single items (17 content word forms and 7 paraphasias). Content word forms included 9 (53%) nouns, 4 (23%) verbs, 3 (18%) adjectives and 1 (6%) adverb. Her errors included 6 (86%) phonological paraphasias and a circumlocution (14%). There was an abundance of nouns with respect to verbs. All the verbs that P1 produced were in the simple present tense and inflected for the first person only. Function word forms were limited to the first person pronoun /ənæ/ 'I' and the quantifier /kɔːl/ 'every'. These features indicate that P1 had agrammatic production (Basso, 2003; Caramazza and Berndt, 1985; Saffran, Berndt and Schwartz, 1989).

Numbers of speech units (verbal and non-verbal vocal utterances), turns (including substantive and minimal turns), content word forms (excluding paraphasias), nouns and errors were measured in the middle five minutes of the sample. The majority of her turns (72%) were lexically empty i.e. minimal turns. Only 28% were substantive turns i.e. included content word forms. Long pauses preceded lexical items. The predominant error type in P1's conversation was phonological. All her phonological errors were phonological-related non-word form errors (e.g. /tɪlɪfʊːn/ 'telephone' → /lɪfʊːn/ 'non-word form'). Her only semantic error was a circumlocution. This performance indicated that lexical retrieval difficulties were present in P1's conversation.

Lexical retrieval difficulties were present in P1's picture naming and conversation. Presence of semantic errors, failures to respond in picture naming and semantic circumlocution in conversation indicates a possible semantic deficit, or damage to the route connecting semantics and phonological output lexicon (Caramazza and Hillis, 1990; Whitworth et al., 2005). P1 may have produced other semantic errors in conversation that could not have been noticed by the researcher as it is difficult to identify target word forms in a conversation. The presence of phonological related non-word form errors in picture naming and conversation indicates damage to phonological output lexicon or processes within phonological assembly (Whitworth et al., 2005).

P1's scores on the auditory minimal pairs discrimination and auditory lexical decision tasks indicate impairment to the auditory input system. Her performance on the visual lexical decision task suggests that visual orthographic analysis was intact.

P1's score in spoken word form to picture matching was within the normal range, which shows that semantic processing from spoken input was intact for this set of items. Her good spoken word form comprehension was accompanied by deficits in the auditory phonological analysis and the phonological input lexicon. This contrast can be interpreted as a result of top down processing from semantics in tasks involving pictures (Humphreys, Riddoch and Price, 1997), which supports the weak or distorted auditory message.

P1's performance in written word form to picture matching is just outside the normal range which implies that semantic processing from visual input is affected. This was accompanied by good visual lexical decision which indicates that the source of her errors on this task may not be attributed to deficient orthographic input lexicon. Her spoken word form to picture matching was within normal range which indicates that semantic processing is intact. This contrast suggests that P1's errors on the written word form comprehension resulted from impaired access to intact semantics from intact orthographic input lexicon. Her errors in written word form to picture matching were two selections of a semantic distracter, and one selection of an unrelated distracter. Semantic distracter selection can result from the degree of visual similarity between the semantic distracter and the target item. For example, she selected a picture of 'shoes' instead of the target picture 'boots'. Cole-Virtue and Nickels (2004) maintain that semantic distracters in spoken/written word forms to picture matching tasks share visual properties with the target items which could lead to confusion.

P1's semantic processing was intact, for this set of concrete items. The difficulties in lexical comprehension tasks occurred at levels prior to semantic system. These difficulties may be due to input processing rather than a central semantic deficit. This suggests that her lexical retrieval difficulties did not arise at semantic level. Her semantic errors in picture naming were a result of damage to the route connecting semantics and phonological output lexicon (Caramazza and Hillis, 1990).

In reading aloud of word forms, P1's score was outside the normal range; correct = 17%; Phonological errors=8%; Perseveration=8%; Unrelated response=13%; No response=54%. Her phonological errors resulted in non-word forms (e.g. /mɒstɒffə/ 'hopsital' → /mɒffə/ 'non-word form'). P1's failures to respond in reading aloud can be a result of damage to the route connecting semantics and phonological output lexicon. If reading bypasses semantics, failures to respond can result from difficulties in accessing phonological output lexicon from orthographic input lexicon. Her perseverative errors may result from difficulty in activating the target response and therefore retrieve a more available item (see Plaut and Shallice (1993) for a connectionist view on perseverations).

In repetition of word forms, P1's score was outside the normal range. Her errors were all phonological-related non-word forms (e.g. /mɪfɪtæh/ 'key' → /ɪtæh/ 'non-word form'). Her performance in this task may have been affected by her impaired auditory input processes and phonological assembly. This performance is better than her performance in picture naming and reading aloud. This contrast suggests that the process of repeating word forms was supported by direct lexical processing from phonological input lexicon to phonological output lexicon bypassing semantic processing, and by sub-lexical processes simultaneously.

Reading non-word forms is completely impaired as P1 failed to read the presented items. This indicates damage to the orthographic-to-phonological-conversion sub-lexical route. In repetition of non-word forms, her score was outside the normal range. The only non-word form that P1 could repeat was monosyllable (/θi:b/ 'CVC'). This indicates damage to the phonological-input-to-output-conversion sub-lexical route. P1's digit and phoneme spans were reduced to 2 digits and 2 phonemes which is below the norm (mean = 6.4, range = 5-7). This suggests that an auditory short-term memory difficulty was present. Damage to phonological assembly contributed to her inability to read and repeat non-word forms as it is reliant on maintaining the set of phonemes in the short-term memory without lexical support.

P1's phonological errors in all spoken output tasks and conversation indicate damage to processes within phonological output lexicon or within phonological assembly. However, all spoken output tasks were affected. All her phonological errors in picture naming, reading aloud and repetition involved target word forms of three or more syllables which suggests damage to phonological assembly (Butterworth, 1992). Furthermore, her non-word form processing was worse than word form processing as evident from her scores on reading and repetition tasks. Her overall pattern of performance suggests that her phonological errors arise at phonological assembly level rather than phonological output lexicon.

P1's comprehension of syntactic structures in the conversational speech sample was relatively well preserved as she could understand the questions addressed to her. However, her scores in spoken and written sentence to picture matching showed otherwise. Her scores on both spoken and written versions of this subtest were outside the norms. In spoken sentence comprehension, her errors included 3 subject-verb-object reversible sentences, 2 sentences with embedded structures and 3 reversible sentences with locative prepositional phrases. In written sentence comprehension, her errors were of 3 subject-verb-object reversible sentences, 1 sentence with passive construction and 2 reversible sentences with locative prepositional phrases. P1 presented with impaired comprehension of syntactic structures. Difficulties in processing these types of syntactic constructions are key features of agrammatism at comprehension level (Basso, 2003).

## P2's neuropsychological profile

P2 is a right handed female who is literate and a native speaker of Jordanian Arabic, she is monolingual. She was 24 years old at the time of the study. She holds an undergraduate degree in education and was educated in Arabic through school. Prior to her CVA, P2 was a primary school teacher. Nine months prior to LA's participation in this study, she suffered a single CVA resulting from an arteriovenous malformation (AVM) on the middle cerebral artery (MCA) causing a left sylvian haematoma. Computerized tomography (CT) scan conducted two days post-onset showed a fronto-parietal acute haemorrhage in the area mainly supplied by the MCA. Her speech and language therapist described a right-sided hemiparesis and transcortical motor aphasia (TMA).

P2's performance in picture naming was outside the normal range. Her semantic errors included one semantic-coordinate error (/θəʃlæb/ 'fox' → /kəlb/ 'dog'), and one semantic-visual error (/mædxəl/ 'gate' → /bæb/ 'door'). All phonological errors were phonological related non-word forms (e.g. /mʊʁəlæf/ 'envelope' → /mʊʁəlæb/ non-word form). P2's lexical retrieval in conversation was analysed. A sample of this interview is presented in extract 1. Pause lengths are presented in brackets. The participant's responses to the questions are presented with a gloss. A translation of each turn is provided.

### Extract 1: A sample of P2's conversation with the researcher (TK)

**TK:** /mətə tæxærdʒti/?

'when did you graduate?'

**P2:** [audible breath] sənə ləʔ θni:n (2) jəʃni gəbl (1) səntein

[feminine singular noun - negation particle - cardinal number - present tense verb - feminine dual noun]

'a year no two (2) I mean (1) two years'

**TK:** /ʃʊ btiðəkæri ʃən həðək el ju:m/?

'what do you remember from that day?'

**P2:** /ʌh ʃelʊ sæʃbæti edʒiʊ (1) ʃʊ esemhæʔ əʁ (2) əʁ (1) əri:dʒ wə kəməən səhər/

[speech filler – adjective - feminine plural noun - past tense verb - interrogative particle - feminine singular noun - word form fragment - word form fragment - proper noun - conjunctive particle - proper noun]

'ah nice, my friends come what's their names? Ar Ar Areej and Sahar'

P2's expressive language was non-fluent, effortful and contained pauses. Her responses to questions were interrupted with word form finding difficulties. The majority of her utterances were simplified grammatical structures. Single word forms and two-word form phrases formed the vast majority of her utterances. The most complex syntactic structures she produced were subject-verb-object sentences which were grammatical. She did not produce complex structures such as passive constructions. Nouns were

abundant over verbs. She produced 80 content word forms of which 45% were nouns and 25% were verbs, the remaining were adjectives and adverbs. Simple present tense verbs were more common than past tense verbs which formed 10% of total verbs produced. Production of function word forms was restricted to the negation particle /læ/ 'no', the interrogative particle /ʃɒ/ 'what' and the conjunctive particle /wə/ 'and'. These features indicate that P2 had agrammatic production (Basso, 2003; Caramazza and Berndt, 1985; Saffran, Berndt and Schwartz, 1989).

Numbers of speech units (verbal and non-verbal vocal utterances), turns (including substantive and minimal turns), content word forms (excluding paraphasias), nouns and errors were measured in the middle five minutes of the sample. The vast majority of P2's turns (80%) were lexically empty i.e. minimal turns. Only 20% were substantive turns i.e. included content word forms. Her errors were semantic circumlocutions (e.g. /ədʒæmiə/ 'the university' → /bɪnɪdrɪs mɒhæðərə/ 'study lecture') and phonological related non-word forms (e.g. /həflə/ 'party' → /həfl/ → non-word form). This performance indicates that lexical retrieval difficulties were present in her conversation. It is possible that P2 had greater difficulties in lexical retrieval than her conversation sample showed, as it is difficult to identify target word forms unless the participant provides sufficient information which may lead the researcher to identify the target word form. In confrontational naming tasks, the target word form is known, and therefore it is easier to identify errors (Perkins, 1995). P2's performance in picture naming and conversation indicates that she had lexical retrieval difficulties. Presence of semantic errors and failures to respond indicates a possible semantic deficit, or damage to the route connecting semantics and phonological output lexicon (Caramazza and Hillis, 1990; Whitworth et al., 2005). The presence of phonological related non-word form errors indicates a possible damage to phonological output lexicon or phonological assembly (Whitworth et al., 2005).

P2's scores on the auditory minimal pairs discrimination and auditory lexical decision tasks indicate that auditory phonological analysis and phonological input lexicon processes were preserved. Her performance on the visual lexical decision task suggests intact orthographic input lexicon. These results show that auditory and visual inputs to semantics were preserved.

P2's scores in spoken and written word form to picture matching are within the normal range. She made one error in each test, both of which involved selection of the semantic distracter. P2's performance on the input tasks and lexical comprehension tasks indicates that semantic processing from spoken and written inputs was preserved, at least for this set of items. This suggests that her lexical retrieval difficulties are unlikely to arise due to a deficit in semantic processing. Similar participants presenting with semantic errors and circumlocutions in the absence of a central semantic deficit have been reported in previous studies (e.g. RGB and HW: Caramazza and Hillis, 1990; MH: Herbert and Best, 2010; GM and JS: Lambon-Ralph et al., 2000).

In reading aloud of word forms, P2 scored just below the normal range. Her inaccurate responses were a phonological error (/mɒstəfə/ 'hospital' → /mæffə/ non-word form), a perseveration, and two failures to respond to the stimulus. Her phonological error indicates damage to phonological output lexicon or processes within phonological assembly. Her failures to respond can be a result of damage to the route connecting semantics and phonological output lexicon. However, if reading bypasses semantics, these errors can result from damage to the route connecting the orthographic input lexicon and phonological output lexicon. Her perseverative error may have resulted from difficulty in activating the target response, and therefore she retrieved a previously mentioned noun which was more available than the target response. A connectionist interpretation of perseverative errors is provided in Plaut and Shallice (1993).

In word form repetition, P2 repeated all the presented word forms correctly, which contrasts with her performance on the other two spoken word form production tasks (picture naming and reading aloud) and conversation. This contrast suggests that the process of repeating word forms is supported by direct lexical processing from phonological input lexicon to phonological output lexicon bypassing semantic processing, and by sub-lexical processes.

P2's performance in reading aloud and repetition of word forms is better than her performance in picture naming. This suggests impaired access to phonological output lexicon from semantics rather than a deficit within the phonological output lexicon (Whitworth et al., 2005). The presence of phonological related non-word form errors in naming and reading aloud indicates damage to the phonological assembly. The contrasting good performance in word form repetition suggests that processes within phonological assembly may be partially damaged; when the output is constrained by the input stimulus in the form of auditory word form, processing proceeds without errors. However, errors occur when there is no constraint (such as lexical retrieval in picture naming and conversation), or limited constraint requiring trans-coding from graphemes to phonemes (reading aloud).

P2 scored outside the normal range on reading aloud of non-word forms. The source of this impairment cannot be impaired visual orthographic analysis as evident from her performance on the visual lexical decision task, but indicates damage to the orthographic-to-phonological-conversion sub-lexical route. Her repetition of non-word forms was outside the normal range. This performance indicates damage to the phonological-input-to-output-conversion sub-lexical route. Auditory phonological analysis was good, as evident from her performance on the auditory minimal pairs discrimination. P2's digit and phoneme spans were reduced to 3 digits and 2 phonemes which is outside the norm (mean = 6.4, range = 5-7). Besides the possible damage to sub-lexical routes, her difficulties in processing non-word forms were caused by damage within phonological assembly as it is reliant on maintaining the set of phonemes in the short-term memory without lexical support.

P2's comprehension of syntactic structures during conversation was relatively intact; she did not have difficulties in understanding questions. Furthermore, her performance was within the normal range in spoken and written sentence comprehension. P2 did not have problems comprehending sentences with reversible structures or passive constructions. The data indicate that P2's input processing of syntax was intact, for the current set of items.

### **P3's neuropsychological profile**

P3 is a 62 year old right-handed male who is a native speaker of Jordanian Arabic and literate, he is monolingual. Prior to his injury, P3 was a retired assistant engineer. He had been formally educated up to secondary school and left when he was 17 years old. Arabic was the language of education through his school. Twelve months before his involvement in this study, P3 suffered a single cerebrovascular accident (CVA) in the left cerebral hemisphere. His CVA resulted in a hypo-dense lesion in the left parietal region representing an ischemic infarct, according to his most recent computerized tomography (CT) scan conducted eight months post-onset. Prior to his CVA, P3 had a history of hypertension, diabetes mellitus and ischemic heart disease which are believed to have predisposed him to CVA. The speech and language therapists reported that P3 had a right-sided hemiparesis and transcortical motor aphasia.

P3's performance on the picture naming task and conversation sample was examined. Response categories included correct responses (58%), phonological errors (26%), neologisms (8%), no responses (8%). P3's performance in picture naming was outside the normal range. Phonological errors were the predominant error type. His phonological errors resulted in non-word form productions. For example, he produced /nəʃləb/ 'non-word form' instead of /θəʃləb/ 'fox' and /gæzi:r/ 'non-word form' instead of /xænzɪ:r/ 'pig'.

A sample of P3's conversation is presented below. Numbers of speech units (verbal and non-verbal vocal utterances), turns (including substantive and minimal turns), content word forms (excluding paraphasias), nouns and errors were measured in the middle five minutes of the sample.

#### **Extract 3: A sample of P3's conversation with the researcher (TK)**

**TK:** /ʃʊ kʊnt tɛftəʃel/?

'what did you work?'

**P3:** /bel əɾð wəl məsæħə (1) kʊnt əsæʃed əl (2) ʃʊ ʔɪsɪmħɪm? (1) bɛftəʃɪʊ wə bɛrsɪmʊ/

[preposition – noun – feminine singular noun – past tense verb – particle – masculine plural noun – simple present verb – simple present verb]

'in the landscape department (1) helped the (2) their name? (1) they work and draw'

**TK [cuing]:** /mʊ/

**P3:** /æh mɔhændɪs (2) ləʔ əkθər (1) mɔhændɪsɪn [slurred speech]/  
 [speech filler – masculine singular noun – negation particle – adverb – masculine plural noun]  
 ‘ah engineer (2) no more (1) engineers [slurred speech]’

P3’s expressive language was non-fluent and effortful. P3 produced single word forms, two-word form phrases and some grammatically correct sentences. His most complex grammatical structures were subject-verb-object sentences and sentences with prepositional phrases as compliments for verb phrases. Word form finding difficulties were present through his conversation. In one occasion P3 gave phonological and syntactic information about a word form he could not retrieve i.e. /mɔhændɪsɪn/ ‘engineers’. He stated that it referred to more than one person and that it was a long word form. A phonemic cue was successful on this occasion. He produced 76 correct content word forms: 37 (48%) nouns, 32 (42%) verbs and 7 (10%) adjectives and adverbs. All verbs were correctly inflected and tenses were produced correctly. In addition, P3’s expressive language contained function word forms, he produced prepositions (e.g. /be/ ‘in’), the conjunctive particle /wə/ ‘and’, interrogative particles (e.g. /ʃt/ ‘what’), the negation particle /ləʔ/ ‘no’ and pronouns embedded in verbs such as /əʃæʃed/ ‘I helped’. There was no evidence of agrammatic production. Lexical retrieval difficulties were present in P3’s conversation. The vast majority of his turns (59%) were minimal turns. Only 41% were substantive turns. His phonological errors resulted in non-word forms.

P3’s picture naming and conversation indicate that lexical retrieval difficulties are present. His expressive language did not include semantic errors, which suggests that the semantic system is intact. The predominance of phonological errors in picture naming, and phonological errors in conversation demonstrate that damage to the phonological output lexicon or phonological assembly is present. The failures to respond in picture naming indicate impaired access to phonological output lexicon from semantic system.

P3’s scores on the auditory minimal pairs discrimination and auditory lexical decision tasks show that his auditory input was good. Visual input processes were compromised as evident from his score on the visual lexical decision task.

P3’s performance on the spoken and written word form to picture matching is within the normal range. This suggests that semantic processing from spoken and written inputs is intact. This claim is supported by the absence of semantic errors in his picture naming. However, P3’s good written word form comprehension is accompanied by impaired orthographic input. This contrast suggests that the weak distorted orthographic message is supported by top down processing from semantics in tasks involving pictures (Humphreys, Riddoch and Price, 1997).

P3 scored outside the normal range in reading aloud and repeating word forms. He produced 4 phonological errors and a perseveration in reading. His errors in repetition

were 3 phonological errors and a failure to respond. All his phonological errors resulted in non-word forms (e.g. /mʊstəfə/ 'hospital' → /mæfəfə/ 'non-word form'). P3's perseverative error in reading may have resulted from inability to activate the phonological form of the target word form and, instead, he produced a previous response which was more available. His failure to respond in repetition indicates difficulties in access to the phonological output lexicon to retrieve the phonological form of the target. P3's score was outside the normal range in reading and repeating non-word forms. This may be explained by the damage to the process within phonological assembly or it may indicate additional damage to the orthographic-to-phonological-conversion and the phonological-input-to-output-conversion sub-lexical routes. His digit and phoneme spans were reduced to 2 digits and 2 phonemes which was outside the norm (mean = 6.4, range = 5-7). This may have contributed to his inability to read and repeat non-word forms as these tasks are reliant on maintaining the set of phonemes in the short-term memory without lexical support (Whitworth et al., 2005).

P3's performance on all spoken output tasks was impaired. His predominant error pattern in all output tasks and conversation were phonological errors resulting in non-word forms as a result of omission and metathesis of phonemes. His performance in non-word form reading and repetition was worse than his performance in word form reading and repetition. This pattern of performance suggests that his phonological errors in spoken output tasks resulted from damage to phonological assembly rather than phonological output lexicon (Whitworth et al., 2005).

P3's comprehension of syntactic structures in conversation was relatively well preserved as he understood the questions addressed to him. However, his scores in spoken and written sentence comprehension tasks were outside the normal range. In spoken sentence to picture matching, his errors included 1 subject-verb-object non-reversible sentence, 1 sentence with embedded structure and 2 reversible sentences with locative prepositional phrases. In written sentence to picture matching, his errors included 2 subject-verb-object reversible sentences, 2 sentences with passive construction and 3 sentences with embedded structures. P3 presented with impaired comprehension of syntactic structures. Difficulties in processing these types of syntactic constructions are features of agrammatism at comprehension level (Basso, 2003).

Lexical processing and speech sample analyses revealed that all three participants had similar types of anomia, with varying degrees of severity; the severest was P1, and the mildest was P3. P1's lexical processing analysis disclosed the source of her word form finding difficulties in picture naming and conversation. Access to the phonological output lexicon from the semantic system, and impaired phonological assembly were the functional loci at which her anomia arise. Her anomia arises at access to the phonological output lexicon from the semantic system, and partial damage to the phonological assembly. P3's anomia was a result of impaired phonological assembly and

partial damage to accessing phonological output lexicon from semantics. Patterns of performance of all three participants suggest impairment to the lemma level, hence difficulties in morpho-syntactic processing of word forms.

The analysis of their sentence processing tasks and speech samples revealed that agrammatism was present in all participants with varying degrees and modal patterns. P1's expressive language in conversation shows that she presented with agrammatic production as she had difficulty in formulating well-formed grammatical constructions. P1 presented with agrammatism in comprehension, as revealed by her performance in sentence comprehension tasks. Agrammatism was present in P2's production as evident from her conversation. Spoken and written sentence comprehensions suggest that agrammatism was not present at comprehension level. Input to semantics from auditory and visual stimuli was preserved as evident in her performance on the auditory and visual input tasks. P3's expressive language was restricted to subject-verb-object sentences, as evident from his conversation. Sentence comprehension tasks revealed that agrammatism was present in comprehension.

### **3.2.2 Arabic plurals naming subtest**

Forty-five word forms and their pictorial representations were selected from the Levantine Arabic normative dataset (Khwaileh, Body and Herbert, 2014). These items were selected according to their plural type (sound vs. broken). The first set included 15 items with sound plurals. The second set included 30 items with broken plurals. Their pictorial representations were presented on a laptop screen in a Microsoft Power Point file (Microsoft Office, 2003). Each picture was 320 x 200 pixels. The screen background was white. Each picture appeared on the screen in two different conditions. The 45 selected items appeared in two conditions. The first condition was dual condition where two pictures of the same object were presented on the screen at the same time. The second condition was the three-plus plural condition where three or more pictures of the same item were presented on the screen. In total, each participant was presented with 90 pictorial representations; 45 duals (e.g. picture of two apples) and 45 sound and broken plurals (e.g. picture of three apples). Slides were randomized in order to avoid the effect of location in the set on picture naming.

In order to ensure that all items were matched for significant variables that may affect lexical retrieval, one-way ANOVA tests were carried out, which showed that there were no significant differences between the sets with regard to normative naming latency ( $F(1, 43) = 0.296, p = .604$ ), age of acquisition ( $F(1, 43) = 0.157, p = .444$ ), imageability ( $F(1, 43) = 0.240, p = .880$ ), visual complexity ( $F(1, 43) = 0.004, p = .996$ ) and phoneme number ( $F(1, 43) = 0.120, p = .138$ ). Stimuli were matched for normative naming latency in order to control for difficulty of naming, in the absence of frequency values for Jordanian spoken Arabic, following methods used in languages with no frequency data (e.g. Croft, Marshall, Pring and Hardwick, 2011). All Arabic norms were taken from the Levantine normative database (Khwaileh, Body and Herbert, 2014).

Under each presented picture there were two lines to prompt a participant that he/she should produce two word forms. The first word form would be the numeral and the second word form would be the plural form of the word form. For example, if there were three repeated pictures of a 'bird' appearing on the screen at once, they were expected to say /θələθ ʔəsæfi:r/ [numeral-masculine plural noun] 'three birds'. Producing a numeral referring to the number of pictures first would prompt the participant to produce the plural form of the noun.

In the dual condition there was only one line drawn below the presented pictures because duals in Arabic cannot be preceded by numerals. The number is embedded in the dual suffix /-ein/. However, in the three plus plurals condition, a numeral preceding the noun is essential.

Each participant sat at a comfortable distance from the laptop screen. Participants were presented with one picture at a time and asked to name the image aloud as quickly as possible. A Sony headset microphone adjusted to 5cm from each participant's mouth was used to detect spoken responses. The researcher controlled the presentation of pictures. Once the participant named the pictures appearing on the screen, the researcher clicked a button to move to the next picture. Each stimulus remained 20 seconds on the screen. If a participant did not name the picture within 20 seconds of its presentation, the researcher would move to the following stimulus. Responses were audio recorded via a digital recorder (Olympus VN-2100PC).

### 3.3 Coding the data

The data were coded twice by the researcher, to assess intra-rater reliability. The first time was at assessment. The transcribed and coded data were then recoded by the researcher ( $r=.912$ ). The time between the first coding procedure and the second one was greater than 3 months.

Two main coding systems were developed (Khwaileh, unpublished): Lexical accuracy and morpho-syntactic accuracy, and each response was coded for both factors. The former referred to the retrieval of the lexical stem of the item in question. The latter referred to the retrieval of the appropriate morpho-syntactic form of the target item. For example, a response was coded as lexically accurate but morpho-syntactically inaccurate if a participant produced /bəgərə/ [feminine singular noun] 'cow' instead of the target noun /bəgərət/ [feminine plural noun] 'cows'. However, a response was coded as lexically inaccurate and morpho-syntactically accurate if a participant produced /kəlbæt/ [feminine plural noun] 'dogs' instead of the target noun /bəgərət/ [feminine plural noun] 'cows'.

## 4. Results

Five levels of accuracy analysis were conducted: overall correctness (the accuracy of the response overall), lexical meaning correctness (the accuracy of consonantal roots

regardless of morpho-syntax), morpho-syntax correctness (the accuracy of morpho-syntactic information-gender and number-conveyed by the vocalic pattern, regardless of lexical meaning), morpho-syntactic error type analysis (e.g. error category), and morpho-syntactic error form analysis (omissions, substitutions, insertions).

#### 4.1 Accuracy analysis

Accuracy of regular and irregular plural structures were compared. Table 4 presents the proportion of responses which were both lexically and morpho-syntactically correct, lexically correct responses regardless of morpho-syntactic accuracy, and morpho-syntactically correct responses regardless of the lexical accuracy.

Table 4: about here

Production of plural nouns was impaired in all three participants. The differences in accuracy between plural subtypes might be a result of an inability to retrieve the lexical stem, or an inability to generate the morpho-syntax. These results indicate an effect of morpho-syntactic regularity on accuracy of plural production. While P2 and P3 were more accurate in producing plurals with regular morpho-syntax, P1 was more accurate in irregular plurals.

Statistical analysis of the data presented in table 4 showed a significant difference between regular and irregular plural production for P2 (Sign<sup>1</sup> test;  $p < .05$ ) and P3 (Sign test;  $p < .05$ ) but not for P1 (Sign test;  $p > .05$ ), when responses were scored for both lexical and morpho-syntactic accuracy. There were no significant differences in the retrieval of lexical stems of regular and irregular plural constructions for P1 (Sign test;  $p > .05$ ), P2 (Sign test;  $p > .05$ ) or P3 (Sign test;  $p > .05$ ). Regular and irregular plural productions were compared in terms of morpho-syntactic accuracy. The difference in retrieval of the morpho-syntax between regular and irregular was significant for P1 (Sign test,  $p < .05$ ), P2 (Sign test,  $p < .05$ ) and P3 (Sign test,  $p < .05$ ). The regularity effect shown in the table above was mirrored in the results for morpho-syntactic accuracy, indicating that for all three participants the dissociation between regular and irregular structures was due to morpho-syntax. The source of this effect was morpho-syntactic rather than lexical.

Accuracy analysis of the data showed that an effect of regularity on plural production was present in all participants. P1 was better in producing irregular plurals. P2 and P3 were better in producing regular plurals. Accuracy analysis suggests that regular and irregular morpho-syntactic structures are processed differentially. This effect was further examined via error analysis.

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<sup>1</sup> The Sign test used in this study, unlike the Wilcoxon Signed-Rank test, does not assume symmetric distribution of the differences around the median, and does not use the magnitude of the difference. The Wilcoxon Signed-Rank test need samples to be equal but the Sign test does not require that.

#### 4.2 Morpho-syntactic error type analysis

Error analysis of lexical stems showed that there was no difference in error types of lexical stems of regular and irregular forms. Lexical error patterns across regular and irregular plurals were similar in all three participants. Therefore, regularity effect on lexical stem errors was negligible.

Morpho-syntactic error types and forms were analysed to examine whether regular and irregular plurals differ in terms of the types of errors arising in morpho syntax . Proportions of response types are presented in table 5.

Table 5: about here

The lexical substitution of morpho-syntax was present in regular and irregular subsets for all participants. Examples 5 and 6 below present instances of this error type in regular and irregular plurals, respectively.

- (5) /dʒəməleɪn/ [masculine dual noun] 'two camels' → /dʒəməl-eθneɪn/ [masculine singular noun-cardinal numeral] 'camel two'
- (6) /txu:t/ [masculine plural noun] 'beds' → /tæxt-ərbæʃ/ [masculine singular noun-cardinal number] 'bed-four'

This error pattern indicates that participants could access the lexical stem for this set of items but could not retrieve the target plural morpho-syntax. All the singular forms of the target noun had preserved gender. In the above error category, only number inflection was erroneous. It was compensated by adding a cardinal number after the singular form of the noun. An effect of regularity on this error category was evident in responses from P1, P2 and P3. P2 had a higher proportion of this error in the irregular subset. However, P1 and P3 showed a reverse pattern.

The gender inflection error was present in the responses of P1 and P2 to regular subsets, but not in P3's responses. It is illustrated in 7 below.

- (7) /mʊʁənɪjeɪn/ [feminine dual noun] 'two female singers' → /mʊʁənjeɪn/ [masculine dual noun] 'two male singers'

In the case of broken plurals (irregular) this type of error was not present. In a broken plural the omission of the gender inflection results in the omission of the vocalic pattern (as gender is built-in to the vocalic pattern) which eventually leads to production of a phonologically illegal word form that is not pronounceable. Example 8 illustrates how omission of a vocalic pattern could result in an illegal word form.

(8) /səwæni/ [feminine plural (broken) noun] 'trays' → /swn/ (illegal word form)

The number inflection error was present in responses of P1 and P3 but not P2. No effect of regularity was evident on this error category. Examples 9 and 10 illustrate number inflection errors in regular and irregular constructions, respectively.

(9) /kitæbein/ [masculine dual noun] 'two books' → /kitæb/ [masculine singular noun] 'book'

(10) /xəwætɪm/ [masculine plural noun] 'rings' → /xætɪm/ [masculine singular noun] 'ring'

The over-regularization of the morpho-syntax of the target word form was present in responses of P2 and P3 but not in P1. In both cases, there was an effect of regularity. P2 and P3 produced this category in response to irregular items only. Examples 11 and 12 illustrate this error type.

(11) /tənəni:r/ [feminine plural (broken) noun] 'skirts' → /tənɔræt/ [feminine plural (sound) noun] 'skirts (wrong plural inflection)'

(12) /əhzmə/ [masculine plural noun] 'belts' → /həzəmət/ [masculine illegal-plural noun] 'belt + suffix'

The analysis of morpho-syntactic error types revealed that two types of errors were governed by the regularity of the morpho-syntax. While gender inflection errors occurred in responses to regular structures only, over-regularisation of the morpho-syntax occurred in responses to irregular structures only.

### 4.3 Morpho-syntactic error forms

Morpho-syntactic errors demonstrated in the previous section were a result of omissions or substitutions of the target inflection. The current subsection examines the effect of regularity on morpho-syntactic error forms. Error forms were compared across morpho-syntactic errors to regular and irregular plurals. The number of morpho-syntactic errors and the proportion of omission versus substitution errors for each participant were calculated, and presented in table 6. Errors that were classified as 'other' and 'no response' were excluded from the error form analysis.

Table 6: About here

There was a difference in error form between regular and irregular plural forms. Errors of regular plurals consisted of omission and substitution of the dual or sound plural

suffix. However, errors of irregular plurals were substitutions of the vocalic pattern only. Example 13 illustrates an omission error in regular constructions. Examples 14 and 15 show substitution errors of regular and irregular constructions, respectively.

(13) /kitæbein/ [masculine dual noun] 'two books' → /kitæb/ [masculine plural noun] 'book'

(14) /taʊltein/ [feminine dual noun] 'two tables' → /taʊlæt/ [feminine plural noun] 'tables'

(15) /xəwætɪm/ [masculine plural noun] 'rings' → /xætɪm/ [masculine singular noun] 'ring'

Regular errors were mainly omissions while irregular errors were substitutions. It is also important to note that within errors of regular plural formations, omission errors outnumbered substitution errors by a considerable amount.

## 5. Discussion

The data obtained in this study were compared against existing accounts of regular and irregular morpho-syntactic processing. Accuracy, error type and error form analyses suggested differential processing between regular and irregular plural forms in all participants. The discussion below sheds light on showing how the current data supported the dual mechanism account for regular and irregular morpho-syntax. The degree to which the single mechanism can account for the data in question is also addressed.

P1 scored higher in processing irregular morpho-syntax than regular morpho-syntax. Both P2 and P3 presented a reverse pattern in which regular morpho-syntax processing was significantly higher than irregular. This double dissociation suggests that processing of regular and irregular morpho-syntax of word forms may be governed by independent cognitive processes. The double dissociation found in the current study appears to be an effect of (ir)regularity of morpho-syntax, not confounded by other variables, for a number of reasons. First, all participants were better at retrieval of lexical stems than morpho-syntactic forms, as seen through higher scores for lexical accuracy than for morpho-syntactic accuracy. Second, the stimuli in the Arabic plural naming subtest were matched for visual complexity, imageability, age of acquisition, name agreement, normative naming latency and length (phoneme number). This indicates that the current results may not have been biased by any of these variables. Therefore, it is reasonable to attribute their impairment to regularity of morpho-syntax of the presented stimuli, which challenges Chialant and Caramazza's (1995) model in which they do not differentiate between word forms based on their morphological features but merely on their psycholinguistic characteristics i.e. frequency of occurrence. The current data supported Pinker and Ullman's (2002) proposal in which they maintained that it is the morphological system that forms the basis on which the dual mechanism operates. They added that effects of psycholinguistic variables could be present within each route. This view maintains that regular inflection is the predictable form which can be applied to novel word forms and invokes a combinatory rule (English past tense regular form rule: stem + -ed; e.g. print-ed). However, irregular inflections are stored

forms that may not be predicted by the form of the stem and may not be applied to novel word forms (e.g. meet → met). The fact that our stimuli were matched for psycholinguistic variables, yet dissociation in retrieval of morpho-syntax was evident in all three participants, suggests that this dissociation could not be attributed to psycholinguistic characteristics of the word forms in question, which is in agreement with Pinker and Ullman (2002) but in disagreement with Chialant and Caramazza's (1995).

Pinker and Ullman (2002) proposed that agrammatic participants have difficulties in managing rule based processes while non-agrammatic participants do not. Since regular forms rely on rule based processes it should be the case that agrammatic participants have difficulties in regular forms rather than irregular ones, while non-agrammatic participants should be better in processing regular forms. Consistent with this, P3 did not have agrammatic production and he was better in regular than irregular forms. In addition, P1 had agrammatism in production and in turn she had poorer performance on regular forms. Inconsistent with this, P2 had agrammatism in production, yet she was better in production of regular than irregular forms. Both P1 and P2 had agrammatic production but showed different patterns of performance. This discrepancy supports previous studies which point to the fact that linking agrammatism to effects of regularity in the dual mechanism account needs to be revised (De Diego Balaguer et al., 2004; Laiacona and Caramazza, 2004; Shapiro and Caramazza, 2003). These studies have reported participants who showed differential processing between regular and irregular forms but did not show the expected pattern of agrammatism. Participants JM and MP (De Diego Balaguer et al., 2004), RC (Shapiro and Caramazza, 2003) and MR (Laiacona and Caramazza, 2004) had agrammatic aphasia but poorer performance on irregular forms than regular ones. Diego Balaguer et al. (2004) concluded that "a major component of agrammatic production is a deficit in morpho-syntactic processing, independently of whether this processing ultimately involves regular or irregular forms" (p. 212).

Error type analysis suggests that two error types may have been governed by the regularity of the plural morpho-syntax. Gender inflection errors occurred in regular plural constructions only. In contrast, over-regularization of morpho-syntax occurred in irregular plural morpho-syntax constructions. Participants produced other error types, but these two types are of interest to this discussion, since their occurrence was governed by the regularity of morpho-syntax, as explained below.

Gender inflection errors were only present in regular plurals, which indicated that gender inflection in regular plural formations was separable from the stem, unlike irregular plurals where gender inflection is built within the vocalic pattern. This inseparability was evident from the lack of gender inflection omissions in P1, P2 and P3's production of irregular plurals. One could interpret this as a result of two different processes; one permitting the omission of gender morpho-phonology, and the other not

authorizing such omission. However, the fact that the omission of gender information in irregular forms results in an illegal phonological form suggests that the same effect can be present in the case of the single mechanism system, provided that it follows the phonological rules of Arabic language. Neither models offer an interpretation of language-specific features like this one, warranting further modifications of models to fit language-specific features.

An alternative language-specific account provides a better understanding of this error type. The fact that there were no gender inflection errors in broken irregular production could be due to the fact that syntactic information, such as gender, is already embedded in the vocalic patterns for irregular forms i.e. broken plurals (McCarthy, 1975; 1981). This can be understood within the framework of concatenative versus non-concatenative morphology (McCarthy, 1975; 1981; also described in Prunet et al., 2000). Concatenative word form formation refers to linear word form formation in which affixes are added to the stem to change the inflection or derivation of a given word form (e.g. /məlik-æt/ 'queen-s'). Regular plurals are formed via a concatenative mechanism. Non-concatenative word form formation is achieved via internal change to the vocalic pattern of a given word form. Irregular plurals are formed in a non-concatenative mechanism. In non-concatenative word form formation, the vocalic pattern bears syntactic information such as gender. The vocalic pattern in non-concatenative structures cannot be omitted as this would result in a phonologically illegal utterance. However, in concatenative constructions gender is represented via a bound morpheme, which is at risk of omission in impaired language production. The omission of this morpheme results in a real word form in its singular form.

The presence of this dissociation in gender inflection errors can be considered as a feature of Arabic morpho-syntax. Previous studies investigating regular and irregular processing have mentioned that the dual mechanism approach accounts for data but fails to explain presence or absence of errors resulting from language specific features. For example, Walenski et al. (2009) interpreted their Italian data within the dual mechanism approach, however this approach failed to account for an aspect of Walenski et al.'s (2009) results: the lack of regularization errors in the participant's production (e.g. swim → \*swim-ed; Pinker and Ullman, 2002). This elucidated important language specific differences in regular and irregular processing. The authors attributed this to language specific features of Italian, such as frequency of occurrence of irregular and regular forms.

The second error type of interest is over-regularization, where participants produced a regular form instead of the irregular target noun. According to the dual mechanism account, over-regularization errors are a result of applying regular inflection to irregular forms when memory fails to supply the irregular stored form for word forms. This error type reflects an over-reliance on rule based mechanisms to compensate for the inability to retrieve irregular forms (Pinker, 1999; Pinker and Ullman, 2002). Participants P2 and P3 presented with loss of access to irregular stored forms and produced over-

regularization errors. In contrast, P1 presented with agrammatic production and a deficit in generation of regular inflections, did not produce over-regularization errors, as impaired rule based mechanisms may have prevented these errors. This dissociation suggests that production of regular and irregular plurals is governed by two independent mechanisms. If a single mechanism was involved, it would be possible to have both over-regularization of irregular targets, and ir-regularization of regular targets.

On an error form level, a dissociation in error forms of regular and irregular plurals was also present in all participants. Omissions formed the vast majority of errors to regular plurals. In contrast, substitution was the only error mechanism that occurred in irregular plural errors. Omission of inflectional affixes indicates that regular word forms can be broken into morphemes which can be omitted. Substitution errors suggest that irregular forms cannot drop affixes but substitute them. This substitution suggests that both consonant and vocalic patterns involved in producing an irregular form may be stored, and neither consonant roots nor vocalic patterns can be further subdivided, but can be substituted. On the other hand, consonant roots and vocalic patterns of regular forms can be subdivided and affixes can be separated. This strengthens the claim for differential representation and processing of regular and irregular forms.

The findings from the current study are consistent with studies from English (e.g. Miozzo, 2003; Newman, Ullman, Pancheva, Waligura and Neville, 2007; Tyler, Stamatakis and Marslen-Wilson, 2005; Ullman et al., 1997), which reported a double dissociation in the processing of English regular and irregular past tense in participants with aphasia. These studies interpreted their results within the dual mechanism approach. The current findings are also consistent with conclusions from studies on Hebrew (Berent, Pinker and Shimron, 2002), German (Penke, Janssen and Krause, 1999) and Italian (Walenski et al., 2009). For example, Penke, Janssen and Krause (1999) reported two major findings from German speakers with aphasia. First, irregular constructions were selectively impaired while regular formations were retained. Second, a frequency effect was observed for irregular formations but not regular ones. The authors interpreted this effect as evidence on the storage nature of irregular forms. Both findings were compatible with the main principles of the dual mechanism account (Pinker and Ullman, 2002). However, Penke et al. (1999) failed to account for the fact that irregular formations being affected after agrammatism violates the dual route assumption that agrammatic participants retain irregular formations (Pinker and Ullman, 2002). Penke et al. (1999) did not offer an interpretation for this inconsistency. Furthermore, the authors did not provide information on the neuropsychological assessment of participants.

The above discussion has focused on showing how the current data may be accounted for better by the dual mechanism. The degree to which the single mechanism can account for the data is considered below.

In her study of regular and irregular morpho-syntax in English, Faroqi-Shah (2007) concluded that models which propose differences in processing regular and irregular morpho-syntax fail to account for the whole spectrum of regular morphology. She argued that models which make a binary distinction between regular and irregular forms based on past tense morphology fail to account for the presence of preserved progressive –ing or plural –s in the absence of regular morphology in the past tense (such as participants reported in Friedmann and Grodzinsky, 1997) suggesting that the dissociation is not a result of differential processing of regular and irregular morphology. Faroqi-Shah (2007) stated that a dissociation between regular and irregular morpho-syntax could be a result of phonological similarities and differences rather than morphological features. She argued that English regular past tense verbs have similar phonological endings while irregulars do not. Therefore, a phonological effect could be present; for example a length effect could result in dropping the –ed in regular past tenses. In the current dataset, Arabic data gave insight into this issue which English data fail to do. The regular form of Arabic plural nouns has four different suffixes depending on gender and number (dual masculine: /-eɪn/; dual feminine: /-teɪn/; plural masculine: /-ɔn/; plural feminine: /-æt/), unlike the English past tense which has one regular ending (-ed). Unlike English regular suffixes, Arabic regular suffixes are phonologically distinct, yet a dissociation between regular and irregular formations was found. This finding supports the claim that differential processing between regular and irregular morphologies was present and cannot be reduced to phonological similarities as proposed by Faroqi-Shah (2007), due to the phonological distinctiveness of suffixes in Arabic.

A further issue relates to the claim that problems with regular forms are a result of a phonological deficit but a deficit in the irregular forms reflects a semantic deficit (Bird et al., 2003; Braber et al., 2005; Joanisse and Seidenberg, 1999; Lambon Ralph., 2005; Patterson et al., 2001). The current data challenge this assumption. The functional loci for anomia in P1, P2 and P3 were phonological. Evidence of a central semantic deficit was absent. According to Joanisse and Seidenberg's (1999) assumption, all three participants should process irregular forms more effectively than regular ones. However, P1 showed an advantage for irregular plurals, while P2 and P3 showed the opposite, which is incompatible with the single mechanism assumption. It is important to mention, however, that the assessment of semantic processing in all three participants was limited to tests that were available at the time of assessment, and therefore more rigorous testing of semantics would be needed to eliminate this possibility. The current data were consistent with findings from Tyler, Stamatakis and Marslen-Wilson (2005) who conducted a review of functional imaging studies and behavioural studies investigating regular and irregular morpho-syntax in English. Tyler et al. (2005) concluded that neither were regular deficits reduced to phonological impairment nor were irregular deficits reduced to semantic impairment. Furthermore, participant AW (Miozzo, 2003) had intact semantic processing with impaired production of irregular nouns and verbs. This pattern was compatible with participants P2 and P3 who did not have central semantic deficits but had impaired production of irregular

forms which is inconsistent with the single mechanism assumption (Joanisse and Seidenberg, 1999).

## **6. Conclusion**

The current data showed that the dual mechanism account extends to the Arabic morphological system for word forms, which is a different system to English and other languages reviewed above. The dual mechanism theory provides a better interpretation of the current data than the single mechanism approach. It also showed that certain aspects of regular and irregular morpho-syntactic processing are governed by the same principles across languages and are consistent with the dual mechanism assumptions.

However, this dataset provided evidence of further issues regarding the dual mechanism account. It showed that language specific features may not be accounted for by the dual mechanism approach. Language specific parameters need to be set to account for data from different languages. The dual mechanism approach could not provide interpretation to language specific error types. The lack of gender errors in P1, P2 and P3's responses to irregular stimuli can be attributed to the non-concatenative nature of Arabic morphology in which gender is embedded in the vocalic pattern of a given noun. Furthermore, this study has given an insight into the nature of processing within the dual mechanism approach, and agreed with previous critiques that the link between agrammatism and regular inflection needs to be revised in the dual mechanism approach, to explain the discrepancies reported, and to account for language-specific features.

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## Appendix A

### Lexical accuracy coding system

1. **Correct response:** this category was scored when participants produced the target response.
  - 1.1 **Correct response in slurred speech:** this subcategory was scored when the participant produced the target response in slurred manner of speech.
2. **Visual error:** when participants produced an inaccurate response that shared one or more visual features with the target response. This category consisted of two subcategories:
  - 2.1 **Visual error where participants give a name of a similar object,** such as saying /tɪlɪfɪzjən/ 'television' instead of /kəmˈpjʊtər/ 'computer'
  - 2.2 **Visual error due to a visual distracter in the presented picture,** such as saying a /dʒaɪbət/ 'pocket' for a picture of 'trousers with pockets'
3. **Semantic error:** included inaccurate responses where the response shares one or more semantic feature/s with the target picture. This category consisted of seven subcategories:
  - 3.1 **Semantic super-ordinate error:** production of a semantically related error that is super-ordinate to the target response. Such as producing /haɪwæn/ 'animal' instead of /xərəʊf/ 'lamb'.
  - 3.2 **Semantic coordinate error:** when participants produced a semantically coordinate response to the target response. Such as producing /ʊfæhə/ 'apple' instead of /mɔːze/ 'banana'.
  - 3.3 **Semantic subordinate error:** when participants produced a name of a subordinate object to the target one. Such as producing /hɪsæn/ 'horse' instead of /haɪwæn/ 'animal'.

- 3.4 Semantic associate error:** production of a response that is associated to the target response. Such as producing /dʊxɑ:n/ 'smoke' instead of /sɪgərə/ 'cigarette'.
- 3.5 Semantic circumlocution error:** production of a description of the target word form rather than producing the target word form itself. This included descriptions with a minimum of one content word form. For example, a participant would produce an utterance like /bɪtɪgəjər/ 'you peel it' instead of saying /bɜrtʊgæl-ə/ 'orange'.
- 3.6 Semantic and visual error:** when participants produced an inaccurate response that shares semantic and visual features with the target word form. Such as, producing /leɪmʊn/ 'lemon' instead of /bɜrtʊgælə/ 'orange'.
- 3.7 Semantic and phonological error:** when participants produced an inaccurate response that shared semantic and phonological (share 50% or above of the phonemes of the target response) features with the target response. Such as producing /hɪmær/ 'donkey' instead of /hɪsæn/ 'horse'.
- 4. Phonological error:** this category included erroneous responses where the target and the erroneous response share 50% or more phonemes; for example the participants would say *cut* instead of *cup*. This included three error subcategories:
- 4.1 Phonological related real word form:** when participants produced a phonological error that is a real word form. Such as producing /kætəbə/ 'he wrote' instead of /kɪtæb/ 'book'
- 4.2 Phonological related non-word form:** production of a phonological error that resulted in a non-word form. Such as producing /gələd/ 'non-word form' instead of /gələm/ 'pen'.
- 4.3 Partial production of the target word form:** production of one syllable or part of the target word form. Such as producing /fɒn/ instead of /tɪlɪfɒn/ 'telephone'.

5. **Other error:** This category included responses that did not fit within any of the categories above. This included three subcategories:
- 5.1 **Unrelated word form:** this subcategory was scored if participants produced a real word form that is visually, semantically and phonologically unrelated to the target response. Such as producing /mɪsmær/ 'nail' instead of /wɛræg/ 'paper'.
  - 5.2 **Unrelated non-word form:** production of a non-word form that is phonologically unrelated to the target response. Such as producing /kæbɜ:l/ 'non-word form' instead of /fær/ 'mouse'.
  - 5.3 **Unintelligible response:** production of an unintelligible response instead of the target response.
6. **Morpho-syntactic error:** production of the target consonantal root with a morpho-syntactic error. This included two main subcategories:
- 6.1 **Inflectional error:** This subcategory was scored if a participant's inaccurate response was presented with an inflectional error. This was scored if the incorrect number or gender inflections were present. Such as producing /kɒtɒb/ [plural-noun] 'books' instead of /kɪtæb/ [singular-noun] 'book' or /mɒmərið/ [masculine-noun] 'male nurse' instead of /mɒməriðə/ [feminine-noun] 'female nurse'.
  - 6.2 **Derivational error:** this subcategory was scored if the participant's inaccurate response was presented with a derivational error. Such as producing an adjective or a verb derived from the same consonantal root of the target response. An example of this would be producing /bɔrtɔgæl-i/ [adjective] 'orange-adjective' instead of /bɔrtɔgæl-ə / 'an orange'.
7. **No response:** this category was scored when participants took more than 20 seconds (from the moment the stimulus was presented) to respond.

## Appendix B

### Morpho-syntactic accuracy coding system

1. **Correct:** this category was scored if participants produced the target response in full.
2. **Error response:** included responses other than the target response. It included two subcategories:
  - 2.1 **Morpho-syntactic error:** this subcategory included responses where participants produced the target lexical item with incorrect morpho-syntax. It incorporated:
    - 2.1.1 **Lexical substitution of the morpho-syntax of the target response:** It included producing the uninflected singular form of the target noun followed by a lexical cardinal number instead of producing a head noun inflected for number as a result of omission to the target number inflection. Therefore, the number inflection was substituted with a lexical item representing the number. For example:
 

/hɪmæɹ eθneɪn/  
[masculine-singular-noun numeral]  
'donkey two'  
instead of producing  
/hɪmæɹ-eɪn/  
[masculine-dual noun]  
'two donkeys'
    - 2.1.2 **Gender inflection error:** omission of the feminine gender inflection from the target noun which results in a masculine noun such as producing:
 

təbɪbeɪn/  
[masculine-dual-noun]  
'two male doctors'

instead of

/təbɪbteɪn/

[feminine-dual-noun]

'two female doctors'

- 2.1.3 Number inflection error:** responses with omissions or substitutions of number inflection in a given target noun. A singular or dual form is substituted for a target plural noun, or a singular or plural is substituted for a target dual noun. For example:

/kɪtæb-eɪn/

[dual-masculine-noun]

'two books'

instead of

/kʊtʊb/

[plural-masculine-noun]

'books'

- 2.1.4 Over-regularization error:** included responses that were produced with a regular inflection instead of the original irregular one. For example, broken plurals (irregular inflection) that were produced as sound plurals (regular inflection) were included in this category. For example:

/tənʊr-æt/

[feminine plural (sound) noun]

'skirts (wrong plural inflection)'

Instead of

/tənəni:r/

[feminine plural (broken) noun]

'skirts'

- 3. Other response:** this category included responses that did not fit with any of the above categories. These responses were mixed and heterogeneous in nature. In

addition they were not frequent in a participant's performance and did not form a recurrent pattern.

4. **No response:** this category was scored if participants did not produce any utterance within 20 seconds from the moment the stimulus was presented.

### **Appendix C:**

Instructions for data collection and analysis: Conversation data; taken from Herbert et al. (2008).

1. Collecting the sample: The sample of conversation should be as close to everyday reality as possible. To this end the person with aphasia should record a conversation between themselves and one other person who is well known to them and does not have aphasia. The conversation should take place somewhere that is familiar to them, usually their home.

2. Type of sample: No restrictions upon choice of topic should be made. The pair should be instructed to talk as they would do normally. Speakers should be instructed to avoid performing for the tape recorder or doing anything they would not normally do. Explicit instructions may be needed to enable both speakers to take part, and to avoid a monologue being produced by either of the two speakers.

3. Recording the data: The data is tape-recorded and the tape later analysed and transcribed.

4. Length of sample: The conversation sample should be at least 10 minutes long. From this sample the middle 5 minutes are used for the analysis. This may mean starting or ending the analysis midway through a turn. In this case the partial turn is counted as one turn.

5. Data analysis: The conversation should be transcribed using basic conversation analysis notation, and the analysis carried out from the written transcription. This is a lengthy procedure but provides the most accurate means of analysis. Alternatively, for ease in the clinical setting, the analysis can be performed directly from the tape recording.

6. Output data: The data from the analysis provides raw scores only. In order to compare pre and post therapy scores relevant proportions of key variables should be computed.

- A. Number of speech units: Count all word forms and other tokens (such as eh? oh, mm, etc.). Treat contractions such as can't as one unit. Include part word form responses and false starts/revisions. Do not include sections of unintelligible speech.

- B. Turn taking: B1 A turn is a contribution to the conversation. The end of one turn comes when the other person starts to talk, or a lengthy pause occurs in which neither person talks. B2 A

substantive turn is defined as a turn that contains at least one content word form, even where this is a repetition of a previous token, or a paraphasia whose target is known.

C. Word form retrieval and speech errors: C1 Content word forms are defined as nouns, proper nouns, verbs, adjectives, adverbs and numerals. Adverbs are defined as ending in -ly. When common verbs such as get, have, be, do, know are main verbs they are included. If an item is repeated count each occurrence of the item separately. Exclusions: Generic terms such as stuff, thing, something etc. Modal verbs (can, must, should, might) and auxiliaries be, have, do, will, and shall. Paraphasias. C2 Extract number of nouns from above. C3 Semantic paraphasias: the presumed target and the error are content word forms. Circumlocutions must contain at least one content word form. In both cases the target must be clear to the conversation partner. Phonological paraphasias: resulting in both word forms and nonword forms where the target is apparent. The error should contain 50% or more of the target phonemes in the correct order, or the target must contain at least 50% of the error phonemes in the correct order. Also include partial attempts and false starts, e.g., par par partner. Neologisms: non-word forms where the target is not apparent.

**Table 1: Background information for participants with aphasia**

Participant	Age (years)	Sex	Hand	Hemiplegia	Etiology	Time post-onset (months)	Lesion site	Education (years)
P1	22	F	Right	Hemiplegia Right	CVA	12	L-anterior and middle cerebral artery	15
P2	24	F	Right	Hemiplegia Right	CVA	9	L-fronto-parietal lesion	16
P3	62	M	Right	Hemiplegia Right	CVA	12	L-parietal area	12

F= female, M= male, L= left, CVA= cerebrovascular accident

**Table 2: Aphasia assessment results**

Category of subtest	Subtest	P1		P2		P3		Norm*: mean (range)
		Raw score	(%)	Raw score	(%)	Raw score	(%)	
Lexical retrieval	Picture naming (n=24)	6	0.25	15	0.63	14	0.58	23.3 (21-24)
Input processing	Auditory minimal pairs discrimination (n=10)	4	0.40	10	1.00	8	0.80	Not available
	Auditory lexical decision (n=12)	7	0.58	12	1.00	11	0.92	Not available
	Visual lexical decision (n=15)	14	0.93	14	0.93	10	0.67	Not available
Semantic processing	Spoken word to picture matching (n=15)	14	0.93	14	0.93	13	0.87	14.7 (13-15)
	Written word to picture matching (n=15)	12	0.80	14	0.93	14	0.93	14.9 (14-15)
Output processing	Reading aloud of words (n=24)	4	0.17	20	0.84	19	0.79	23.7 (22-24)
	Repetition of words (n=16)	13	0.81	16	1.00	12	0.75	15.9 (15-16)
	Reading aloud of non-words (n=5)	0	0.00	1	0.20	1	0.20	4.7 (3-5)
	Repetition of non-words (n=5)	1	0.20	3	0.60	1	0.20	4.7 (2-5)
Syntactic processing	Spoken sentence to picture matching (n=16)	8	0.50	15	0.94	12	0.75	15.3 (14-16)
	Written sentence to picture matching (n=16)	10	0.62	13	0.81	9	0.56	15.2 (12-16)

**Table 3: Summary of results from P1, P2 and P3 conversation samples**

Category	Subcategory	Number of items		
		P1	P2	P3
Speech units	N/A	45	113	105
Turns	Total turns	11	15	17
	Substantive turns	3	3	7
	Minimal turns	8	12	10
Content words excluding paraphasias	N/A	17	80	76
Number of nouns	N/A	9	36	25
Errors	Circumlocutions	1	2	0
	Phonological paraphasias	6	6	7

**Table 4: Proportions of participants' accuracy**

Participant	Lexical and morpho-syntactic correctness		Lexical correctness regardless of morpho-syntax		Morpho-syntactic correctness regardless of lexical meaning	
	Regular (n = 60)	Irregular (n = 30)	Regular (n = 60)	Irregular (n = 30)	Regular (n = 60)	Irregular (n = 30)
	Dual and sound plurals	Broken plurals	Dual and sound plurals	Broken plurals	Dual and sound plurals	Broken plurals
P1 (proportions)	0.10	0.16	0.58	0.58	0.10	0.33**
P2 (proportions)	0.68**	0.40	0.83	0.80	0.73**	0.40

<b>P3 (proportions)</b>	0.45**	0.26	0.63	0.53	0.63**	0.36
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\*\* Difference statistically significant (p< .05)

**Table 5: Proportions of morpho-syntactic response types**

Response category	P1		P2		P3	
	Regular (n = 60)	Irregular (n = 30)	Regular (n = 60)	Irregular (n = 30)	Regular (n = 60)	Irregular (n = 30)
	Dual and Sound	Broken	Dual and Sound	Broken	Dual and Sound	Broken
<b>Correct</b>	0.11	0.33**	0.73**	0.40	0.66**	0.36
<b>Lexical substitution of morpho-syntax</b>	0.53	0.40	0.07	0.30	0.16	0.06
<b>Number inflection error</b>	0.16	0.07	----	----	0.01	0.03
<b>Gender inflection error</b>	0.03	----	0.05	----	----	----
<b>Over-regularization of morpho-syntax</b>	N/A	----	N/A	0.16	N/A	0.30
<b>Other</b>	0.11	0.07	0.07	----	0.10	0.13
<b>No response</b>	0.06	0.13	0.08	0.14	0.07	0.12

\*\* Difference Statistically significant (p< .05)

**Table 6: Number of morpho-syntactic errors, and proportions of substitutions and omissions**

Error form	P1 (# morpho-syntactic errors)		P2 (# morpho-syntactic errors)		P3 (# morpho-syntactic errors)	
	Regular (44)	Irregular (14)	Regular (8)	Irregular (14)	Regular (11)	Irregular (12)
Substitutions	0.11	1.00	0.12	1.00	0.18	1.00
Omissions	0.89	----	0.88	----	0.82	----