INTERROGATING 'HEURISTICS': COMPENSATORY STRATEGIES OF APHASIA AND COMPLEX ADAPTIVE THEORY

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Abstract: *Background:* There appear to be inconsistencies in the aphasiology literature, surrounding the use of the term 'heuristics' to refer to compensatory strategies in aphasia, and the actual neural origins of compensatory strategy production. *Aims:* This study aimed to interrogate the use of the term heuristics in this context by examining compensatory strategies as the product of the language faculty as a complex adaptive system. *Methods and Procedures:* A probabilistic data analysis was conducted using AphasiaBank interview data. Two phenomena were examined which were believed to demonstrate compensatory strategies and complex adaptive response: unvoiced clause-medial verbs and habituated discourse marker structures. *Outcomes and Results:* The results for both variables reached statistical significance, supporting the hypotheses that compensatory strategies evidence component system reallocation within a complex adaptive system, and that linguistic reanalysis is a reallocated system used for compensatory strategy production in habituated structures. *Conclusions:* The label 'heuristic' is an inaccurate descriptor of compensatory strategies, as it seeks to emphasise procedural distinctions between aphasic language parsing and premorbid language parsing which are non-existent. Instead, compensatory strategies can be seen as the product of component system reallocation, whereby algorithmic parsers within the language faculty must operate from different points of access. It is suggested that this is the reason why compensatory strategies have been perceived as heuristic in the previous literature.

PART 1

1. INTRODUCTION

Aphasia is a speech disorder which, in different forms, can affect speech comprehension and production. The form of aphasia which shall be examined here is stroke-induced Broca's aphasia. Broca's aphasia, also referred to as 'agrammatic aphasia', affects the fluidity, grammaticality, and structural components of the individual's speech. Whilst this disorder does not necessarily impact the retrieval of names for things, as in nominal aphasia, it can impact the relationships between words within the individual's language, as the individual must adapt their own language to repair limitations in fluidity and ability to create grammatical structures. The products of this process are the widely-reported 'Compensatory Strategies' (Gleason et al., 1975, Simmons-Mackie & Damico, 1997, Purdy & Koch, 2006, Tsapkini et al., 2014). Compensatory Strategies can be described as a means through which individuals with aphasia are able to bypass their expressive limitations, by developing idiosyncratic speech patterns and behaviours which can be interpreted by other interlocutors. Given that Broca's aphasia is primarily an inhibitor of grammatic retrieval, and can affect production of a broad range of linguistic structures, these strategies can manifest in a wide variety of ways, which have been reported over a number of decades. Studies by Gleason et al. (1975) and Tsapkini et al. (2014) identified certain compensatory strategies which pertained to a shift in the point of lexical access and word retrieval, whereby participants used phonological and prosodic features to access linguistic elements, rather than syntactic or morphological features. Additionally, Simmons-Mackie & Damico (1997) and Purdy and Koch (2006) identified strategies which were geared toward expression, such as novel gesture patterns (Simmons-Mackie & Damico, 1997: 766) and novel verbal constructions (1997: 768).

The issues surrounding compensatory strategies which will be addressed in this study involve the treatment of their neurological origins and make-up in the existing literature on this topic. In the pursuit of codifying an understanding of compensatory strategies, a range of means of defining them have been created, which have led to inconsistencies in the literature. Gleason et al. (1975) suggest that those with Broca's aphasia are 'operating with the remains of [their]

premorbid grammatical system', a theory supplemented by the research of Simmons-Mackie & Damico (1997), who identified behaviours which involved the recasting and exaggeration of features previously used in the premorbid system (1997: 768). However, this definition has an ambiguous relationship with the label 'heuristics', used to refer to compensatory strategies in studies such as Clark (2011: 718-730), Kolk & Heeschen (1990: 229), and Caramazza & Zurif (1976: 572-582). This is because a damaged pre-existing system can only operate via the neural procedures with which it has always operated, and whilst the compensatory strategies which arise from this system may be novel and idiosyncratic, the procedural means from which they were conceived cannot be. These systems of premorbid natural language are systematically underpinned by 'universals', which inherently contradict the notion of being heuristic. Furthermore, it is hypothesised that compensatory strategies are the product of a complex adaptive system. Based on previous findings that cognitive flexibility is a significant predictor of compensatory strategy usage (Purdy & Koch, 2006), it will be suggested that rather than emerging from non-algorithmic heuristic processes, compensatory strategies arise from the substitution of damaged parsing networks for intact ones, to accommodate for retrieval loss.

Regarding the idea that compensatory strategies are the product of premorbid processes within a complex adaptive system, two interconnected hypotheses will be presented. The first hypothesis is that rather than being labelled 'heuristic', compensatory strategies can better be distinguished from non-aphasic behaviours by examining 'point of access'. To this effect, the aphasic individual retains premorbid language parsing procedures, but creates novel and idiosyncratic surface-level strategies as a result of changes to the point at which they can obtain lexical and grammatic access. The notion of 'point of access' will be illustrated using a study by Tsapkini et al. (2014), in which participants were more effective in achieving lexical access syllabically than morphologically. The aim of this is to illustrate a 'moving of the goalposts' effect, meaning that the parsing procedure only appears to be newly-acquired and heuristic because of new changes to the points at which aphasic individuals are able to elicit lexical access and word retrieval.

The second hypothesis involves linguistic reanalysis. In continuation of the idea that compensatory strategies must belong to a premorbid system, it is hypothesised that linguistic reanalysis underpins a number of observable compensatory strategies in individuals with Broca's aphasia. Reanalysis is defined by Langacker (1977: 58) as 'change in the structure of an expression or class of expressions that does not involve any immediate or intrinsic

modification of its surface structure'. That is to say, prior to realised surface-level changes to an expression, there is first a more abstract re-evaluation of the semantic/syntactic structure which lies beneath its written or vocalised form. Significant work in the literature on reanalysis has been concisely codified by Traugott and Trousdale (2010), and will be referred to in this study.

This study will be formed of two parts. Part 1 will contain sections introducing some background into compensatory strategies and complex adaptive theory, followed by discussion of the two hypotheses, labelled 'Point of Access', and 'Reanalysis'. Each section will contain some review and analysis of the present literature relevant to each area of the study. The section which discusses the second hypothesis, regarding linguistic reanalysis, will be supplemented by an overview of some existing research into the process of grammaticalisation. The purpose of this is to examine how grammaticalisation emerges as an epiphenomenon of linguistic reanalysis (Roberts, 1993: 254, cited in Traugott and Trousdale, 2010), in order to help illustrate how reanalysis could similarly enable the emergence of compensatory strategies, and to gauge what can be learned about the influence of reanalysis on surface-level linguistic phenomena. The inclusion of this section is supported by the claim made by Gahl and Menn (2016: 1372) that 'studies of sentence processing in aphasia rarely include any reference to research on neurotypical sentence processing'. They take issue with this finding on the grounds that, like aphasic language processing, non-aphasic processing is neither 'uniformly stable' nor 'robust'.

Part 2 involves a data analysis study, using spoken interview data taken from TalkBank (B. MacWhinney et al., 2011). The two hypotheses of 'point of access' and 'reanalysis' introduced in Part 1 were based on speech phenomena observed in the data, and one phenomenon relating to each hypothesis has been selected for examination in this study. The first phenomenon, relating to 'point of access' is the omission of clause-medial verbs. Participants who struggled to retrieve clause-medial verbs preferred to elicit lexical access to the omitted form (to the other interlocutor) via corresponding arguments and complements, using pragmatic context to elicit the unvocalised verb. It is therefore hypothesised that omitted clause-medial verbs can be viewed as *unvoiced* rather than fully omitted, with a shift in point of access from phonetics to pragmatics. The second phenomenon, relating to reanalysis, is the production of auxiliary verbs internal to discourse markers. A number of participants had developed habituated, idiosyncratic discourse markers to accommodate for fluidity issues in their speech, and there was an identifiable imbalance in participants' ability

to execute auxiliary verbs internally and externally to these discourse markers. The hypothesis for the second phenomenon is that auxiliary verbs, when contained within habituated discourse marker structures, have undergone semantic reduction whilst retaining their phonetic structure. It will subsequently be explained how both of these phenomena infer the role of a complex adaptive system in language processing.

1.1.   Introduction to Compensatory Strategies of Aphasia

'Compensatory Strategies' has become a widely recognised term for the linguistic and communicative means by which individuals with aphasia bypass the limitations imposed on their communication. These strategies have long been studied in the field of aphasiology and have been identified across a range of linguistic domains, including morphosyntax, phonology, pragmatics, semantics, and syntax. As a result, compensatory strategies can vary in how detectable they are in speech and communication. Gleason et al. (1975) and Simmons-Mackie and Damico (1997) found a broad range of strategies detectable directly from first-hand communication, such as using a stressed word to begin an utterance, over-generalisation of vocatives (Gleason et al., 1975), use of novel discourse markers, and increased use of gesture (Simmons-Mackie & Damico, 1997). However, compensatory strategies can be less detectable, and serve as indicators of the underlying mental processes which enable strategies to be formed. For example, Tsapkini et al. (2014) found in a study of aphasia in Greek individuals that participants were more inclined to parse information from early phonological information (2014: 315) through syllable-parsing, than through decomposition of the morphological elements of words. Simmons-Mackie and Damico (1995: 95) identified that strategy usage by aphasic individuals can be predicted by a differentiation in 'transactional' and 'interactional' communication, the former referring to 'transacting an exchange of information', and the latter to communication which 'serves primarily to establish and maintain social relationships' (1995: 95). Purdy and Koch (2006: 337) found through testing participants' cognitive flexibility, that cognitive flexibility was a better predictor of participants' ability to use compensatory strategies than severity of aphasia.

These findings suggest that compensatory strategies are devised as part of a domain-general neural system, and that a number of cognitive domains are involved in the process of choosing and deploying compensatory strategies in aphasia. The study by Simmons-Mackie and Damico (1995) demonstrates this by showing how aphasic individuals are able to use

understanding of social and pragmatic cues to aid the decision of which strategies to deploy. Purdy and Koch (2006) demonstrate this perhaps more explicitly, as their findings show that aphasic individuals with higher cognitive flexibility, an indicator of the ability to innovatively access and use different domains of the language faculty circumstantially, are more effective at using compensatory strategies. Compensatory strategies, when viewed as the product of a domain-general system for language, provide insight into the ways in which the human brain is able to accommodate for unprecedented limitations imposed on it, such as those caused by Broca's aphasia, as the strategies provide evidence that other processing centres within the language faculty have been brought into use to accommodate the loss of linguistic access in the damaged area.

1.2.   *Complex Adaptive Theory*

This section will aim to briefly introduce complex adaptive theory, in order to contextualise the hypotheses made about compensatory strategy formation and the corresponding phenomena observed in the data analysis conducted for this study. Chan (2001: 1) describes complex adaptive systems as containing 'a large number of component systems at different levels of organization'. Holland (1992: 20) claims that 'because the individual parts of a complex adaptive system are continually revising their ("conditioned") rules for interaction, each part is embedded in perpetually novel surroundings (the changing behavior of the other parts)'. Complex adaptive systems can be defined by the presence of interconnected component systems, as mentioned by Chan, which are able to adapt and evolve their own operating procedures and abilities, based on findings from a constant stream of data inputs, provided to and by each corresponding component system. Holland (1992: 20) claims that complex adaptive systems 'exhibit an aggregate behaviour that is not simply derived from the actions of its parts', and furthermore that 'for the brain, [the aggregate behaviour] is the overt behaviour it evokes and controls'.

The relevance of complex adaptive theory to this study lies in the hypothesis that viewing compensatory strategies as the product of a complex adaptive system can rebut the idea that these strategies are 'heuristic'. Instead, from this perspective, compensatory strategies can be viewed as the product of a set of component systems operating under 'novel surroundings' as described by Holland (1992: 20). Chan's (2001: 1) suggestion of component systems within a complex adaptive system at different levels of organisation can also be applied to compensatory strategies. The 'novel surroundings' of stroke-induced aphasia are such that

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certain language-parsing component systems are lost or damaged, leading to retrieval issues. To resolve this issue, the language faculty, as a complex adaptive system, is able to utilise reactive cognitive flexibility (Rende, 2000) to instigate the use of the next available intact language-parsing component system in its place. Due to the fact that the newly activated parser will be at a lower level of organisation to the primary, impacted component system, the compensatory strategies it produces may consequently yield a lower probability of accurate, easily decodable outputs in speech. It is suggested in this study that this issue has led to the use of the label 'heuristics', in contrast to algorithmic processes (Caramazza & Zurif ,1976: 572-582). The issue taken here with this is that the processes *must* remain algorithmic, if being produced by a component system which is less organised for this purpose. This is because in order to remain adaptive, a complex adaptive system must base all alterations to its procedure on usage/frequency-based, probabilistic data inputs, collected within and between component systems.

Heimbauer et al. (2018: 268) note that 'it has been suggested that language use may be best characterized by relatively simple computational processes that may be more akin to finite-state systems than their more complex context-free counterparts'. The finite-state systems proposed here comply with the concept of component systems proposed by Chan (2001: 1). The finite-state systems proposed by Heimbauer et al. (2018: 268) are capable of simultaneous decomposition of finite-state grammars which consist 'of local organizational principles only, with statistical regularities limited to neighboring units or connected "states"'. It is proposed in this study that the complex-adaptive parsing mechanism available to Broca's aphasic individuals is more closely related to Heimbauer et al.'s interconnected network of finite-state systems, as opposed to a parser for a context-free phrase-structure grammar, which 'entails center embedding of units that form nested dependencies' (Heimbauer et al, 2018: 268). As a result, this suggests that the compensatory parsing methods of aphasic individuals do not pertain to heuristics but are part of an inhibited system, which has regressed to finite-state parsing following inhibition of the phrase-structure grammar parser. This suggestion will become relevant again in the study as it is applied to Clark's (2011: 724) use of 'heuristics' in the following section.

The idea of component system re-allocation for language parsing complements findings by Baumgaertner, Hartwigsen, and Siebner (2013, cited in Gainotti, 2015: 1025), who found in aphasic patients that 'functional activation in right-hemispheric homologues of classic left-hemispheric language areas may be partly due to processing nonlinguistic perceptual features

of verbal stimuli', a finding clarified by fMRI results. Gainotti claims that these findings may 'at least partially reflect increased attentional focus on nonlinguistic perceptual aspects of language' in aphasic patients with left-hemisphere stroke who exhibited activation of right inferior frontal areas during language tasks (Gainotti, 2015: 1025). This finding demonstrates a physical representation of the process of component system re-allocation, as the right hemisphere has been activated in absence of the functionality of the 'classic left-hemisphere language areas'.

1.3. Hypothesis 1: Point of Access

This section will introduce the first hypothesis, which suggests that rather than developing novel heuristic processing mechanisms, the post-stroke language faculty operates on the basis of re-allocating component systems, to accommodate a shift or loss in the point at which the premorbid system would acquire lexical access or word retrieval. Furthermore, this section will explore how compensatory strategies emerge as a result of component systems having to operate in the 'novel surroundings' (Holland, 1992: 20) of the post-stroke language faculty.

The term 'heuristic' has been used to refer to the self-educating nature of processes of compensatory strategy acquisition and development in a number of historic studies, including Caramazza and Zurif (1976: 572-582) and Kolk and Heeschen (1990: 221-231). Caramazza and Zurif justify use of this term by drawing comparisons to an 'algorithmic' equivalent process in non-aphasic speakers, creating the distinction that non-aphasic language parsing is mathematically logical, whilst heuristic compensatory strategies are not backed up by equally measured reasoning. Kolk and Heeschen (1990: 221-231), interestingly, refer to such heuristics as an 'adaptation symptom'. Both of these justifications for use of the term 'heuristic' will be interrogated here by looking at compensatory strategies as the product of a domain-general neural system for language.

Findings by Tsapkini et al. (2014) gave evidence that lexical access via morphology had a greater mental processing cost for participants with aphasia, than lexical access via syllabic content. Participants in their study perceived derived forms as linguistic wholes, with derivational affixes merged with the entire linguistic unit of words used in the test. As a

result, participants preferred the syllable as a point of lexical access over the bound stem morpheme, and made efforts to derive semantic content from the first syllabic unit in a word, to 'compensate for insufficient access to bound stems and suffixes' (2014: 315). Regarding the algorithmic-heuristic distinction proposed by Caramazza and Zurif (1976), this raises a theoretical question about how this process can be perceived. An intuitive response is to suggest that Tsapkini et al. exposed the algorithmic-heuristic distinction, by demonstrating participants' inability to algorithmically decompose the linguistic unit and perform minimal stripping of its elements, instead using a heuristic novel repair mechanism to extract semantic context from the next accessible layer, the syllable. However, the finding that aphasic participants were 'exploiting early phonological information' (2014: 315) fails to provide sufficient evidence to suggest that the procedure involved here is necessarily heuristic.

The reason for this can be explained by cognitive flexibility. Given the findings by Purdy and Koch (2006) that intact cognitive flexibility was a significant predictor of compensatory strategy use, there is a strong possibility that the participants were using another intact processing algorithm, borrowed from another neural domain. In premorbid language parsing, whilst a parser for morphosyntactic decomposition takes precedent, there are 'background' parsers constantly gathering data from other domains of speech, such as pragmatics, semantics, phonology, and prosody. The cognitive flexibility involved in this compensatory strategy lies in the ability to select the next best available background parser, to be substituted in place of the parser tied to the now lost point of access. This part of the process is where the compensatory strategy lies; once the parser has been selected, the process continues as it would in the premorbid system, but with shifted parameters. It can be expected that syllabic access yields a lower probability of target-like parsing accuracy than morphosyntactic decomposition, but that is the nature of being forced to operate a mechanism better geared toward an irretrievable point of access; the procedure's effectiveness is inhibited by the shifted parameters, but the involved algorithm itself does not become heuristic.

An example created by Su, Lee, and Chung (2007, cited in Clark, 2011: 724) was used by Clark (2011: 724) to evidence that heuristic processes play a role in aphasic speech comprehension. Using the following example expression, Su, Lee, and Chung (2007) found that Mandarin-speaking participants had little difficulty in interpreting predicate adjectives in the matrix clause of centre-embedded subject-relative sentences, unlike English participants (Hiccock et al, 1993, cited in Clark, 2011: 724).

zhui   gou   de   [maoi   hen   xiao]

chase   dog   COMP   [cat   very   small]   *(Clause-final substrings in square brackets)*

The cat that chased [the dog was very small].

Clark cites the agreement of the clause-final substring with the matrix clause *'the cat… was very small'* (i.e *'cat very small'* in Mandarin has agreement; *'the dog was very small'* in English, does not) as a predictor of participants' ability to correctly attribute agent and theme roles. Whilst there is sound cause to suggest, based on the outperformance of English-speaking participants by Mandarin-speaking participants, that thematic role assignment has been accessed at the clause-final substring, the suitability of this finding as evidence of a 'heuristic' parsing procedure is debatable. What can be established from this finding is that a point of access change has enabled the emergence of a re-allocated parser from elsewhere in the domain-general system to decode the sentence. The original, premorbid point of access to the thematic roles lay in the morphosyntactic structure of the entire expression. However, with loss of access to centre-embedded subject-relative clause decomposition, the Mandarin-speaking participant instead detaches the clause-final substring, 'cat very small', from the entire expression, accessing the substring as an unambiguous, decodable unit with S-V-Adj structure.

Clark (2011: 725) refers to this as operating at 'chance level' and claims 'subjects are incapable of computing certain structures and therefore guess' (2011: 725). However, a usage-based approach to this issue, complemented by complex adaptive theory, can be used to illustrate the argument that the degree of 'chance' involved does not necessarily determine a process as heuristic. Firstly, there is cause to argue that chance is involved in *all* neural parsing processes; in a domain-general system, the brain uses the processing centres and points of parsing access which it expects will yield the highest accuracy in parsing output. This is an inherently probability-led means of operating, and is learned from usage-based data collection. The language faculty in this instance, having lost access to centre-embedded subject-relative clause decomposition, must perform the same process at the next best available point of access, which is the syntactically simpler and wholly decomposable clause-final substring, which tells them that the cat in question is very small. The idea that this is guesswork neglects to appreciate that blind guessing as a means of processing information is typically unnatural to the premorbid language faculty. Clark makes a misconception in

assuming that because the participant has selected an access point and a language parser which would naturally yield a lower probability of target-like accuracy than parsing via morphosyntactic decomposition, this means that the individual has adopted a novel parsing mechanism which simply surmounts to 'guessing'. Guesswork is never part of a premorbid language faculty; the only way humans can ever operate is by using the best available component network, applied to the best available point of parsing access. Limitations to access points inflicted by aphasia do not spontaneously arouse the emergence of novel heuristic parsing mechanisms; this would require instead some sort of cognitive development that would not naturally emerge from the instances of trauma or neurodegenerative diseases which cause aphasia.

What better suits this phenomenon than guessing or heuristics is regression from phrase-structure parsing to finite-state parsing. There is clear parsing of the 'local organisational principles' as mentioned by Heimbauer et al. (2018: 268) as part of a finite-state system. This is shown in the parsing prioritisation of the clause-final substring, which involved decoding of a simple, localised grammatical governance. The issue of centre-embedment in Su, Lee, and Chung's exemplar utterance relates coherently to a phrase-structure grammar based on 'nested dependencies' (Heimbauer et al. 2018: 268), the parser to which has been inhibited in the aphasic individual. Complex adaptive theory then states that a non-heuristic, but finite-state grammar based parser has been substituted for the premorbid system, which has resulted in parsing of the clause-final substring.

The term 'repair mechanism' as used by Tsapkini et al. (315) implies a whole mechanism present in the aphasic brain which is absent in the non-aphasic linguistic parser. However, under complex adaptive theory, the only possibility is that the same probabilistic algorithm, used by aphasic individuals for syllabic decomposition, is present in both aphasic individuals and non-aphasic individuals, and here has been borrowed from some other area of neural processing for use in language. All of these previously mentioned terms, 'heuristic', 'repair mechanism', 'adaptation symptom', are problematic because they suggest the emergence of something in the aphasic brain which non-aphasic individuals do not have, which is accurate given the nature of the physical condition of aphasia. What each of these terms neglect to consider is that the brain has simply re-allocated another algorithmic processing centre to resolve the issue of lost access. This complements findings by Purdy and Koch (2006), that individuals who had acquired compensatory strategies eventually also learned to generalise the new strategies to other areas of their life, which suggests that these strategies do play a

part in a domain-general, complex adaptive neural system which substitutes and borrows areas for processing, dependent on situational relevance and intact points of access. As a result, the procedural difference here can be seen as merely a response to a different point of access.

The interrogation of the use of 'heuristics' in this section would be insubstantial without supplementary data analysis which actually supports the 'point of access' hypothesis. This hypothesis was illustrated following a finding in the TalkBank data (MacWhinney et al., 2011) that participants frequently omitted clause-medial verbs, which will be reviewed in detail in Part 2 of this paper. The hypothesis surrounding this finding is that, following loss of retrievability of the clause-medial verb, participants divert the access point of the verb's semantic content to the verb's corresponding argument, or to the argument which takes the thematic role of theme or recipient in a transitive structure. It is believed that this finding reaffirms the complex adaptive system approach, as participants demonstrate cognitive flexibility here, firstly by substituting phonetic access for lexical access via *pragmatic* cues, placing greater weight on probabilistic context dependency. The aphasic individual further demonstrates cognitive flexibility by trying to elicit the same flexible reasoning in the other interlocutor, who must decode the content of the unvoiced verb using pragmatic and contextual understanding. This is emphasised by instances of participants placing prosodic stress on the argument from which they aim to elicit the unvoiced verb. This demonstrates how compensatory strategies rely on premorbid and algorithmic strategies based on probability, rather than on novel heuristic means.

1.4.   *Hypothesis 2: Reanalysis*

The first hypothesis aimed to define 'point of access' as a defining reason why the procedures of compensatory strategy formation are not heuristic but are instead dependent on a complex adaptive neural network. This section proposes a second, interconnected hypothesis, which also suggests the role of a complex adaptive system as part of compensatory strategy formation. In this section, it is hypothesised that a number of identified compensatory strategy formation procedures in fact evidence semantic/syntactic reanalysis. Langacker's (1977: 58) definition of semantic/syntactic reanalysis will be utilised here, which suggests reanalysis involves structural changes to an expression prior to immediate or intrinsic modifications to its surface structure. This is a useful definition which emphasises reanalysis

of underlying forms, which in turn permits critical analysis into the relationships between mental representations of underlying forms and surface-structure expressions, and for the purpose of this study, how the limitations of aphasia may impact these relationships.

This section will aim to introduce the pre-established understanding of reanalysis as a neural linguistic function, then discuss how this process can provide a procedural platform on which compensatory strategies can emerge. This will be achieved through review of compensatory strategies in the existing literature, including Simmons-Mackie and Damico's (1997) study. The emergence of compensatory strategies as epiphenomena of reanalysis will be compared to the emergence of grammaticalisation, a well-researched phenomenon which is viewed as a derivative of grammaticalisation (Traugott and Trousdale, 2010). A comparative review of the procedural stages which lead to grammaticalisation, against those which lead to compensatory strategies, will be made in this section. Finally, this section will introduce the data analysis used in this study, which will further be used to suggest reanalysis as a predictor of compensatory strategy formation.

An intuitive way to define how linguistic reanalysis works is to approach reanalysis via its relationship with grammaticalisation. Traugott and Trousdale (2010) identify grammaticalisation as a 'derivative' of reanalysis, with grammaticalisation occurring at the surface-structure level, following reanalysis, which impacts the structure of underlying forms. Traugott and Trousdale also refer to how Roberts and Roussou (2003: 202) identify grammaticalisation as 'successive upward reanalysis along the functional hierarchy', meaning that grammaticalisation is a unidirectional process consisting of sequential re-analyses of one linguistic structure. Lehmann's (2004: 165) comments on reanalysis state that 'reanalysis is a categorical process, grammaticalization is a gradual process' and demonstrates this distinction through two illustrative sequences. Firstly, Lehmann gives the sequence of surface level change in grammaticalisation, 'S1, S2, … Sn'. This is then shown to be underpinned by a sequence of independent underlying reanalyses, which give the sequence 'S1 > S2, S2 > S3' and so on. This distinction shows grammaticalisation, shown in the first sequence, as the result of unidirectionally sequenced changes. Reanalysis, demonstrated in the second sequence, is shown as strings of independent, stand-alone re-analyses of forms at each stage: 'it is a sheer coincidence if S2 turns out to be to S3 as S1 was to S2' (Lehmann, 2004: 165). To conclude this definition, an individual reanalysis can be viewed as the 'abrupt' (Haspelmath, 1998: 327, cited in Traugott & Trousdale, 2010), synchronic moment at which

elements of the underlying form of an individual linguistic unit obtain a new semantic/syntactic structure.

It is hypothesised that, similarly to grammaticalisation, identifiable compensatory strategies of aphasia are a surface-structure level derivative (Traugott & Trousdale, 2010) of linguistic reanalysis. In order to illustrate this, this section will look at the neural processes involved in grammaticalisation which have been observed in the existing literature, and apply these processes to compensatory strategies. Grammaticalisation refers to a process whereby a linguistic construction (Bybee, 2003: 602) obtains a new semantic or grammatic structure through use over time in a new linguistic context. Cheshire (2007: 155-193) identifies four stages which constitute the process of grammaticalisation: 'phonetic reduction, decategorisation, semantic change and pragmatic shift'. Bybee (2003) applies a usage-based approach to understanding how these processes come about, claiming that grammaticalisation relies on 'habituation'. Habituation refers to a process whereby high-frequency usage of a linguistic construction leads to weakening of its 'semantic force', to the extent that the meaning of a construction, in its new grammaticalized context, becomes dissociated from its meaning in its original context. This loss of association enables the element to be used in new contexts with new pragmatic associations (Bybee, 2003: 602). This is relevant to findings in this study that aphasic individuals developed habituated discourse markers.

Furthermore, examination of some procedural definitions of grammaticalisation exposes its emergence as a product of linguistic reanalysis. Heine (2003: 579) defines four changes to constructions which result from the grammaticalisation process: desemantisation, pertaining to semantic loss; extension, pertaining to shift in its pragmatic use; decategorialisation, pertaining to morphosyntactic category loss; and erosion, pertaining to loss of phonetic substance. This definition of the grammaticalisation procedure is preferred for the context of this study because it shows that whilst grammaticalisation can be viewed as a fluid, diachronic phenomenon, there are clearly rigid and synchronic intersections at which reanalysis meets surface-level changes. Following Bybee's (2003) usage-based approach, this appears to occur on two intersections: first, at the intersection of pragmatics (habituation) and semantics (desemantisation), whereby highly frequent usage of a construction weakens its semantic force (Bybee, 2003: 602). At this intersection, there is reanalysis of the semantic meaning of a construction, which is based on an understanding of how the construction operates pragmatically in both its initial context and in its new, grammaticalized context. The next intersection is between desemantisation (semantics) and decategorialisation

(morphosyntax), whereby reanalysis of the meaning of a construction governs any subsequent surface-level changes to its morphosyntactic structure, when used in its new grammaticalized context. This exposes how the surface structure of a construction becomes grammaticalized following the initial stage of reanalysis, and how the process of grammaticalisation therefore entails reanalysis.

This section will seek to expose the presence of these intersections, between reanalysis of underlying forms and changes at the surface-structure level, in observed compensatory strategies. Compensatory strategies found in past studies include the creation of idiosyncratic discourse markers by individuals with aphasia, which are used to improve the fluency of discourse on occasions when the aphasic individual is struggling to access a certain required expression (Simmons-Mackie & Damico, 1997). These discourse markers can contain chunks of phrasing which are high-frequency in speech and familiar to the individual, but with their semantic/syntactic structure modified in order to function in new contexts.

Simmons-Mackie and Damico refer to certain discourse marker production by observed participants with aphasia as 'a recast of a premorbid or normal conversational behaviour', providing the example of a participant who used the phrase 'all the time' on many occasions to express magnitude, identifying that 'the phrase referred not only to time, but also to amount, size or number' (1997: 768). It is suggested here that this compensatory strategy indicates a semantic/syntactic reanalysis process. The individual units within the phrase 'all the time' can be seen to have undergone semantic reduction, leading to a shift in autonomy from the individual units to the entire expression. This pertains to Langacker's (1977) idea of boundary loss between the individual units, in turn enabling semantic over-generalisation of the phrase based on its quality of 'magnitude'. Viewing this compensatory strategy in this way permits the application of Bybee's habituation process (2003: 602) in grammaticalisation, to the effect that the 'semantic force' of the individual units within the premorbid phrase 'all the time' has been weakened as the phrase has become over-generalised through frequent use in its new context. Furthermore, Heine's (2003: 579) stages of desemantisation and decategorialisation also apply to this use of the expression, as the phrase has been generalised beyond its original pragmatic use, and has lost its original specific semantic structure. Bybee describes the process of reduction in grammaticalisation as the product of 'loss of compositionality and analysability' (2011), which is also applicable to Simmons-Mackie and Damico's 'all the time' strategy. The composition of 'all the time' as

an adjectival noun phrase is lost, as neither the concepts of 'all' nor 'the time' are specifically relevant in their new pragmatic contexts, meaning that the phrase can no longer be syntactically decomposed nor analysed in this way.

The processes of semantic reduction and habituation described by Bybee (2003, 2011), observed both in grammaticalisation and in compensatory strategies such as this one, can be viewed in both contexts as surface-structure level changes which are the product of individual, independent re-analyses of underlying forms, as defined by Lehmann (2004: 165). The clearest distinction between re-analyses in compensatory strategies and in grammaticalisation involves the issue of circumstance, and in turn the timescale on which they occur. Grammaticalisation processes, such as the '*going to*' → '*gonna*' example provided by Bybee (2003: 624), are the result of a desire to maximise expressivity and minimise the cost/effort of expressivity. This enables these processes to occur on a diachronic scale, negotiated in the E-language (External language) interface of an entire speech community. In contrast, compensatory strategies such as the 'all the time' example must occur synchronically and instantaneously to accommodate a loss of lexical access, before they can become habituated into something close to what Kolk and Heeschen refer to as 'adaptation symptoms', which they describe as 'behavioural abnormalities that are the result of a patient adapting to impairment' (Kolk & Heeschen, 1990: 221). The point of access, as a result, is also different in the process of compensatory strategy formation and grammaticalisation. This is because the diachronic sequence of re-analyses involved in grammaticalisation suggest a sort of 'moving target', whereby the grammaticalized expression, as a point of access, is altered with each successive reanalysis. In contrast, the re-analyses in compensatory strategies are synchronic and 'abrupt' processes, in line with Haspelmath's definition (1998: 327, cited in Traugott & Trousdale, 2010), and occur at one immediately-retrieved point of access, which is the initial, 'premorbid' (Simmons-Mackie & Damico, 1997: 768) expression.

Data collection conducted in this study complements the findings by Simmons-Mackie and Damico (1997), which are suggested to evidence semantic reduction and habituation in compensatory strategies in aphasia. A phenomenon observed in the TalkBank data whilst collecting data for the present study was that participants tended to produce structures containing auxiliary verbs at a significantly greater rate, when in the context of habituated discourse markers. The hypothesis suggests that these phrases have become automated as a

means of expressing difficulty in speech, in order to elicit assistance or patience from the other interlocutor. This evidences usage-based semantic weakening as described by Bybee (2003: 602), and boundary loss as described by Langacker (1977).

Having established how compensatory strategies can emerge as an epiphenomenon of reanalysis in a similar fashion to grammaticalisation (I. Roberts 1993: 254, cited in Traugott & Trousdale, 2010), it can be evidenced how these strategies operate as part of a complex adaptive system. Comparably to the to the previously mentioned compensatory strategies observed by Clark (2011: 725) and Tsapkini et al. (2014), the neural procedure underlying the 'all the time' strategy can be illustrated in a way which aligns with complex adaptive theory, as it demonstrates a re-purposing of reanalysis, a premorbid linguistic universal, for a novel purpose. The immediate loss of lexical retrieval has been accommodated for in this instance by the use of a premorbid parsing system, used previously to execute grammaticalisation processes in the aid of maximising expressivity. The compensatory strategy here achieves the same purpose, and operates with observable procedural similarities, only under novel circumstances and with the increased pressure of having to occur instantaneously, to aid conversational fluency. Furthermore, these types of reanalysis can only occur within the I-language (Internal language) of the individual, rather than enjoying the mutually-agreed interface of the E-language shared by an entire speech community. These distinctions, however, only concern the *circumstance* of these different kinds of re-analyses, and do not stretch so far as to suggest that the *procedure* itself of the compensatory strategy, as a result, must be heuristic.

1.5.   *Conclusion*

This section proposes two hypotheses which provide cause for the application of complex adaptive theory and usage-based theory to compensatory strategies. The 'point of access' hypothesis suggests that compensatory strategies are the product of substituted component systems (Chan, 2001: 1) within a complex adaptive system, which are deployed for linguistic parsing following loss of component systems prioritised for use in the premorbid system. The 'reanalysis' hypothesis sought to demonstrate practically how this process can occur, as the parser for linguistic reanalysis is re-purposed to accomodate the novel circumstances of processing inhibitions inflicted by aphasia. Both of these hypotheses favour an algorithmic approach to compensatory strategies rather than introducing heuristics, as the component

systems, whilst operating in novel surroundings (Holland, 1992: 20), are 'remains of a premorbid system' (Gleason et al. 1975) and are not activated for instantaneous self-educating means.

PART 2

2.1. INTRODUCTION

The proposal behind this piece of research is that observable speech behaviour taken from participants with Broca's aphasia can provide evidence to the contrary that compensatory strategies are to be considered 'heuristic'. The hypothesis is that re-purposed premorbid language parsing methods, used as part of a complex adaptive system, can be evidenced in the speech of individuals with Broca's aphasia, through compensatory strategies which evidence two processes: shifts in points of parsing access, and linguistic reanalysis. The latter will be shown through compensatory strategies which demonstrate similar reanalysis patterns to those observed in the process of grammaticalisation in English. The rationale behind these hypotheses is that the parsing procedures are both algorithmic, and are borrowed from the premorbid language parser, and as such do not meet the criteria of a 'heuristic' process. This study will use data taken from interviews taken from TalkBank, and will involve observation of two speech phenomena, which are:

- Unvoiced clause-medial verbs
- Auxiliary production internal to discourse markers

Each of these phenomena were identified within the TalkBank interviews. This section will provide an overview of each of these linguistic phenomena, and will address reasons for their selection. Participant data which exhibited these linguistic phenomena were selected for review in this study because they provided the most appropriate data with which to test the hypothesis. This is because the identified commonality between these two phenomena is that they are capable of providing evidence for re-purposed premorbid parsing methods within a complex adaptive system, suggesting that the involved procedures are inherently algorithmic rather than heuristic.

Chan (2001: 1) claims that complex adaptive systems can be 'characterized by apparently complex behaviors that emerge as a result of often nonlinear spatio-temporal interactions among a large number of component systems at different levels of organization'. This

definition holds relevance to both of the hypotheses in this study and the corresponding phenomena used to test them. Regarding the 'point of access' hypothesis, tested through observation of unvoiced clause-medial verbs, the substituting of phonetic parsing for pragmatic and usage-based probability parsing involved in eliciting the unvoiced verb is suggested to demonstrate the co-operation of numerous 'component systems at different levels of organisation'. Furthermore, the reanalysis hypothesis, tested through observation of auxiliary verb production in discourse markers, relates to the idea of 'nonlinear spatio-temporal interactions'. Lehmann's (2004: 165) proposal that re-analyses occur independently of each other also complements Chan's suggestion that spatio-temporal relations in complex adaptive systems are 'nonlinear'.

Phenomenon 1: Unvoiced Clause-Medial Verbs

One observed behaviour was that clause-medial verbs were frequently omitted from speech. This phenomenon is realised in sentences such as *'and then you hafta … peanut butter'* (MacWhinney et al., 2011). This sentence was taken from the 'peanut butter and jelly sandwich task' (MacWhinney et al., 2011), in which participants are asked to describe the process of making a peanut butter and jelly sandwich. On the surface, what may appear to occur in this instance is that the participant has simply omitted the verb due to lack of lexical access, leaving the utterance with missing semantic information. However, what is hypothesised here is that the verb, rather than being omitted, is instead *unvoiced*.

Broca's aphasia inhibits the production and vocalisation of certain expressions in certain contexts, but is not a speech disorder which tends to significantly impact language comprehension. Thompson and Shapiro (2005: 1026) cite that 'Broca's aphasic individuals retain access to verb argument structure during online processing, yet show deficits in verb and verb argument structure production'. Therefore, within the mental lexicon of the aphasic individual, the underlying form within the V node still contains the semantic/syntactic content of the target form. Therefore, the VP, assumedly *'spread the peanut butter'*, is sub-vocally present in the sentence, but due to an issue of lexical access it cannot be vocalised. However, rather than simply 'giving up' on trying to provide this information, the participant instead skips to the next accessible argument, 'peanut butter'. The semantic information contained in the sentence-final argument 'peanut butter' allows the participant to use context and pragmatics to gather the unvoiced information.

Phenomenon 2: Production of Auxiliary Verbs Internal to Discourse Markers

One behaviour identified in the observed participants was the deployment of idiosyncratic discourse markers. These can be used for a number of reasons, but typically are used to balance the rhythm of conversation, preventing long pauses or inconsistencies within their speech. These discourse markers are particularly used in instances where the individual may be struggling for lexical access of a term which they may be trying to express, or struggling to find another appropriate strategy for expressing themselves. These instances are referred to here as 'struggle signals', as they are attempts by the aphasic individual to express to the other interlocutor that they are struggling with some aspect of their communication. One observation of note was that in some instances, these discourse markers contained fully realised, standardised grammatical structures which were not present in any other areas of speech. For example, one participant was able to repeatedly construct the phrase *'I don't know how to say it'*, containing the accurately executed auxiliary *don't*, with accurate negative contraction. What this indicates is that this feature, predictably a memorisable utterance, has become a whole, autonomous structure. The ability to execute the VP with auxiliary effectively within the structure of discourse markers, but significantly less effectively elsewhere in speech, demonstrates a usage-based habituation process similar to the habituation stage of grammaticalisation laid out by Bybee (2003: 602).

Given that the participant demonstrates a lack of access to these more difficult VP structures elsewhere, it is likely that syntactic reduction has taken place and the form has been re-analysed as part of a new autonomous structure. Semantically, the meaning of the new autonomous structure has been generalised, to also cover instances where the speaker is not completely lacking in access to the target utterance, but is using the discourse marker as a 'struggle signal' to indicate that they may need time or some guided assistance from the other interlocutor. Langacker's (1977) resegmentation typology of reanalysis can be demonstrated through this use of discourse marker. This reanalysis demonstrates the 'boundary shift' Langacker cites as an underlying feature of resegmentation, with the reduction of the grammatical morpheme specifically within the auxiliary *'don't'*, and shift of the morphemic boundary such that it affects the entire structure of the utterance. Semantically, what is retained is the sense of negation which is communicated as part of the 'struggle signal', suggesting that there is some linguistic or access issue present, and the required form of expression or target utterance is not immediately available.

Gahl and Menn (2016: 1373) claim that 'studies of probabilistic effects at the sentence level in aphasia are essential', due to the fact that sentence comprehension in aphasia has a 'gradient nature… rather than being intact or absent'. This study complements this recommendation, as it respects the non-binary nature of retrievability loss and production inhibition, by examining these phenomena through usage-based data. This also complements the theoretical approach of complex adaptive theory, as probabilistic behaviour data can expose the effectiveness of different deployed component systems.

2.2. METHOD AND DATA

Use of probabilistic data

In order to test the ability of the observed phenomena as predictors of complex adaptive responses, each was assigned a measurable variable, so that probabilistic data could be collected. A probabilistic approach was favoured on the basis of Gries and Ellis' (2015: 230) claim that 'the most fundamental factor that drives learning is the frequency of repetition in usage'. Gries and Ellis (2015: 229) also claim that 'assessing these probabilities is nontrivial, because constructions are nested and overlap at various levels' and that 'there is continuing interplay… between memorized structures and more open constructions.' Exploring the probability of compensatory strategy usage helps not only to extract these constructions from large chunks of speech, but also to identify 'memorised structures' through high-frequency phenomena observed in the data.

On the basis of findings by Purdy and Koch (2006), it is hypothesised that a high probability of compensatory strategy usage more strongly suggests the involvement of cognitive flexibility, enabling the use of complex adaptive responses and linguistic reanalysis. It is suggested that results yielding high variable probabilities would indicate that the underlying processes involved in producing these strategies are favourable to the individual, are easily accessible, and existed within the premorbid language faculty. Comparatively, a heuristic 'repair mechanism' (Tsapkini et al., 2014) which had only arisen following the development of aphasia, would need time to fully take shape and become consistently effective, and even longer for the individual to become comfortable and adept at utilising the mechanism to form

compensatory strategies (Kolk and Heeschen, 1990). It is therefore predicted that high probabilities in the data would suggest that participants are comfortable using these strategies intuitively, suggesting furthermore that strategy formation procedures are much more likely to stem from premorbid processes.

The Data

Corpus participant data was acquired from TalkBank. The corpora data was taken from the corpora BU, Elman, Fridricksson, and MSU (MacWhinney et al., 2011). A total number of six participant interviews were examined. All participants had aphasia in the form of stroke-induced Broca's aphasia. This type of aphasia was preferred for this study because it permitted judgments about grammatical parsing components, concerning whether the processes performed by these components are part of a premorbid system, or are the result of damage within a post-stroke language faculty.

As the interviews between corpora varied in length, probabilities were taken using percentage scores proportional to the length of each individual interview. All quantitative data is taken from readings of the transcribed interviews. The video interviews were analysed for additional qualitative context which will be reviewed in the *Results* section when necessary. Participant interviews were selected based on observed presence of the outlined phenomena, in order to be able to test the hypotheses for each. A measured variable was drawn up for each phenomenon in order to best determine the relationship between the observed phenomena and the corresponding hypotheses for each. These variables are as follows.

Phenomenon: Unvoiced Clause-Medial Verbs

Variable: Rate of Clause-Medial Verb Omission

The measured variable for this phenomenon is the rate of omission of clause-medial verbs. It is predicted that a significant probability of clause-medial verb omission would indicate the use of a learned compensatory strategy, acquired in a fashion comparable to Kolk and Heeschen's 'adaptation symptom' (1990). Furthermore, if compensatory strategy has been identified through this variable, this indicates that that omitted verbs are unvoiced rather than completely omitted, with their underlying form accessible via pragmatic decoding. Verbs counted in the interviews were organised as 'omitted' or 'retained'. For consistency, and to make 'omitted verbs' a measurable unit, omitted verbs are defined as instances in which the

structure of a vocalised participant utterance can be uncontroversially seen to lack an accurately produced clause-medial verb, which would make the expression target-like.

Phenomenon: Habituated Auxiliary Verbs in Discourse Markers

Variable: Rate of Discourse Marker-External Auxiliary Production

The measured variable for this phenomenon is the rate of production of auxiliary verbs external to identified discourse markers. It is predicted that a high frequency of auxiliaries used in discourse markers, with low frequency in non-discourse marker utterances, will indicate that the auxiliaries within discourse markers have undergone semantic reduction, whilst retaining their phonetic structure. It is predicted that the elements within the expression have undergone semantic reduction due to habituation, to the effect that the expression has lost its original meaning and now serves instead as a pragmatic functor. To aid consistency in measuring this variable, discourse markers will be defined as vocalised expressions which identifiably meet the following criteria: firstly, that the expression is unrelated to the semantic content of the present discourse, and can be uncontroversially considered a pragmatic device; second, that the expression demonstrates a desire to express difficulty in self-articulation. The rate of production was based on the proportion of discourse marker utterances to the whole number of participant utterances within the interview.

2.3. RESULTS

Two sets of data were analysed in this study to test two variables: omission of clause-medial verbs, and the rate of discourse marker-external production of auxiliary verbs. Statistical significance was determined by p values acquired from chi-squared tests conducted for each variable, based on observed frequencies and corresponding expected frequencies.

Test 1: Clause-Medial Verb Omission

Clause-medial verb omission rates were measured to determine whether participants were attempting to elicit inaccessible verb data pragmatically, through context-based probability conditioning via the surrounding arguments and complements. It was predicted that a significant probability of clause-medial verb omission would indicate that this phenomenon

was being executed as a means of acquired compensatory strategy. The dependent variable for this data analysis was the frequency of clause-medial verb omission. The independent variable was the participant interview selected. The dependent variable was a categorical variable, with result values categorised as 'omitted' or 'retained'. Clause-medial verb omission results showed a mean (M) of 28.14% with a standard deviation (SD) of 14.06. The results of a chi-squared test revealed that this score was extremely statistically significant (chi-squared = 43.886 (2df), $p < 0.001$, where $*p < .05$; $**p < .01$; $***p < .001$). Raw frequency data are shown in Table 1 with expected frequencies in Table 2.

Table 1.

OBSERVED FREQ	PARTICIPANT 1 (%)	PARTICIPANT 2 (%)	PARTICIPANT 3 (%)	M (%)
OMITTED	11.11	27.78	45.54	28.14
RETAINED	88.89	72.22	54.46	71.86

Table 2.

EXPECTED FREQ	PARTICIPANT 1 (%)	PARTICIPANT 2 (%)	PARTICIPANT 3 (%)	M (%)
OMITTED	34.81	28.29	21.33	28.14
RETAINED	65.19	71.71	78.67	71.86

The data for this variable suggests that clause-medial verb omission is a significant identifiable speech behaviour in the observed participants. This strongly supports the hypothesis that compensatory strategy has been deployed, as significant probability of usage implies this is an acquired speech behaviour.

Test 2: Discourse Marker-External Auxiliary Production

Discourse marker-external production rates were measured to determine participants' proficiency in producing novel auxiliaries in other linguistic contexts. It was hypothesised that a low discourse marker-external production rate would indicate the semantic reduction of auxiliaries through habituation of discourse-marker production. Participant interviews for this variable were selected in which each participant exhibited one identifiable discourse marker. Accurate production of auxiliary verbs was demonstrated in each usage of discourse markers,

and their production data is shown in Table 3, which shows the frequency of utterances which contained the observed discourse marker. Whilst discourse marker production frequencies were low, 100% of produced discourse markers contained at least one accurately-produced auxiliary verb.

Table 3.

	DISCOURSE MARKER	PRODUCTION FREQUENCY (%)
PARTICIPANT 4	*'I don't know how to say it'*	7.3
PARTICIPANT 5	*'How am I gonna do that?'*	3.2
PARTICIPANT 6	*'Don't care'*	3.6

The dependent variable for this data analysis was the frequency of utterances containing discourse marker-external auxiliary verbs. The independent variable was the participant interview selected. The dependent variable was a categorical variable, categorised as '+AUX', which refers to utterances which contain discourse marker-external auxiliaries, and '-AUX' referring to utterances not containing discourse marker-external auxiliaries. This variable showed a mean of 11.3% with a standard deviation of 14.15. The results of a chi-squared test revealed that this score was extremely statistically significant (chi-squared = 23.268 (2df), p = <0.001, where *p < .05; **p < .01; ***p < .001). Raw frequency data are shown in Table 4 with expected frequencies in Table 5.

Table 4.

OBSERVED FREQ	PARTICIPANT 4 (%)	PARTICIPANT 5 (%)	PARTICIPANT 6 (%)	M (%)
+AUX	21.1	11.7	1.1	11.3
-AUX	78.9	88.3	98.9	88.7

Table 5.

EXPECTED FREQ	PARTICIPANT 4 (%)	PARTICIPANT 5 (%)	PARTICIPANT 6 (%)	M (%)
+AUX	10.1	11.2	12.6	11.3
-AUX	89.9	88.8	87.4	88.7

The data for this variable suggests that discourse marker-external auxiliary production is significantly low. Discourse marker-internal production rates, at 100%, were 88.7% higher

than discourse marker-external production rates, at 11.3%. This suggests that this variable strongly supports the hypothesis that auxiliaries within discourse markers are produced habitually and have undergone semantic reduction, as the data suggests significantly low proficiency in auxiliary production in novel linguistic surroundings.

Overall, both of the phenomena tested for were shown to be statistically significant and results consistently merited cause to suggest that they support the hypotheses corresponding to the use of compensatory strategies, which include clause-medial verb access through pragmatic decoding, and the linguistic reanalysis of discourse markers to serve as struggle signals through semantic reduction of their vocalised elements.

2.4. DISCUSSION

Phenomenon 1

Prior to conducting the data analysis, it was hypothesised that results yielding statistical significance for phenomenon 1 would indicate 'unvoiced' rather than omitted clause-medial verbs. What this means in practical terms is that whilst access to the vocalised target verb is still inhibited by aphasia, its underlying form is still retained within the structure of the expression. This is not achieved by altering the underlying structure of the verb itself, but by substituting the component system (Holland, 1992: 20) through which it is accessed in the neural language parser. The results appear to confirm this hypothesis, as the statistical significance of the frequency of this phenomenon within the speech data suggests acquisition of a learned behaviour comparable to an adaptation symptom (Kolk & Heeschen, 1990).

Ellis (2006: 8, cited in Gries and Ellis, 2015: 229) claims that in language acquisition, individuals are tasked with learning 'P(interpretation | cue, context), the probability of an interpretation given a formal cue in a particular context, a mapping from form to meaning conditioned by context'. This idea can be applied to the compensatory strategy on display here. The aphasic individual firstly learns this probability score for a range of linguistic contexts over a lifetime of language use. As a result, they are then able to assess the degree of conditioning by the linguistic context on the probability of an interpretation of the cue, here the unvoiced verb. The individual then must determine that the conditioning of the unvoiced verb's linguistic context is strong enough for them to assume that the other interlocutor will be able to interpret the unvoiced verb from its surrounding context. The aphasic individual is

attempting to elicit a complex adaptive response in the other interlocutor to the effect that their phonetic language parser 'downs tools' and hands the processing cost over to their pragmatic language parser. This demonstrates reactive cognitive flexibility as described by Rende (2000:21) as 'the ability to shift cognitive set, thought, or attention to perceive, process, or respond to situations in different ways'. Furthermore, this demonstrates a probability-focussed algorithmic process within a complex adaptive system, containing 'component systems at different levels of organization' as described by Chan (2001: 1). This contradicts the notion of 'self-educating' heuristics, as the aphasic individual is taking significant cognitive cost to use parsing methods which are readily available to both the aphasic language parser and to the intact premorbid parser, using algorithmic processes shared by both.

Under usage-based theory and complex adaptive theory, it can be suggested that this compensatory strategy is defined by regression of the phrase-structure parser to a finite-state parser, suggesting a change in neural network activation, rather than the novel production of a heuristic parsing mechanism. Rather than relying on dependencies within the syntactic phrase-structure of the expression, a usage-based pragmatic parser has been activated, with a set of finite-state organisational principles (Heimbauer et al., 2018: 268) pertaining to usage-based conditioning for context probability. The inhibited phrase-structure parser, damaged by the physical aphasia symptoms, cedes priority to the finite-state context probability parser. This finite-state mechanism has been activated as a result of being substituted in as the available component system which is expected to yield the highest parsing accuracy. What distinguishes this from heuristic parsing is that this mechanism is not novel or instantaneously self-educating, but has in fact been ever-present in the premorbid parser as a background or supplementary operator. Within a usage-based system, Pleyer and Hartmann (2019: 3) claim that 'linguistic knowledge, and knowledge of constructions, proceeds via the abstraction and schematization of actual language use in context, yielding fixed chunks as well as more abstract linguistic patterns that become cognitively entrenched'. In structures such as transitive SVO utterances, the cognitive entrenchment of these 'fixed chunks' can be identified in their ease of access via the means of probabilistic parsing demonstrated in this compensatory strategy.

Phenomenon 2

The hypothesis for phenomenon 2 was also confirmed by the results of the data analysis. It was hypothesised that a disproportionately high probability of accurate auxiliary verb production internal to discourse markers, compared to discourse marker-external production, would indicate that the auxiliaries within discourse marker structures would have incurred semantic reduction, following a shift to phrasal autonomy spanning the structure of the entire expression. With a production disparity of 88.7% between discourse marker-internal and external auxiliary production, this hypothesis is shown to have been supported with statistically significant results. This indicates a reanalysis based parsing process. Following the hypothesis, the participants, having identified the need to produce a novel utterance structure to compensate for inhibitions in their conversational fluency, have re-analysed frequent premorbid units of speech as entire autonomous phrases which serve this new discourse function. This is complemented by the identifiable use of premorbid phrases with negation as a theme of their semantic properties, such as *'don't care'*, or more explicitly, *'I don't know how to say it'* indicating a need to express negated lexical access, or negated expressive ability in that moment. This not only indicates the use of a non-heuristic and premorbid parsing system in linguistic reanalysis, but it also demonstrates the ability of the complex adaptive system to prioritise component systems in novel surroundings; the parser for linguistic reanalysis through boundary shift (Langacker, 1977) and semantic reduction would usually lie dormant in this linguistic context, but the language faculty has employed this component system for this novel purpose.

The two variables proved successful in illustrating the role of complex adaptive theory within the formation of compensatory strategies. The first measured variable demonstrated firstly that the language faculty as a complex adaptive system can substitute component systems when necessary, and the second variable, demonstrating a novel re-purposing of linguistic reanalysis, provided a practical example of how this can happen. This shows the algorithmic and non-heuristic nature of these processes, as the language faculty uses frequency data to make a probabilistic judgment about which component system can be utilised to best suit the novel parsing circumstances induced by aphasia.

2.5. CONCLUSION

This study demonstrated the benefit of obtaining probabilistic corpus data in compensatory strategy studies, as this means of data analysis permits a usage-based behavioural approach. This approach enabled the study to expose complex adaptive mechanisms which generate compensatory strategies, by observing compensatory strategy behaviours acquired through frequent usage. The results of the data analysis confirmed hypotheses that circumstantial component system re-allocation, enabled by cognitive flexibility within the language faculty, precedes compensatory strategy formation, and that linguistic reanalysis as a cognitive precursor to compensatory strategies can further evidence this. These findings support the crux of this theoretical approach, which is anti-heuristic and pro-algorithmic with regard to the formation and execution of compensatory strategies, given that the implied component systems of the language faculty existed within a vast network of finite-state parsers within the premorbid language faculty.

GENERAL CONCLUSION

This study succeeded in interrogating inconsistencies in the aphasiology literature which involved contradictory ideas about heuristics and the neural formative background of compensatory strategies in aphasia. The idea that compensatory strategies emerge as self-educating, trial-and-error, and experimental (Merriam-Webster, 2022) heuristic mechanisms is shown to be inherently contradictory to the nature of a mechanism which is the product of the premorbid language faculty, which through complex adaptive theory is suggested to consist of a vast network of finite-state parsers. The re-allocation of intact component networks is suggested to be the formative root of compensatory strategies, rather than the novel production of heuristic, instantaneously self-educating parsing mechanisms which are excluded from the entire body of algorithmic components within the language faculty. It is recommended that this theoretical approach be used to inform further research concerning aphasia treatment, in a similar vein to Thompson and Shapiro's study (2005: 1021-1036) which found that treatment of underlying forms yielded improvements in production of trained and untrained structures (2005: 1033). The findings in the present study, that underlying parsing mechanisms in Broca's aphasia are borrowed from intact components of the language faculty, complement the therapeutic approach taken by Thompson and Shapiro that prioritises treatment of underlying grammatical parsing.

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