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What can repetition, reading and naming tell us about Jargon Aphasia?

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1 **What can repetition, reading and naming tell us about Jargon Aphasia?**

2 **Abstract**

3 Jargon Aphasia is an acquired language disorder characterised by high proportions of
4 nonword error production, rendering spoken language incomprehensible. There exist two
5 major hypotheses relating to the source of nonword error; one implicates disruption to
6 phonological processing and the other suggests both phonological and lexical contributions.
7 The lexical sources are described as failure in lexical retrieval followed by surrogate
8 phonological construction, or a lexical selection error further compounded by phonological
9 breakdown. The current study analysed nonword error patterns of ten individuals with fluent
10 Neologistic Jargon aphasia in word repetition, reading and picture naming to gain insights
11 into the contributions of these different sources. It was predicted that, if lexical retrieval
12 deficits contribute to nonword production, naming would produce a greater proportion and
13 severity of nonword errors in comparison to repetition and reading, where phonology is
14 present and additional sub-lexical processing can support production. Both group and case
15 series analyses were implemented to determine whether quantity and quality of nonwords
16 differed across the three production tasks. Nonword phoneme inventories were compared
17 against the normative phoneme distribution to explore whether phonological production takes
18 place within a typically organised, lexically constrained system. Results demonstrated fewer
19 nonword errors in naming and a tendency for nonwords in naming to be characterised by
20 lower phonological accuracy. However, nonwords were, for the most part, constructed with
21 reference to target phonological information and, generally, nonword phonological
22 production patterns adhered to the statistical properties of the learned phonological system.
23 While a subset of the current group demonstrated very limited lexical processing capacity
24 which manifested as nonword errors in naming being most disrupted, overall the results
25 suggest that nonwords are largely underpinned by some degree of successful lexical retrieval

26 and implicate phonological sources, which manifest more severely when production is
27 accomplished via nonlexical processing routes.

28 **Keywords:** Jargon aphasia; nonword; neologism; Phonological Overlap Index (POI); word
29 production

30 **1. Introduction**

31 *1.1 Nonword production*

32 Jargon aphasia is a form of acquired language impairment characterised by nonword errors in
33 spoken production. Nonwords occur across all output tasks, and the presence of nonwords
34 within connected speech renders spoken production incomprehensible (Marshall, 2006).
35 Efforts to elicit nonword errors in neurologically healthy speakers have applied external
36 manipulations such as phonological priming and response pressure to word production tasks.
37 However, real words, i.e. words with existing conceptual and lexical representations,
38 continue to dominate output, whilst nonword errors are rarely realised (Baars, Motley, &
39 MacKay, 1975; Goldrick & Blumstein, 2006; Vitevitch, 2002). This failure to prime nonword
40 errors to the same extent at which they are observed within the Jargon aphasia population
41 limits understanding of the mechanism(s) underlying nonword production and hinders the
42 development of hypotheses attempting to explain how such production comes to dominate in
43 a form of acquired language impairment.

44 Despite this, there exist a number of theoretical accounts pertaining to nonword error
45 generation, mostly derived from studies of picture naming in clinical populations. The most
46 widely accepted hypothesis postulates that nonwords stem from a *single* impairment source –
47 a deficit in phonological encoding. The phonological encoding account states that deficient
48 activation of target phonological segments for output allows alternative phonemes to compete
49 and intrude, giving rise to non-target phonology in production (Kertesz & Benson, 1970).
50 Nonwords with high proportions of target phonology (paraphasia, e.g. village, /lɪvɪdʒ/) are
51 hypothesised to arise through mild disruption to this stage of phonological processing,
52 whereas errors with little or no target phonology (neologism, e.g. tribute, /krɪbrɪ:/) are
53 thought to follow more significant disruption during segment selection and organisation. By

54 this hypothesis paraphasias and neologisms occupy opposite ends of a single continuum of
55 nonword severity and the majority of nonwords fall somewhere in between and contain
56 moderate degrees of target phonology (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997;
57 Olson, Halloran, & Romani, 2015; Olson, Romani, & Halloran, 2007; Schwartz, Wilshire,
58 Gagnon, & Polansky, 2004). However, some case studies document evidence that challenge
59 this hypothesis, reporting individuals who produce significant proportions of nonwords that
60 share very little or no target phonology and high proportions of non-target phonological
61 segments. Such observations have given rise to alternative hypotheses which propose that
62 nonwords stem from a *dual* impairment in lexical and phonological processing. Under such
63 hypotheses, severe neologisms are underpinned by a separate or additional lexical deficit.
64 One such hypothesis suggests that severe distortions occur when the lexical representation
65 belonging to the target word is unable to be retrieved and subsequently a surrogate
66 phonological string is assembled for output, without reference to the target lexical
67 representation (Buckingham, 1977; 1990; Butterworth, 1979, 1992; Butterworth, Swallow, &
68 Grimston, 1981; Buckingham, 1977). A complementary hypothesis suggests that severe
69 neologisms are formed by compound errors, in which erroneous lexical selection is followed
70 by faulty phonological encoding (Schwartz, Wilshire, Gagnon, & Polansky, 2004). Evidence
71 for the single and dual source hypotheses can be examined by exploring the phonological
72 accuracy of nonwords and the distribution of this accuracy. A single phonological locus (one
73 source) would generate a majority of errors containing moderate levels of target phonology,
74 since nonword construction follows appropriate lexical retrieval. Additionally, there would be
75 a comparative scarcity of errors with few/significant portions of target phonology, thus
76 eliciting a normal distribution of accuracy (Olson et al., 2007; 2015; Pilkington et al., 2017;
77 Schwartz et al., 2004). A separate lexical deficit would generate an independent error
78 population, characterised by a significant proportion of responses containing chance levels of

79 target phonology, secondary to surrogate phonological usage in the absence of a specified
80 lexical target or phonologically distorted lexical errors. The coexistence of lexical and
81 phonological error sources would be reflected in a bimodal distribution of accuracy and has
82 been illustrated in some case studies of Jargon individuals (Buckingham & Kertesz, 1976;
83 Kohn et al., 1996).

84 *1.2 Production task differences*

85 An alternative approach to differentiating between the single and dual source hypotheses is to
86 analyse production patterns across separate output tasks which are characterised by different
87 lexical and phonological processing demands. Specifically, picture naming requires
88 independent semantic and lexical retrieval prior to phonological encoding, such that errors
89 arising through lexical processes, either default phonological selection secondary to lexical
90 failure, or compound lexical and phonological errors should be more likely in this task, and
91 so a greater number of nonword errors should occur, if a lexical source exists. Furthermore,
92 given that some of these errors are characterised by lexical selection errors/failures, the
93 quality of nonword errors in naming should be affected, with lower accuracy in phonological
94 production expected (Olson et al., 2007). Reading and repetition can be supported by both
95 lexical and nonlexical processes concurrently and so fewer nonwords should be observed in
96 these tasks, since nonlexical processing can support and facilitate production, thereby
97 allowing production to be accomplished with less weight on lexical retrieval (Coltheart,
98 Curtis, Atkins & Haller, 1993; Roelofs, 2004). Since phonological encoding is common in all
99 three production tasks, a single phonological locus would elicit similar numbers of nonword
100 errors across tasks. However, previous production task comparisons in Jargon aphasia have
101 produced inconsistent results. The nature and number of nonword errors produced in
102 repetition, reading and naming has been observed to be relatively consistent in some
103 individuals with Jargon aphasia (Moses, Nickels, & Sheard, 2007; Olson et al., 2007; 2015)

104 whereas other cases have presented with greater nonword errors in naming than in other
105 production tasks including reading and repetition (Ackerman and Ellis, 2007; Corbett,
106 Jeffries, & Lambon-Ralph, 2008; Moses, Nickels, & Sheard, 2004). Importantly, much of this
107 previous evidence is derived from single case studies or includes individuals with mixed
108 behavioural profiles and relatively mild Jargon deficits, limiting the applicability and
109 relevance of these conclusions to individuals with more severe production deficits.

110 *1.3 Jargon phonological inventories*

111 Further evidence into the source of nonword errors can be gained by exploring the
112 phonological inventories of individuals with Jargon aphasia. Phonological inventories, the
113 frequency of occurrence of each phonological segment within an individual's nonword
114 inventory, reflects the statistical properties of the phonological system and suggests whether a
115 lexical influence remains over production, as the phonological segment selection is inherently
116 linked and influenced by a word's lexical representation. A number of Jargon aphasia cases
117 have been identified in which individuals present with idiosyncratic phonological usage.
118 This indicates that the phonological system does not retain its statistical structure and that
119 nonwords may not be constrained by lexical processing and supporting the total lexical
120 retrieval failure hypothesis (Butterworth, 1979; Eaton, Marshall, & Pring, 2010; Moses et al.,
121 2004). Originally, such patterns were proposed to arise from a neologism generating device
122 or mechanism (Buckingham, 1990; Butterworth, 1979). However, an alternative
123 interpretation is that idiosyncratic phonological useage arises through long term disruption to
124 phonological encoding, which distorts the phonological system and the frequency at which
125 each individual segment resides (Eaton, Marshall, & Pring, 2010; Moses et al., 2004; Robson,
126 Pring, Marshall, & Chiat, 2003).

127 *1.4 The current study*

128 In the current study, we apply these methodological approaches to a case series of individuals
129 with Neologistic Jargon aphasia to draw inferences regarding the source(s) of impairment and
130 functioning of the phonological system. Single word naming, reading and repetition data
131 were collected from ten participants with Jargon aphasia. We analyse the prevalence of
132 nonword errors across the three separate production tasks and examine the phonological
133 accuracy of nonword responses to understand whether nonword errors manifest differently in
134 the separate tasks. We also explore whether phonological segment frequency within
135 nonwords conforms to typical English frequencies to determine whether production is
136 constrained by a typically organised lexico-phonological processing system.

137

138 **2. Methods**

139 *2.1 Participants*

140 Ethical approval for this project was gained from the North West NHS Research Ethics
141 Committee. Ten individuals (one female; age \bar{x} = 69 years, σ = 10.2 years; time post onset \bar{x}
142 = 19 months, σ = 22.15 months) with Jargon aphasia are reported. Data were collected by the
143 last author between 2009 – 2011 and all participants gave informed consent. All ten
144 individuals produced high proportions of neologistic and/or paraphasic errors, with fluent
145 speech and impaired single word comprehension (see Table 1). All ten individuals were
146 classified as having Wernicke’s Aphasia at the time of data collection, according to the
147 Boston Diagnostic Aphasia Examination (Goodglass, Kaplan, & Barresi, 2001).

148

149 Table 1: Demographic and Boston Diagnostic Aphasia Examination (BDAE) short form
 150 percentile results.

BDAE percentile scores							
Pt code	Age (years)	Sex	Time post onset (months)	Comprehension	Fluency	Word repetition	Sentence repetition
p1	70	M	42	45	100	15	40
p2	60	M	5	6.5	84	5	10
p3	59	M	6	17	100	10	30
p4	74	M	6	12	51	10	15
p5	64	M	6	10	68	15	15
p6	77	M	24	40	90	5	45
p7	78	F	72	5	68	5	15
p8	86	M	13	10	80	5	10
p9	53	M	7	15	68	<1	<1
p10	73	M	6	3	63	<1	<1

151 *Note. Participants ordered by the total number of nonwords produced across the three production*
 152 *tasks from fewest (p1) to highest (p10).*

153

154 **2.2 Tasks**

155 Participants undertook three single word production tasks – picture naming, reading and
 156 repetition. The picture naming test from the Cambridge Semantic Battery (Adlam, Patterson,
 157 Bozeat, & Hodges, 2010) consisted of 64 black and white line drawings from the Snodgrass
 158 and Vanderwart set. Reading and repetition tests were 80-item subtests from the PALPA
 159 (Psycholinguistic Assessment of Language Processing in Aphasia, subtests 9 and 31: Kay,
 160 Lesser, & Coltheart, 1996). To make the naming, reading and repetition tests numerically
 161 equivalent, a subset of 64 PALPA items were selected based on frequency ratings from N-
 162 Watch (Davis, 2005) and the MRC psycholinguistic database (Coltheart, 1981). The
 163 repetition and reading sets included the same 64 target items (see Appendix 1) which had a

164 mean frequency of 47.98 ($\sigma = 1.40$), mean familiarity 512.245 ($\sigma = 69.96$), mean imageability
165 431 ($\sigma = 175.99$), average number of letters 5.89 ($\sigma = 1.40$), mean number of phonemes 5, (σ
166 = 1.49) and average syllable number 2.03 ($\sigma = 0.76$). The picture naming items had a similar
167 mean frequency ($\bar{x} = 28.37$, $\sigma = 56.60$, $t(109) = 1.945$, $p = .0543$), familiarity ($\bar{x} = 514.02$, $\sigma =$
168 73.66, $t(107) = 0.128$, $p = .898$), imageability ($\bar{x} = 396$, $\sigma = 291.10$, $t(126) = 0.807$, $p =$
169 0.421), letter number ($\bar{x} = 6.17$, $\sigma = 2.16$, $t(126) = 0.874$, $p = .384$), phoneme number ($\bar{x} =$
170 4.918, $\sigma = 1.85$, $t(126) = 0.103$, $p = .785$) and syllable number ($\bar{x} = 1.90$, $\sigma = 0.80$, $t(126) =$
171 0.914, $p = .359$) to the repetition/reading tasks.

172 ***1.3 Recording and error coding***

173 Responses were transcribed into DISC symbols (1:1 phoneme: symbol correspondence, i.e.
174 IPA = [i:], DISC = [i]); to enable automated data extraction via Microsoft excel. When
175 multiple responses were given, the final complete utterance was accepted. Correct responses
176 were identified, all non-lexical responses were labelled as nonwords, and remaining errors
177 were grouped together.

178 ***2.4 Analyses***

179 ***2.4.1 Group error prevalence***

180 For each participant, the number of correct responses, nonword errors and other error types
181 were counted. The number of nonwords observed from each participant on each production
182 task (repetition, reading, naming) was entered into a one way repeated measures ANOVA to
183 examine whether the number of nonword errors differed across repetition, reading and
184 naming at the group level.

185 ***2.4.2 Phonological accuracy of nonwords***

186 ***2.4.2.1 Observed accuracy***

187 The Phonological Overlap Index (POI) (number of phonemes shared between response and
188 target x2)/(total phonemes in target + total phonemes in response) (Bose, 2013; Schwartz et
189 al., 2004) was calculated for each nonword. This calculation assigns responses which contain
190 all appropriate target phonemes a value of one, and responses which contain no target
191 segments a value of zero. When all appropriate phonemes are selected, irrespective of their
192 order a nonword would attain a value of one (e.g. village, /lɪvɪdʒ/). A one way repeated
193 measures ANOVA was used to determine whether phonological accuracy (POI) differed
194 across repetition, reading and naming. To determine whether phonemes were accurately
195 encoded at the individual level, average POI values for each participant on each production
196 task were compared against a chance level of accuracy via a bootstrapping procedure.

197 *2.4.2.2 Chance phonological accuracy*

198 A chance phonological overlap (POI) statistic represents the degree to which any target -
199 response pairing is likely to share phonology. This statistic quantifies the extent to which a
200 nonword will overlap with a target if it were constructed without reference to target
201 phonology and reflects the degree of accuracy expected from random phonological assembly.
202 To calculate chance, all nonword responses produced by the ten individuals within a specific
203 task were collated, along with their corresponding target words. The response and target sets
204 were randomly shuffled, thereby reassigning each nonword error to a new target word. The
205 number of nonwords produced by each individual in each modality was used to determine
206 how many randomly paired responses to sample from the chance sample; for example where
207 p10 produced 63 nonwords in repetition, 63 random pairings were sampled to derive an
208 individual null distribution. The POI for each new target-nonword pair was calculated and the
209 average across these pairings was derived. This process was repeated 1000 times to yield
210 1000 chance scores. The observed POI was compared against each chance figure to derive a *p*

211 statistic for each individual per production task. Confidence intervals for the null distribution
212 were obtained by identifying the chance values observed at the top and bottom 2.5%.

213 *2.4.2.3 Phonological accuracy distributions*

214 Individual POI distributions were analysed using the Shapiro Wilk test of normality.
215 Normally distributed POI data are proposed to reflect a single phonological nonword error
216 source. A dual error source is proposed to produce a bimodal distribution. Histograms were
217 visually inspected to assess whether bimodal distributions occurred if testing indicated
218 violation of normality. Where normality was violated, histograms were interpreted to
219 determine whether a bimodal distribution was observed, indicating separate nonword error
220 sources underpinned by failed lexical retrieval and phonological error, or erroneous lexical
221 selection followed by phonological distortion.

222 *2.4.3 Phoneme frequency distributions*

223 The frequency of each phoneme in each participant's nonword error set was calculated and
224 compared against the expected phoneme frequency in English, as reported in Denes (1963).
225 Nonword errors were collated across production task to provide sufficient data to run this
226 analysis; focusing on phonemic diversity on a single data point/collection time would make
227 this analysis vulnerable to perseveration and may falsely indicate a distorted phonological
228 inventory. Each individual's phoneme frequency distribution was compared against the
229 normative distribution, using a type two Kolmogorov Smirnov test.

230 **3. Results**

231 **3.1 Group error prevalence**

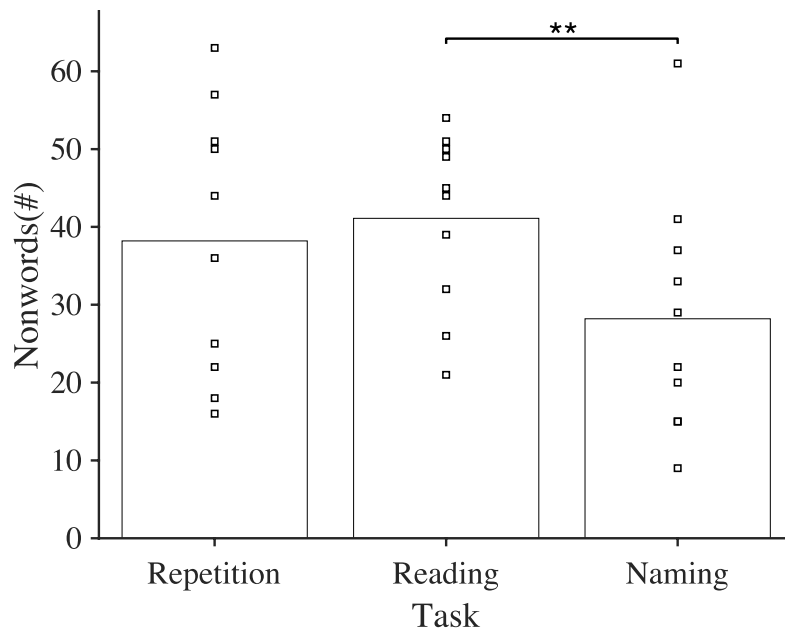
232 Table 2 reports the number of nonword errors produced by each of the ten participants across
 233 repetition, reading and naming. A one way repeated measures ANOVA was used to
 234 determine whether numbers of nonword error differed across task (repetition, reading,
 235 naming). There was a significant effect of production task on the numbers of nonword
 236 production ($F(2, 18) = 4.840, p = .021, \eta^2 = .350$, see Figure 1), and post hoc - pairwise
 237 comparisons tests applying Bonferroni correction identified that picture naming elicited
 238 significantly fewer nonwords than reading ($p = .008$). Additional pairwise comparisons did
 239 not identify any further differences ($p \geq .227$). Information regarding correct responses is
 240 provided in Appendix 2; there was no effect of task on accuracy ($p = .387$).

241

242 Table 2: The number of correct responses, nonwords and other errors produced by each
 243 participant across repetition, reading and naming.

	Repetition			Reading			Naming		
	Correct	Nonwords	Other	Correct	Nonwords	Other	Correct	Nonwords	Other
p1	30	25	9	38	21	5	46	9	9
p2	18	18	28	22	26	16	28	15	21
p3	32	16	16	20	39	5	31	22	11
p4	32	22	10	6	45	13	16	29	19
p5	5	57	2	20	32	12	12	15	37
p6	17	36	11	11	44	9	21	33	10
p7	4	50	10	9	49	6	11	20	33
p8	4	44	16	7	51	6	9	41	14
p9	4	51	9	2	54	8	7	37	20
p10	1	63	0	11	50	3	2	61	1

244 *Other = semantic, formal, mixed, circumlocution, unrelated and non-response collated.



254 Figure 1 Title: Nonword Production in Repetition, Reading and Naming.

255 Figure 1 Legend: Bar chart displays the mean number of nonword responses in each task.

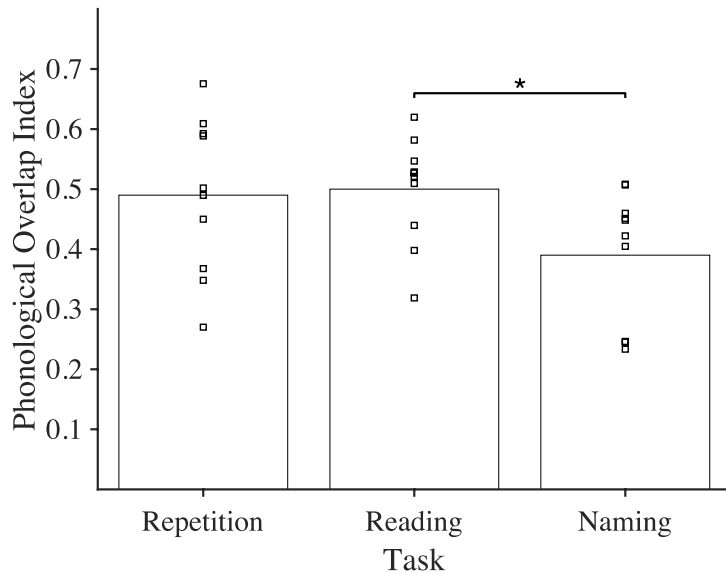
256 Individual markers indicate participant nonword numbers.

257

258 **3.2 Phonological accuracy of nonwords**

259 **3.2.1 Observed phonological accuracy**

260 The accuracy of all nonword errors was measured using the Phonological Overlap Index
 261 (POI) calculation, thereby assigning values between 0 and 1 to all nonwords, with a value of



262 one reflecting complete
 263 phonological overlap
 264 between a nonword and
 265 target word pair. A
 266 repeated measures
 267 ANOVA was used to
 268 compare average POIs
 269 across the three output
 270 tasks. The ANOVA

271 identified a significant effect of task on phonological accuracy ($F(2, 18) = 5.665, p = .012,$
 272 $\eta p^2 = .386$, see Figure 2); with post-hoc, Bonferonni corrected, pairwise comparisons
 273 identifying that picture naming was less phonologically accurate than reading ($p = .014$).
 274 Repetition elicited marginally greater accuracy than naming ($p = .093$).

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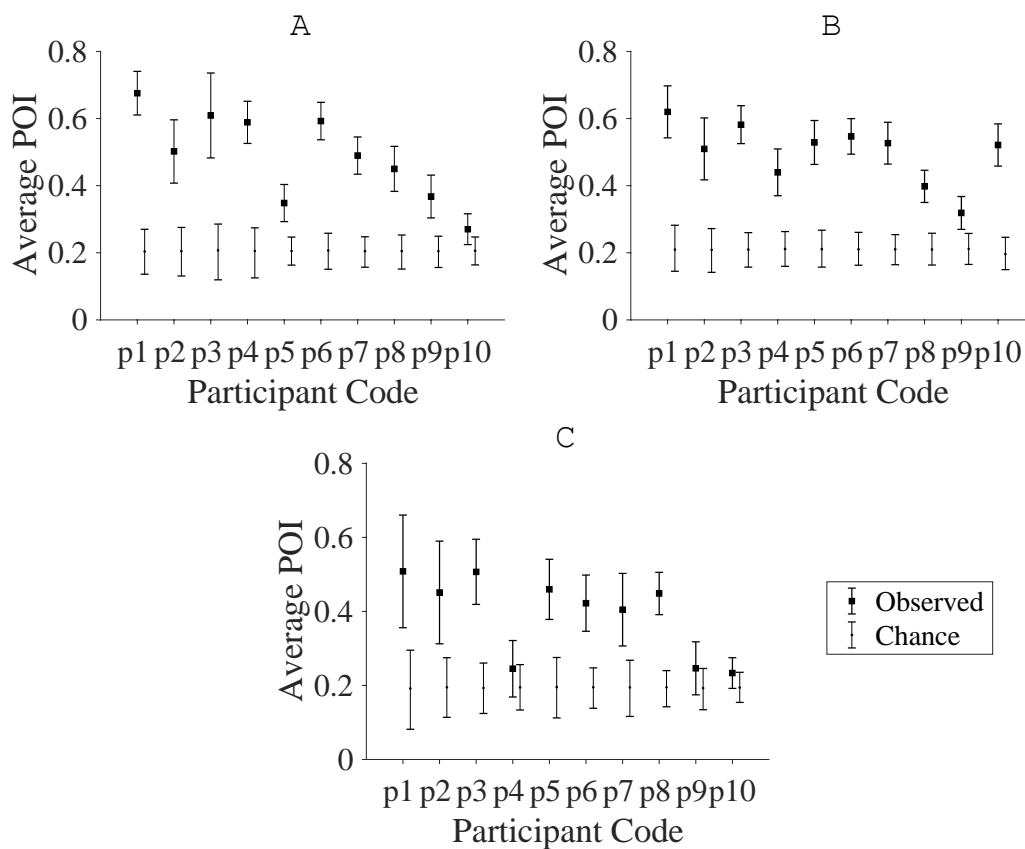
283

284 Figure 2 Title: Phonological Overlap Index in Repetition, Reading and Naming.

285 Figure 2 Legend: Bar chart displays mean Phonological Overlap Index (POI) of nonword
 286 errors in each production task. Individual markers represent participant POI means.

287

288 For each participant the average POI was calculated for all nonwords in each separate
 289 production task and compared against a chance value of phonological accuracy using a
 290 bootstrapping procedure. In repetition all ten individuals produced nonwords that contained
 291 greater degrees of target phonology than predicted by chance ($POI \bar{x} \geq 0.270, p \leq .002$; see
 292 Figure 3a). The same pattern was observed in reading ($POI \bar{x} \geq 0.318, p \leq .001$; see Figure
 293 3b). In picture naming, p4 produced target phonology at chance levels ($POI \bar{x} = 0.245, p =$
 294 0.54 ; see Figure 2c). The remaining nine individuals produced target phonology at greater
 295 than the chance prediction ($POI \bar{x} \geq 0.247, p \leq .035$; see Figure 3c).



296

297 Figure 3: Participant Phonological Overlap Index vs. Chance Phonological Overlap Index
 298 nonwords produced in Repetition (A), Reading (B) and Picture Naming (C). Error bars
 299 indicate 95% confidence intervals.

300

301 *3.2.2 Accuracy distributions*

302 The Shapiro Wilk test was used to examine whether nonword accuracy (POI) spread
 303 conformed to a normal distribution, thereby suggesting a single phonological locus of
 304 nonword error. The POI distributions exhibited by seven individuals (p1, 2, 3, 5, 6, 7, 8)
 305 either conformed to a normal distribution ($p \leq 0.077$) or followed a negative skew, indicating
 306 a tendency towards higher target overlap (a greater proportion of nonwords observed above
 307 the mean, see Table 3 marked ▲). The POI accuracy distribution for p4 did not follow a
 308 normal distribution in naming ($p = 0.013$, skewness = 0.529, Figure 4D); p9 also exhibited a
 309 normality violation in naming ($p = 0.003$, skewness = 0.721, Figure 4C); p10 violated the
 310 normal distribution in repetition ($p = 0.005$, skewness = 0.620, Figure 4B) and in naming ($p =$
 311 0.004 , skewness = 0.258, Figure 4A). Visual inspection of these histograms indicate a heavy
 312 skew towards lower phonological accuracy with a graded increase in accuracy from zero,
 313 rather than a bimodal distribution (see Figure 4).

314 Table 3: p statistic from Shapiro Wilk normality test of POI distribution.

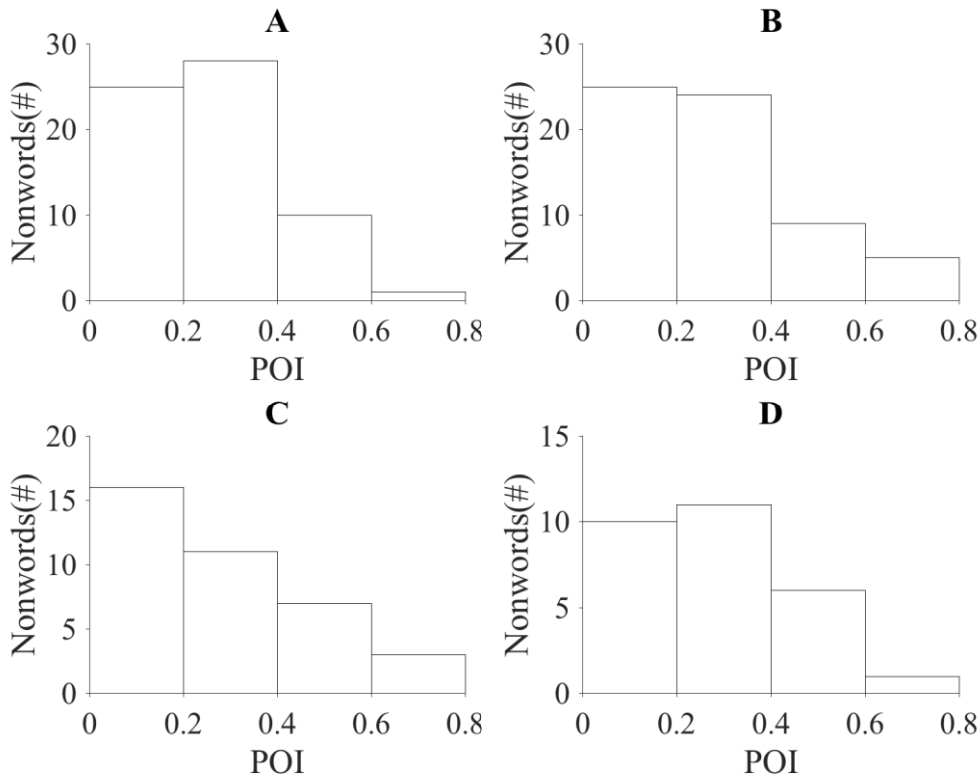
	Repetition	Reading	Naming
p1	0.092	0.204	0.294
p2	0.757	0.090	0.190
p3	0.244	0.263	0.608
p4	0.155	0.187	0.013●
p5	0.115	0.136	0.452
p6	0.020▲	0.153	0.625
p7	0.067	0.039▲	0.077
p8	0.217	0.761	0.663

p9	0.109	0.082	0.003●
p10	0.005●	0.267	0.004●

315 Symbol Key: ▲ negative skew (majority of POIs fell above the mean); ● positive skew.

316

317



318

319 Figure 4: Phonological Overlap Index distributions when normality violated. (A) p10
 320 Naming, (B) p10 Repetition, (C) p9 Naming, (D) p4 Naming.

321

322 3.3 Phoneme frequency distributions

323 The Kolmogorov Smirnov Two-sample test (KS2) was used to identify whether the nonword
 324 phoneme inventory of each individual participant conformed to English norms (Dene, 1963).

325 To ensure sufficient data for this analysis, nonword phonemes were collapsed across

326 production task and overall prevalence of each phoneme was calculated as a percentage. The

327 KS2 test demonstrated that all ten individuals distributed phonemes in line with the expected

328 normative pattern ($p \geq 0.076$; see Table 4 for full results). Figure 5 depicts the phoneme

329 frequency distributions for each Jargon participant, with box plots reflecting negatively
 330 skewed distributions similar to that of English norms.

331

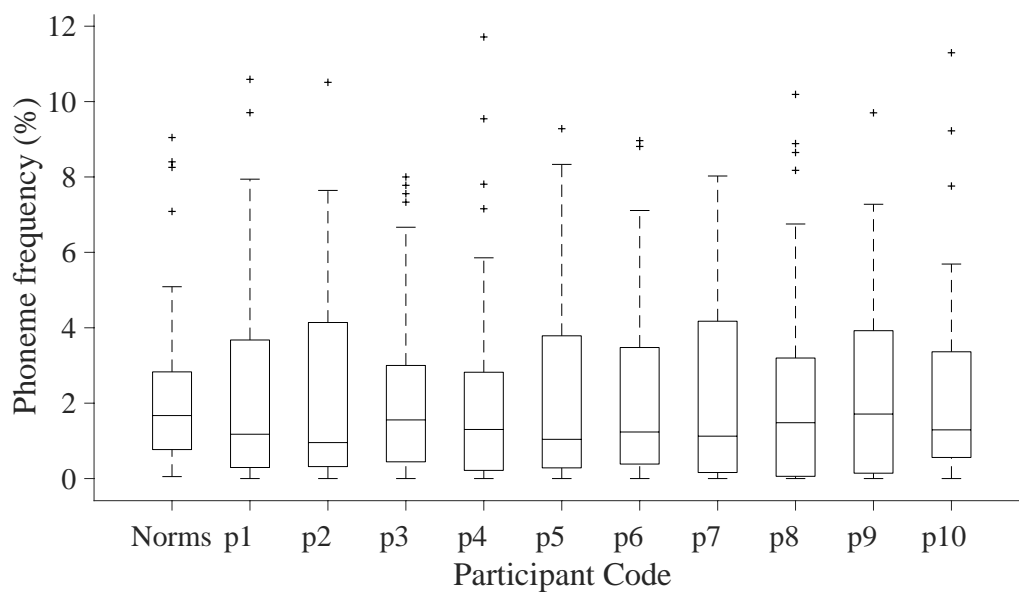
332 Table 4: Z statistic and *p* value from Kolmogorov Smirnov two (KS2) test comparing
 333 normative and individual nonword phoneme frequency distributions.

	KS Z^a	<i>P</i>
p1	1.173	0.128
p2	1.386	0.043
p3	0.853	0.461
p4	0.959	0.316
p5	1.279	0.076
p6	0.853	0.461
p7	1.173	0.128
p8	1.279	0.076
p9	1.173	0.128
p10	0.853	0.461

334 $KS Z^a =$ Kolmogorov Smirnov 2 test Z statistic.

335

336



337

338 Figure 5: Phoneme frequency distributions for English norms and participants.

339 **4. Discussion**

340 ***4.1 Group error prevalence***

341 This study examined the nonword error patterns produced on single word repetition, reading
342 and picture naming tasks in a group of ten people with Jargon aphasia. Current hypotheses
343 propose that nonwords arise through either a single, phonological source or a dual
344 impairment in lexical and phonological processing. A single phonological source predicts that
345 a similar proportion of nonword errors will be produced across the different
346 production tasks, since the phonological encoding requirements are similar (Olson et al.,
347 2007; 2015). A dual source predicts that a greater proportion of nonword errors will be
348 observed in naming than in reading and repetition, as naming weighs more heavily on lexical
349 processing and cannot utilise sub-lexical processing to support production in the event of
350 deficient lexical information (Coltheart et al., 1993; Moses et al., 2004; Nozari, Kitteridge,
351 Dell, & Schwartz, 2010; Olson et al., 2015). Results from the current study did not clearly
352 conform to either of these patterns. Instead there were higher numbers of nonword errors in
353 reading (statistically) and repetition (numerically) than in naming. Nevertheless, this result
354 aligns best with the single phonological source hypothesis, in that more nonwords were
355 produced in tasks with greater focus on phonological processing. Tasks which increased
356 focus on lexico-semantic processing reduced the likelihood of nonword production. These
357 results conflict with previous single case studies which have identified greater neologistic or
358 error production impairments in Jargon naming (Ackerman & Ellis, 2007; Moses et al., 2004;
359 Corbett et al., 2008) and are inconsistent with patterns observed in the aphasia population
360 generally where repetition tends to be more accurate than naming (Nozari et al., 2010). A
361 significant proportion of this evidence comes from computational modelling studies which
362 have described nonword production patterns primarily in naming and attempted to explain
363 error patterns in other production tasks based on the naming models. The fewer numbers of
364 nonword errors produced to tasks involving non-lexical processing components (e.g.

365 repetition) are accounted for by recruitment of nonlexical processing routes which make use
366 of surface word graphemes/phonemes and which can compensate for weak lexical route
367 processing and bolster production accuracy (Dell et al., 1997; Hanley, Dell, Kay, & Baron,
368 2004; Nozari et al., 2010). Picture naming, where nonlexical information is not available,
369 lacks this additional boost and so is more likely to elicit errors. Closer examination of the
370 cases within computational modelling studies (e.g. Nozari et al., 2010) demonstrate that
371 individuals with poor language comprehension abilities such as that observed in Jargon
372 aphasia, for example, those with Wernicke's aphasia, do not clearly conform to this dual
373 route prediction and that these individuals produce error rates that are more equally balanced
374 across the different production tasks; a pattern that is consistent with a subset of participants
375 in the current group.

376 However, 4 participants (p1, p5, p7 and p9) produced more nonwords on both
377 repetition and reading than in naming (similar trends were also observed in 3 other
378 individuals, see Table 2), suggesting that dual route processing is not consistently operational
379 in this sub set of individuals. The pattern exhibited by these 4 participants can, however, still
380 be explained within existing frameworks of naming and repetition. Studies examining the
381 balance between lexical and nonlexical processing in tasks such as reading and repetition
382 have indicated differential routing patterns dependent on the person's ability to comprehend
383 and recognise words (Nozari & Dell, 2013). Individuals with greater lexical-semantic
384 comprehension abilities favour the lexical processing route and make use of this for
385 accomplishing tasks such as auditory repetition. People whose lexical comprehension and
386 recognition are more severely impaired are pushed towards nonlexical processing as an
387 alternative, since subsequent lexically motivated processing cannot proceed without sufficient
388 lexical-word activation. All individuals in the current study had a diagnosis of Wernicke's
389 aphasia and, consequently, severe impairments in analysing and processing input phonology,

390 and comorbid impairments in lexico-semantic processing and comprehension (Robson, Sage,
391 & Lambon Ralph, 2012). In the current group, it is likely that impairments in language
392 comprehension limit participant ability to access and use the lexical-semantic pathway to
393 support production, thereby increasing reliance on surface level (nonlexical) information in
394 tasks where this is possible (Nozari & Dell, 2013). Additionally, the ability to decipher input
395 phonology is significantly impaired in Wernicke's aphasia. Therefore, activation of target
396 phonology from the nonlexical route will be severely disrupted, which will increase the
397 likelihood of observing a nonword. This pattern of processing can explain the greater number
398 of nonword errors observed in repetition/reading in comparison to picture naming.

399

400 ***4.2 Case series analyses***

401 The single source interpretation is challenged by the finding that the phonological accuracy
402 of nonword errors (target-error overlap, measured by the POI) was *lower* in naming than in
403 reading and repetition. This could be taken as evidence for an additional lexical impairment
404 contributing to nonwords either through complete lexical retrieval failure and idiosyncratic
405 phonology generation or through lexical retrieval errors which are subsequently
406 phonologically distorted (compound errors). However, further analysis of the phonological
407 content of nonword errors argues against these interpretations. The phonological overlap
408 between nonword errors and targets was compared to that expected by chance. Above chance
409 level phonological accuracy (e.g. village, /lɪvɪdʒ/) is unlikely without adequate access to the
410 lexical representation of a word, whereas phonological accuracy at the chance level would
411 occur following lexical error or lexical retrieval failure (Godbold et al., 2013; Olson et al.,
412 2007; Robson et al., 2003). This is particularly the case in naming where only a lexical
413 processing route is available. Although this analysis confirmed severe levels of impairment –
414 on average nonwords contained less than half of the targets phonemes (see Figure 2) – the

415 phonological accuracy of nonword errors was above chance in all participants in almost all
416 tasks, supporting the hypothesis that accurate lexical information is available. This was
417 further supported by analysis of the distribution of the POI of nonword errors. It has been
418 proposed that a single phonological nonword error source will produce a normal distribution
419 of phonological accuracy in nonwords whereas a dual lexical-phonological source will
420 produce a bimodal distribution with a large proportion of errors with very limited target
421 overlap (Olson et al., 2007; 2015; Schwartz et al., 2004). The majority of POI distributions in
422 the current study adhered to a normal distribution or were negatively skewed, a trend also
423 noted in existing Jargon case studies (Olson et al., 2007; 2015), suggesting that lexically
424 mediated nonword errors were scarcely produced. In addition to these analyses, qualitative
425 interpretation of participant data demonstrated little to no evidence of compound errors, i.e.
426 moderate phonological disruption of semantic errors, hypothesised as reflecting a lack of
427 lexical influence (Olson et al., 2015). Together these results do not indicate a significant
428 lexical contribution to nonword errors in Jargon aphasia. Instead it is interpreted that greater
429 phonological accuracy in reading and repetition than in naming indicates some ability to use
430 input phonological information to support phonological encoding. This pattern is compatible
431 with the earlier interpretation that tasks of repetition and reading can be accomplished either
432 by lexico-phonological processing when word recognition has triggered at least partially
433 correct phonological information, or nonlexical processing which maps input – output
434 phonology, again, with some degree of success.

435

436 ***4.3 Exception cases***

437 Observation of the case series highlighted a number of notable exceptions. Participant 4's
438 nonword phonological accuracy in naming was not significantly different from chance, and
439 the corresponding POI distribution was non-normally distributed. POI distribution normality

440 violations also occurred for two other participants – p9 in naming, and p10 in naming and
441 repetition. It is possible that these individuals have more significant lexical processing
442 impairment than the other participants and that this impairment contributed to nonword
443 production. The existence of lexically mediated errors, possessing very limited accurate
444 phonology, is expected to co-occur alongside a group of errors containing more moderate
445 degrees of target phonology, together eliciting a bimodal accuracy distribution (Olson et al.,
446 2007; 2015; Schwartz et al., 2004). Bimodal distributions were not observed in these
447 participants. Instead, positively skewed histograms (see Figure 4) were observed, indicating
448 that, for these particular individuals, nonword accuracy was heavily weighted towards lower
449 accuracy production. This trend indicates very severe phonological encoding impairments,
450 particularly in naming where no sub-lexical support was available. Participant 10 displayed a
451 POI normality violation in repetition, alongside a low POI average score for this task (0.27,
452 see Figure 3a). Individuals with Wernicke’s aphasia have well documented auditory and
453 input phonological processing impairments which are associated with their language
454 comprehension impairment (Robson, et al., 2012; Robson, Pilkington, Evans, DeLuca, &
455 Keidel, 2017). Participant 10 displayed the most severe language comprehension impairment
456 (Table 1), indicating considerable auditory processing difficulties and a reduced ability to use
457 phonological input information to boost production in repetition via lexical or nonlexical
458 processing.

459

460 ***4.4 Jargon phonological inventories***

461 Although these three cases presented with the greatest degree of nonword production
462 impairment, the majority of participants in the current study presented with severe Jargon
463 aphasia. It has been proposed that such individuals may suffer from a *distorted* phonological
464 system due to long standing nonword production warping phonological representations and

465 /or their links with the lexical system (Eaton et al., 2010; Moses et al., 2004). This was
466 explored by analysing the occurrence of phoneme segments within nonwords to determine
467 whether nonword phoneme frequency distributions pertain to the typical phoneme
468 distributions observed in English, thus indicating whether the phonological system in Jargon
469 aphasia operates in line with its typical numerical distributional properties. All but one
470 participant (p2) in the current study produced phonological segments in line with that
471 expected in English, suggesting that, for the most part, the phonological system maintains its
472 typical organisation and structure. This is contrary to results reported in previous studies,
473 where evidence of idiosyncratic or default phonological useage is documented (Eaton et al.,
474 2010; Moses et al., 2004). However, the current data were sampled at a single time point
475 within what is typically a prolonged recovery trajectory, when the majority of the group were
476 not classified as chronic. Therefore current results cannot exclude that long-standing nonword
477 production in Jargon aphasia may self-reinforce deviant phonological useage and alter the
478 rates at which specific phonological segments reside. For example, participants p5 and p8 are
479 statistically borderline in how their phonological distribution adhered to the normal observed
480 phoneme useage, and p4 demonstrates over representation of a phonological segment (see
481 Figure 5), suggesting that their phonological selection may be in the early stages of distortion
482 and may evolve into an idiosyncratic system. Therefore, longitudinal analyses may be more
483 suited to investigating this hypothesis.

484

485 **5. Conclusion**

486 This study investigated the degree to which lexical impairment contributed to the production
487 of nonword errors in Jargon aphasia by analysing the number and content of nonword errors
488 produced during repetition, reading and naming in a case series of 10 individuals with
489 neologistic production. Overall, the phonological inventories of the group adhered to English

490 norms indicating that Jargon nonword production arises through a phonological system that
491 maintains the typical phonological organisation and suggests that production is constrained
492 by lexico-phonological processing. The phonological content of nonwords indicated that
493 some accurate lexical information is available for the majority of individuals with Jargon
494 aphasia during word production. However, impairments in lexical recognition and processing
495 lead to reliance on phonological information to support production, thereby increasing the
496 number of nonwords. Picture naming, which does not involve the presentation of
497 phonological material, maximises lexical processing which reduces the likelihood of
498 observing a nonword. These results demonstrate that tasks which maximise phonological
499 processing demands increase the amount of Jargon and indicate that Jargon nonword error
500 production is phonologically mediated.

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597 **Tables**

598 *List of table titles*

599 Table 1: Demographic and Boston Diagnostic Aphasia Examination (BDAE) short form
600 percentile results.

601 Table 2: The number of correct responses, nonwords and other errors produced by each
602 participant across Repetition, Reading and Naming.

603 Table 3: p statistic from Shapiro Wilk normality test of POI distribution.

604 Table 4: Z statistic and p value from Kolmogorov Smirnov two (KS2) test comparing
605 normative and individual nonword phoneme frequency distributions.

606 **Figures**

607 *List of figure titles and legends*

608 Figure 1 Title: Nonword Production in Repetition, Reading and Naming.

609 Figure 1 Legend: Bar chart displays the mean number of nonword responses in each task.

610 Individual markers indicate participant nonword numbers.

611 Figure 2 Title: Phonological Overlap Index in Repetition, Reading and Naming

612 Figure 2 Legend: Bar chart displays mean Phonological Overlap Index (POI) of nonword

613 errors in each production task. Individual markers represent participant POI means.

614 Figure 3: Participant Phonological Overlap Index vs. Chance Phonological Overlap Index

615 nonwords produced in Repetition (A), Reading (B) and Picture Naming (C). Error bars

616 indicate 95% confidence intervals.

617 Figure 4: Phonological Overlap Index distributions when normality violated. (A) p10

618 Naming, (B) p10 Repetition, (C) p9 Naming, (D) p4 Naming.

619 Figure 5: Phoneme frequency distributions for English norms and participants.

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