Orthographic neighbourhood effects during lateralised lexical decision are abolished with
bilateral presentation

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Abstract

Words presented to the right visual field (RVF) are processed more rapidly than those in the left visual field (LVF), presumably because of more direct links to the language dominant left cerebral hemisphere. This effect is moderated by a word's orthographic neighbourhood size (N), with LVF facilitation and RVF inhibition for words with large N. Across two experiments, we sought to further examine lateralised N effects. Experiment 1 examined how hemispheric dominance for language influenced lateralised N effects, in 140 left-handers using a visual half-field task with bilateral presentation. Neither typically nor atypically lateralized participants showed the expected N effect, making the results ambiguous: it could be that left-handers fail to show N effects, or the effect could be abolished by some procedural aspect. Experiment 2 looked to test these options by testing 56 right-handers who responded to the same stimulus set under the original bilateral presentation condition and under unilateral presentation. N effects were found under unilateral but not bilateral presentation. We had adopted bilateral presentation because it had been recommended as better than unilateral presentation for controlling fixation and visual stimulation; our results indicate that this is not a minor methodological modification: it can dramatically affect lateralized effects.

Keywords: Orthographic neighbourhood effects, Lateralized presentation, Laterality, Cerebral hemisphere, Individual differences

Word count: 8,723

Orthographic neighbourhood effects during lateralised lexical decision are abolished with bilateral presentation

In visual half-field paradigms participants are required to respond to stimuli shown in either the left (LVF) or right (RVF) visual field. Variations of this paradigm using linguistic stimuli have yielded one of the most robust findings within the field of neuropsychology: a strong RVF advantage where processing is more efficient for words shown in the RVF relative to the LVF. This RVF advantage is attributed to the additional time taken for transferring LVF information from the occipital cortex of the right hemisphere to the language dominant left hemisphere via the corpus callosum (Banich, 2003; Bourne, 2006; Chiarello, 1985; Hellige, 1993; Krusch & McKeever, 1990; see Hunter & Brysbaert, 2008 for a review of transfer costs). Not only are visual half-field paradigms able to reliably index cerebral lateralisation for language, they provide a viable tool to assess hemispheric differences in how word processing is affected by lexical variables. One such variable is the orthographic neighbourhood size of a word, which has shown to enhance, or facilitate, word identification in the LVF but inhibit word identification in the RVF (Lavidor & Ellis, 2002; Mano et al., 2010; Perea, Acha, & Fraga, 2008; Whitney & Lavidor, 2005). While these effects appear reliable at the population level, there are inconsistencies between participants (Parker et al., 2021) - only 40% of participants displayed both facilitatory and inhibitory effects. There are also inconsistencies across studies, with some reporting negligible (Lavidor & Ellis, 2002; Whitney & Lavidor, 2005) or facilitatory effects in the RVF (Lavidor, Johnston, & Snowling, 2006). The current paper reports two experiments that explore the heterogeneity occurring between participants and studies. Specifically, we consider the impact of (a)typical hemispheric dominance for language on lateralised orthographic neighbourhood effects, as well as the impact of methodological differences in how the visual half-field task is performed. The first experiment involved a sample of left-handers completing a lateralised lexical decision task under bilateral presentation, and the second involved right-handed participants

68 completing the same task under both bilateral and unilateral presentation.

69 Words that are orthographic neighbours share all but one letter in an identical
70 location (e.g. *house* and *horde* are both orthographic neighbours of *horse*). The number of
71 words in a neighbourhood constitutes a word's neighbourhood size or neighbourhood
72 density. This metric is more commonly referred to as '*N*' (Coltheart, Davelaar, Jonasson,
73 & Besner, 1977). When making lexical decisions with centrally presented stimuli, a larger
74 *N* typically results in more accurate and faster decisions (Andrews, 1997; Perea, 2015).
75 This facilitatory effect is theorised to result from excitatory feedback connections from the
76 word to letter level, such that partial activation of orthographic neighbours at the word
77 level may thereby increase letter level activation and speed up word recognition (Andrews,
78 1989, 1997; Coltheart & Rastle, 1994; Whitney & Lavidor, 2005).

79 When words are presented to the left or right visual fields, *N* effects are a little more
80 complex. For words presented in the LVF, having many orthographic neighbours appears
81 to facilitate lexical decision reaction times. In contrast, there are mixed results of having
82 many orthographic neighbours in the RVF (Ellis, 2004; Lavidor & Ellis, 2002; Lavidor,
83 Johnston, & Snowling, 2006; Mano et al., 2010; Perea, Acha, & Fraga, 2008; Whitney &
84 Lavidor, 2005). Despite this heterogeneity, a recent meta-analysis concluded that the *N*
85 effect is reliably inhibitory in the RVF (Parker et al., 2021).

86 The contrasting pattern of *N* effects in the LVF and RVF have been explained within
87 cognitive models of reading, such as the SERIOL model (Whitney, 2001, 2004). This model
88 posits that words presented in the LVF have relatively imprecise letter encoding, and so
89 require more top-down support from the word level to resolve letter level activation; words
90 with larger orthographic neighbourhoods have more top-down support, and therefore faster
91 lexical decision times. By contrast, letter encoding in the RVF is more precise, so there is
92 less need for top-down support during word recognition, making *N* effects smaller or
93 negligible.

While the SERIOL model does a good job at explaining the pattern of N effects reported under lateralised lexical decision at a group-level, it is difficult to reconcile with a recent finding reported by Parker et al. (2021). In a sample of 30 right-handed participants, Parker et al. reported both a facilitatory N effect in the LVF and an inhibitory effect in the RVF when averaging across all participants. However, at the participant-level, only 12 participants (40%) showed both a facilitatory N effect in the LVF and an inhibitory effect in the RVF. This indicates that there are likely to be subtle individual differences in N effects across hemispheres, which are not currently allowed for in cognitive models.

Parker et al. (2021) hypothesised that hemispheric dominance for language may be a cause of the individual differences observed in their results. The direction and degree of language lateralisation seems likely to influence the hemispheric differences observed during visual word form processing. In attempt to examine these individual differences, Parker et al. performed an exploratory analysis to test whether lateralisation was related to the size of the N effect in both the LVF and RVF. The results were null; but this may have been due to methodological limitations, as the experiment was not designed to investigate that question. Firstly, the right-handed participant group had only limited variability in the lateralisation measure, which may have affected the power to detect an effect. Further, the measure of lateralisation (the RVF advantage) was drawn from the same lexical decision task, so may not have been independent from the dependent variable. Finally, participants were assigned to different counterbalanced lists, so any comparison of laterality scores would have encompassed some between-item variance.

Experiment 1 was designed to address these issues and investigate the relationship between lateralised N effects and hemispheric dominance for language more conclusively. Investigating this will improve our understanding of lateralised word identification and inform computational models of reading such as the SERIOL model. By understanding these processes in skilled readers, it may in turn promote our understanding of reading

development and reading disorders.

Experiment 1 included left-handed participants only, as it is known that left-handers show a greater variability in language lateralisation and a greater incidence of atypical lateralisation than right-handers (Bruckert, Thompson, Watkins, Bishop, & Woodhead, 2021; Bryden, 1965; Carey & Johnstone, 2014; Kimura, 1973a, 1973b; Mazoyer et al., 2014; Rasmussen & Milner, 1977; Woodhead, Thompson, Karlsson, & Bishop, 2021). Participants were categorised into typical (left) or atypical (right or bilateral) hemispheric dominance groups using a dichotic listening task. Dichotic listening paradigms are highly reliable in both lab-based (Bless et al., 2013) and web-based (Parker, Woodhead, Thompson, & Bishop, 2021) formats and capture left-hemisphere dominance for language (see Hugdahl et al., 2009, for a review), as well as the subtle differences in lateralisation between left- and right-handers (Karlsson, Johnstone, & Carey, 2019).

To pre-empt the results, Experiment 1 failed to replicate the predicted N-size effects in the typical hemispheric dominance group. This prompted a further experiment to investigate whether the results were impacted by the methodological differences in how the lateralised lexical decision paradigm was delivered. In Experiment 1, we used a bilateral paradigm in which stimuli were presented simultaneously to the left and right visual fields, with a centrally presented arrow indicating which stimulus the participant should respond to. This approach has previously been recommended as a way of balancing the visual stimulation in the two visual fields, and promoting central fixation during the lateralised lexical decision task (Hunter & Brysbaert, 2008); however, the failure to replicate the N effects may indicate that the bilateral presentation may have had unanticipated consequences on word processing. In Experiment 2, we directly compared the N effects with bilateral versus unilateral versions of the paradigm in the same right-handed participants; this confirmed that the different methods of presenting the task radically altered the results.

Experiment 1

Experiment 1 set out to examine whether the pattern of orthographic neighbourhood effects in the LVF and RVF differed in those who were typically and atypically lateralised for language. Here, performance on a consonant-vowel dichotic listening task was used to characterise participants as (a) typically lateralised for language. The experiment had two aims: (1) to replicate the findings of Parker et al. (2021), who reported a facilitatory N effect in the LVF and an inhibitory N effect in the RVF, in a sample of participants who showed left hemisphere dominance for language; (2) to examine whether the effects of N differed between those who showed left vs right hemisphere dominance for language. The paradigm used in Experiment 1 differed from that reported by Parker et al. (2021) in two main ways: firstly, it used bilateral presentation of stimuli rather than unilateral; and secondly, each stimulus was presented in the LVF and RVF an equal amount of times in order to reduce between-item variability within the data. Furthermore, left-handed participants were recruited (rather than right-handers) in order to achieve high levels of variability in hemispheric dominance for language within the sample.

For the group with typical (left) hemispheric dominance we predicted that (1a) there would be a facilitatory N effect in the LVF, (1b) the N effect would differ across visual fields, and (1c) that the N effect would be inhibitory in the RVF. When comparing effects of N between the typical and atypical hemispheric dominance groups, we predicted that (2a) the N effect would differ between groups in the LVF, (2b) the difference in the N effect across visual fields would differ between groups, and (2c) the N effect in the RVF would differ between groups.

The experiment was pre-registered on the Open Science Framework prior to the commencement of data collection. The registration form, materials, data, and R scripts can be found at <https://osf.io/uvykh/>.

Methods

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the experiment.

Participants. Our final sample size was based on a priori power analysis. To begin, we simulated a data set with known properties; that is a -25 ms facilitatory N effect in the LVF and a 15 ms N effect in the RVF for the typically lateralised group. For the atypically lateralised group we simulated weaker effects, i.e. a -15 ms facilitatory effect in the LVF and a 5 ms inhibitory effect in the RVF. The data set contained 240 data points per participant representing each of the 120 word targets in the current experiment which were shown twice (i.e. 60 per experimental condition). One-thousand simulations were run for 45, 50, and 55 statistical subjects per group. We then fitted a series of linear-mixed effects models to examine our simulated data. Within this framework, each hypothesis mapped directly onto a simple main effect (further information below). As shown in Table 1, a group size of 55 participants per laterality group was found to yield power of over 80% for all experimental hypotheses.

Table 1

Results from a priori power analysis. For Hypothesis 2 (H2), participants refers to the count per laterality group.

Participants	H1A	H1B	H1C	H2A	H2B	H2C
45	1.00	1.00	0.72	1.00	1.00	0.95
50	1.00	1.00	0.77	1.00	1.00	0.97
55	1.00	1.00	0.82	1.00	1.00	0.98

Native English speakers were recruited through Prolific (<https://www.prolific.co/>). Participants were left-handed; 18- to 45-years old; had normal or correct-to-normal vision; no significant hearing loss; no history of neurological disease, head injury, epilepsy, or language and/or reading impairment. Recruitment continued until the target sample size

of 55 participants was reached for the two laterality groups; in total, 191 participants were tested. The final sample included in the analysis is described under the *Data Analysis* section below.

Online tasks. Five tasks were delivered online via Gorilla [gorilla.sc] (Anwyl-Irvine, Massonnié, Flitton, Kirkham, & Evershed, 2020): a basic demographics questionnaire, the Edinburgh Handedness Inventory, the Lexical Test for Advanced Learner of English, a consonant-vowel dichotic listening task, and a visual half-field (VHF) lexical decision task.

Demographic questionnaire. The basic demographics questionnaire asked participants to report age, gender and writing hand.

Edinburgh Handedness Inventory. The Edinburgh Handedness Inventory (Oldfield, 1971) was administered to confirm the participants' self-reported handedness with an established test of hand preference. Participants indicated hand preference for 10 everyday activities on a 5-step scale. Scores > 0 were categorised as right-handed, and scores < 0 as left-handed (ranging from -100 to 100).

Lexical Test for Advanced Learner of English. The Lexical Test for Advanced Learner of English [LexTALE] (Lemhöfer & Broersma, 2012) was administered to assess vocabulary as an indicator of language proficiency. Participants were presented with 60 letter strings (40 words and 20 non-words) and had to indicate which words they knew. LexTALE scores were corrected for the unequal proportion of words and non-words by averaging the percentages corrected for these two item types (e.g., $((\text{number of words correct}/40 \times 100) + (\text{number of non-words correct}/20 \times 100))/2$). Accordingly, the LexTALE scores ranged from 0 to 100.

Dichotic listening. The dichotic listening task had previously been reported by Parker, Woodhead, Thompson, and Bishop (2021). In the current experiment, participants completed three blocks of the dichotic listening. Each block contained 36 stimuli which were a pair of consonant-vowel strings first developed by Bless et al. (2013). The consonant-vowel stimuli were formed by pairing six stop-consonants (/b/, /d/, /g/, /p/,

/t/, /k/) with the vowel /a/. Each of the six consonant-vowel stimuli (/ba/, /da/, /ga/, /pa/, /ta/, /ka/) were paired and played in each sound channel (e.g. /ba/-/da/). On a given trial, a fixation cross was displayed for 250 ms, after which a stimulus was played. At this point, participants were instructed to report the syllable they heard or if it seemed like they heard two different sounds, the one they heard most clearly by clicking a button corresponding to one of the six syllables.

To check for adherence to stereo-headphone use, participants completed two tasks. The first involved participants judging which of three pure tones was quietest. Woods, Siegel, Traer, and McDermott (2017) have previously reported the success of this measure in screening out those who did not use headphones. The second task presented participants with sounds in isolation to each headphone channel. Participants had to report which ear the sound was play to. If they scored less than 66.6% on these measures, participants were excluded from the experiment.

Visual half-field task. The VHF task was designed in adherence to many of Hunter and Brysbaert’s (2008) recommendations, e.g., a sufficient number of trials, bilateral presentation, and masking stimuli at offset. Participants completed 2 blocks of the task. Each block comprised 120 word and 120 non-word targets; in half the trials the target was in the LVF, and in half it was in the RVF. Trial order within the block was randomised and block order was pseudorandomised for each participant.

Stimuli. All of the 120 word and 120 non-word targets were five letters long and had two syllables. Out of the 120 word targets, 60 had many substitution neighbours ($M_N = 9.62$, $range_N = 7-12$) and 60 had few ($M_N = 1.40$, $range_N = 0-2$). High N word targets did not differ in zipf frequency (Heuven, Mandera, Keuleers, & Brysbaert, 2014) scores (low N: $M_{zipf} = 3.84$, $SD_{zipf} = 0.61$; high N: $M_{zipf} = 3.80$, $M_{zipf} = 0.56$; Wilcoxon $W = 1854$, $p = 0.779$), bigram frequency (low N: $M_{BG} = 1379$, $SD_{BG} = 641$; high N: $M_{BG} = 1438$, $SD_{BG} = 496$; Wilcoxon $W = 1518$, $p = 0.140$), or age of acquisition (low N: $M_{AoA} = 7.96$, $SD_{AoA} = 2.15$; high N: $M_{AoA} = 7.58$, $M_{AoA} = 2.16$; Wilcoxon $W = 1621$, $p = 0.348$). Non-word targets

had 0-2 substitution neighbours.

120 word and 120 non-word distractors were selected in order to facilitate bilateral presentation. All distractors were five letters long and had two syllables. On half of the trials, the target and distractor were congruent (both words or non-words) and on the other half they were incongruent (a word and non-word).

Procedure. At the start of a trial, a fixation cross was presented centrally for 400 ms. Participants were instructed to keep their eyes on the central fixation point. Then, a target string and a distractor were presented for 200 ms to the left and right of fixation. A central arrow displayed at the point of fixation indicated which of the two letters strings that participants had to make a lexicality judgment for. Upon stimuli offset, a mask (+++++) replaced the strings for 200ms (see Figure 1).

Figure 1. Illustration of a trial on the VHF lexical decision task. In the example, the target, as indicated by the arrow, is angle and the distractor is shiry. For a correct response, participants would press Y to indicate that the target is a word.

Stimuli were presented in black lower case Courier font on a white background. Gorilla's scaling tool was used to ensure that stimulus size and position were kept consistent across participants' experimental setup. Font was scaled to 250% equating to 28pt font, and stimuli were presented at a displacement of 2.5 deg. of visual angle when

presented to the left or right of fixation. Participants were instructed to press one of two buttons on the keyboard to indicate whether the string was a legitimate English word or not (*Y* for word or *N* for non-word). They were instructed to do so as quickly and accurately as possible. The next trial started contingent on the participant's response. Stimuli were divided into two counterbalanced lists with each participant responding to 120 words and 120 non-words in a random order. As participants completed two blocks (i.e. one of each counterbalance list), they responded to 240 words and 240 non-words in total.

General Procedure. The current experiment implemented a mixed design. Both *N* (high or low) and visual field (left or right) in the lexical decision task were within-subjects while laterality (typical or atypical) was between-subjects. Across the battery of tasks, the self-report measures were completed first followed by the behavioral measures. The three blocks of the dichotic listening were intermixed with the lexical decision task.

Data analysis.

Data cleaning and final sample. Of the 191 participants initially recruited, 51 were removed following pre-registered criteria. A total of 15 participants were removed due to scores on the Edinburgh Handedness Inventory falling between zero and 100, indicating preference for the right hand. A further 8 participants were removed due to lower than an advanced level of English vocabulary knowledge on the LexTALE (i.e. <80). As the dichotic listening task included all possible combinations of the syllables, we removed 9 participants who failed to report the correct syllable on 75% of trials where identical syllables were presented to each ear. We then removed 5 participants whose mean accuracy was below 50% across visual fields. Individual trials on the dichotic listening were removed if trials were shorter than 200 ms or longer than 1000 ms.

For the remaining 154 participants, the following data cleaning procedures were applied to data from the VHF task: (1) we removed reaction times shorter than 400 ms; (2) we removed reaction times longer than 2000 ms; (3) we applied Hoaglin and Iglewicz's

(1987) outlier identification procedure to reaction times. Under this procedure outliers are defined as response times that are 1.65 times the difference between the first and third quantiles ($1.65 * (Q3 - Q1)$) below or above the first and third quantile values (e.g: lower limit = $Q1 - 1.65 * (Q3 - Q1)$; upper limit = $Q3 + 1.65 * (Q3 - Q1)$). This criterion was applied to all responses and separately for each experimental condition. Following outlier removal procedures, we removed 14 participants who had more than 50% of their data removed due to these procedures.

After applying data cleaning procedures, we were left with usable data from 140 participants (77 females, 62 males, 1 other). The mean age of participants was 29.17 years ($SD_{years} = 7.31$).

Categorising laterality. The dichotic listening task was used to categorise cerebral dominance for language. To determine lateralisation, we computed a laterality index using counts of correctly identified syllables played to the left and right ears using the equation: $100 * ((Right - Left) / (Right + Left))$. We pre-registered two approaches to examining laterality on the N effect during lateralised lexical decision. The first was to categorise participants as left, bilateral, and right lateralised and compare N effects in those who were left and right lateralised. Here, participants with LIs greater than 5 were categorised as left hemisphere dominant, participants with LIs less than -5 were right hemisphere dominant, and the remaining participants were categorised as bilateral. The second approach was to categorise participants as typically and atypically lateralised and compare N effects on the VHF task. Here, participants with LIs greater than 5 were categorised as being *typically* lateralised and participants with LIs less than 5 were categorised as being *atypically* lateralised. As will become clear, we opted for the second option in order to avoid excessive data loss.

Mixed-effects analysis. To examine our experimental hypotheses, we fitted a series of linear mixed-effects models to the reaction time data. This was accomplished using the *lmer()* function from the *lme4* package [version 1.1.27.1] (Bates, Mächler, Bolker,

& Walker, 2015) within R [version 4.0.5] (R Core Team, 2021). These analyses considered word targets only. Our first set of hypotheses related to N effects in typically lateralised participants. To assess hypothesis 1a and 1b, we fitted a model to left and right visual field data: $lmer(dv \sim N \times VF + (1/participant) + (1/item))$. Using treatment coding, high-N words in the LVF became the intercept to which the remaining conditions were compared. Thus, the fixed N effect would statistically examine the N effect in the LVF (i.e. hypothesis 1a). The interaction term of N x VF would statistically examine whether the N effect differed in the RVF relative to LVF (i.e. hypothesis 1b). Hypothesis 1c was examined via a supplemental model fitted to data for the RVF only: $lmer(dv \sim N + (1/participant) + (1/item))$. The fixed N effect would statistically examine the N effect in the RVF.

Our second set of experimental hypotheses predicted differences in N effects between those who were typically and atypically lateralised. To assess hypothesis 2a and 2b, we fitted a model to data for both typically and atypically lateralised participants across the four experimental conditions: $lmer(dv \sim N \times VF \times Laterality + (1/participant) + (1/item))$. Here, treatment coding meant that high-N words in the LVF for atypically lateralised participants became the intercept to which the remaining conditions were compared. The interaction term N x Group assessed whether the N effect differed in the LVF between laterality groups (i.e. hypothesis 2a). The term N x VF x Group assessed whether the N by visual field interaction differed between groups (i.e. hypothesis 2b). A supplemental model fitted to RVF data ($lmer(dv \sim N \times Laterality + (1/participant) + (1/item))$) was then used to examine whether the N effect in the RVF differed between laterality groups. Due to the coding scheme, the simple main effects of N and visual field enabled us to explore N effects in atypically lateralised participants.

For each model, we report regression coefficients (b), standard errors (SE), and t -values. We consider as statistically significant those cases where $|t| > 1.96$.

To assess the evidence for critical null effects, we supplemented our pre-registered

analyses with Bayes Factor analysis (see Wagenmakers, 2007). Bayes Factors were computed by first fitting Bayesian linear-mixed effects models using the *brm()* function from the *brms* package [version 2.16.0] (Bürkner, 2017). These models included identical fixed effects as our pre-registered hypotheses. For each fixed-effect, we assumed uninformative priors $normal(0,1)$. Each model had four chains and had 12,000 iterations (with 2,000 being discarded due to warmup). Consultation of the Rhat statistic indicated that each model had fully converged. For each fixed-effect, we then used the *hypothesis()* function to compute Bayes Factors (BF10), where $BF10 > 3$ indicates moderate, $BF10 > 10$ indicates strong, $BF10 > 30$ indicates very strong, and $BF10 > 100$ indicates extreme evidence for H1, while $BF10 < 1/3$ indicates moderate, $BF10 < 1/10$ indicates strong, $BF10 < 1/30$ indicates very strong, and $BF10 < 1/100$ indicates extreme evidence for the null hypothesis (Jeffreys, 1961).

Results

Below we report the results for the dichotic listening task and mixed-effects analysis.

Categorising laterality. Performance on the dichotic listening task is shown in Figure 2. A one-tailed paired-samples *t*-test indicated that more syllables were correctly identified in the right- relative to the left-ear, $t(139) = 7.31$, $95\% CI = [-Inf, -3.85]$, $p < .001$; replicating prior research. When applying our approach to categorising hemispheric dominance for language, 86 participants were left lateralised, 43 participants were categorised as right lateralised, and the remaining 11 were bilateral. Our second approach resulted in 86 participants being characterised as typically lateralised and 54 being characterised as atypically lateralised. At this point, we chose to adopt our second approach and categorise participants as (a) typically lateralised rather than recruit additional participants to make a comparison of left and right lateralised participants as this seemed uneconomical. Our sample of 86 typically lateralised participants far exceeded that of the recommendations from our power analyses (i.e. 55 participants). Our sample of 54

atypically lateralised participants was close to the recommendations of our power analysis.

Figure 2. Count of correctly identified syllables in the left and right ear for the sample as a whole. Each data point corresponds to a single participant.

Mixed-effects analysis. While we pre-registered that reaction time data would be used to assess our experimental hypotheses, in Table 2 we report the proportion of correct responses and reaction times across each experimental condition for completeness. From Figure 3, a numerical inhibitory effect of N is observable across visual fields for both laterality groups.

Regarding the typically lateralised group, Model 1A indicated that the N effect was not significant in the LVF (see Table 3). The N x VHF interaction was not significant, indicating that the N effect did not differ across visual fields. Model 1B confirmed that the N effect was not significant in the RVF. Together these results do not confirm any of our predictions. Bayes Factors provided support for these findings. There was moderate evidence for a null N effect in both the left and right visual fields and the Bayes Factor for the interaction term indicated strong evidence in favour of the null. Model 1 did, however, indicate that reaction times were significantly shorter in the RVF for low N words and, as

Table 2

Proportion of correct responses and reaction times for word targets as a function of laterality group, visual field, and neighbourhood size (N).

		LVF		RVF	
		High N	Low N	High N	Low N
Typical	Prop. correct	0.64 (0.48)	0.66 (0.47)	0.79 (0.41)	0.79 (0.41)
	Reaction time (ms)	826 (189.2)	818 (187.8)	809 (181.2)	802 (183.8)
Atypical	Prop. correct	0.67 (0.47)	0.66 (0.47)	0.77 (0.42)	0.76 (0.43)
	Reaction time (ms)	810 (199.5)	794 (190.2)	804 (187.0)	800 (182.3)

this did not differ for high N words, we replicated the RVF advantage.

Moving onto our comparison of typically and atypically lateralised participants, Model 2A indicated that the N x Laterality interaction was not statistically significant (see Table 4). This indicates that the N effect in the LVF did not differ between laterality groups. Furthermore, the N x VHF x Laterality interaction was also non-significant, indicating that the difference in N effects across visual fields did not differ between laterality groups. The N x Laterality interaction in Model 2B confirmed that the N effect in the RVF did not differ between laterality groups. Thus, our statistical analyses did not support hypothesis 2. Bayes factors for these analyses provided evidence in support of the null. However, the effect of VHF in model 2A indicated that reaction times did not differ across VHFs for atypically lateralised participants, which contrasts findings for the typically lateralised participants. Accordingly, the VHF x Laterality interaction was significant for model 2A indicating a difference in the RVF advantage across groups.¹.

¹ Due to the poor correlation between lateralisation for the dichotic listening and VHF task, $r = 0.178$, 95% CIs = [0.122, 0.334], $p = 0.036$, we repeated our pre-registered analyses when using the VHF task to categorise laterality. The pattern of results remained unchanged as did our conclusions.

Figure 3. Mean reaction time (ms) for typically lateralised participants and atypically lateralised participants across the four within subjects conditions. Pink points indicate condition means for words in the LVF and blue points indicate condition means word in the RVF. Error bars indicate the 95% confidence interval around the mean.

Discussion

In Experiment 1, we set out to examine whether the pattern of orthographic neighbourhood effects in the LVF and RVF differed in a sample of left-handed participants who were typically and atypically lateralised on a consonant-vowel dichotic listening task. Our first aim was to replicate the typical pattern of orthographic neighbourhood effects observed under lateralised presentation in participants who were typically lateralised: a facilitatory effect in the LVF and inhibition in the RVF. The data indicated a series of null effects and a lack of support for our a priori predictions. Our second aim was to assess whether the pattern of N effects differed between those who were typically and atypically lateralised. Again, we report a series of null effects here. Given that we failed to observe the typical pattern of N effects in those who were typically lateralised, the lack of evidence for a difference is difficult to interpret.

On a more positive note, we report a strong RVF advantage for the processing of written stimuli in the typically lateralised participants. Interestingly, laterality indices

Table 3

Linear mixed-effects results for reaction times analysis in typically lateralised participants.

	Model 1A: NxVHF+(1 participant)+(1 item)				Model 1B: N+(1 participant)+(1 item)			
Fixed effect	b	SE	t	BF10	b	SE	t	BF10
(intercept)	6.698	0.013	528.476	-	6.675	0.013	514.513	-
N	-0.008	0.006	-1.266	0.014	-0.008	0.006	-1.355	0.014
VHF	-0.026	0.005	-5.457	2.420e+15	-	-	-	-
N x VHF	0.001	0.007	0.086	0.007	-	-	-	-

calculated using this paradigm had good split-half reliability, $r = .82$, indicating that while the paradigm might not be reliable for measuring lateralised N effects, it is consistent in estimating a RVF bias. Furthermore, analyses yielded a significant interaction between visual field and laterality group, indicating that the RVF advantage in the lexical decision task was larger for the typical group. This replicated previous findings in lexical decision studies supporting the notion that the RVF advantage is driven by the transfer times associated with callosal transfer from the stimulated visual hemifield to the dominant hemisphere for language (Cai, Lavidor, Brysbaert, Paulignan, & Nazir, 2008; Krach, Chen, & Hartje, 2006; Lavidor, Hayes, & Bailey, 2003). These observations may be regarded as providing some evidence of positive controls in the study: i.e., we replicated the well-established RVF effect for words, and we also demonstrated that the subdivision of participants into laterality groups related to their lateralisation on the VHF task.

The failure to replicate the standard N effects under lateralised presentation was therefore surprising. There are a number of possible explanations. We have ruled out the possibility that Parker et al.'s (2021) result was a false positive - the literature on the facilitatory N effect in the LVF is robust, and Parker et al.'s study itself was a replication and was backed up by a meta-analysis of similar findings in the literature. We believe it is more likely that our failure to replicate Parker et al.'s findings was due to methodological

Table 4

Linear mixed-effects results for reaction times analysis in typically and atypically lateralised participants.

Fixed effect	Model 2A: NxVHFxLateralality+(1 participant)+(1 item)				Model 2B: NxLateralality+(1 participant)+(1 item)			
	b	SE	t	BF10	b	SE	t	BF10
(intercept)	6.674	0.016	406.571	-	6.678	0.017	399.866	-
N	-0.014	0.007	-1.858	0.043	-0.008	0.007	-1.142	0.012
VHF	-0.001	0.006	-0.093	0.006	-	-	-	-
Lateralality	0.024	0.021	1.148	0.042	-0.003	0.021	-0.142	0.021
N x VHF	0.006	0.008	0.757	0.011	-	-	-	-
N x Lateralality	0.006	0.008	0.715	0.01	<-0.001	0.007	-0.023	0.007
VHF x Lateralality	-0.025	0.008	-3.323	1.804	-	-	-	-
N x VHF x Lateralality	-0.006	0.011	-0.535	0.012	-	-	-	-

differences between the studies in terms of the participant group, the task design or the stimuli, which are discussed in detail below.

Parker et al.'s (2021) study used right-handed participants, whereas we used left-handed participants: this difference may have caused our failure to replicate Parker's results. It is known that left-handers are more variable in their strength and direction of lateralisation than right-handers (e.g. Bruckert et al., 2021; Woodhead et al., 2020); however, we controlled for this by testing the left-handers' lateralisation using a dichotic listening task, and selecting a sub-group of participants with typical (left) lateralisation as well as a sub-group with atypical (right or bilateral) lateralisation. We did not replicate Parker et al.'s result in either group. Nevertheless, it remains possible that even 'typically lateralised' left-handers may differ from typical right-handers in how they process words, and that this could be responsible for the differences that we saw between Parker et al.'s results and our results.

A second possibility is that the bilateral task design used in Experiment 1 eliminated the N effect. Parker et al.'s (2021) study used an online lexical decision task with unilateral

presentation. In this unilateral version of the task, one written stimulus was presented to either the LVF or RVF in each trial, and participants were required to respond by button press to indicate whether the stimulus was a word or a non-word. Experiment 1 used a modified version of this task with bilateral presentation. In the bilateral version of the task, two written stimuli were presented simultaneously in each trial, one in the LVF and one in the RVF. A centrally presented arrow indicated the stimulus that the participant was required to respond to. This bilateral version was chosen as it has been recommended by other researchers as being optimal in terms of balancing visual stimulation in the two visual fields and preventing automatic saccades or attentional bias towards the target stimulus (e.g. Hunter & Brysbaert, 2008). However, it may have had unanticipated consequences for the N effect. Parker et al.'s task differed from Experiment 1 in two further ways. First, Parker et al.'s task had LVF, RVF and central visual field (CVF) conditions, whereas Experiment 1 only had LVF and RVF conditions. Second, Experiment 1 employed backward masking after the written stimuli (e.g., ++++++ presented to the LVF and RVF) to control the duration of visual stimulation, but Parker et al.'s task did not.

A final difference between Parker et al.'s (2021) study and the replication was the choice of written stimuli. Parker et al.'s controlled for lexical frequency only, whereas Experiment 1 controlled for bigram frequency and age of acquisition in addition to lexical frequency. Overall, the stimuli had a lower lexical frequency. Furthermore, Experiment 1 presented participants with 240 word targets, whereas Parker et al. presented 120 targets and this may have had consequences for the reliability of the estimates obtained between studies.

Experiment 2

In Experiment 1, we aimed to replicate and extend the findings of Parker et al. (2021) in a sample of left-handed participants who varied in whether they showed typical or atypical lateralisation. Parker et al. showed that, using a unilateral visual

half-field task in a group of right-handed participants, there was a facilitatory N effect in the LVF and an inhibitory N effect in the RVF. Experiment 1 however found no significant N effect size in either the LVF or the RVF when using a bilateral visual half-field task in left-handed participants with either typical or atypical language lateralisation.

In Experiment 2 we sought to understand why we failed to replicate this result. This was accomplished by recruiting a sample of right-handers to complete both the bilateral VHF task reported in Experiment 1 and a unilateral version more akin to that used by Parker et al. (2021). Both tasks used the same word lists described in Experiment 1. Our decision to test right-handers allowed a comparison of left-handed and right-handed participants with the same task (from Experiments 1 and 2 respectively), to see whether the discrepant results were due to the participants' handedness. By requiring participants to complete both a unilateral and bilateral version of the task we could further explore the extent to which task differences led to the null effects reported in Experiment 1. The experiment was pre-registered on the Open Science Framework prior to the commencement of data collection. The registration form, materials, data, and R scripts can be found at <https://osf.io/uvykh/>.

We pre-registered the following hypotheses. If the failure to replicate the N effects in either visual field in Experiment 1 was the result of differences in processing between left- and right-handers, we would expect right-handers to show (in both the unilateral and bilateral VHF tasks): (a) a facilitatory N effect in the LVF (i.e. a significant facilitatory simple main effect of N); (b) N effects that differ across visual fields (i.e. a significant interaction between N and visual field); and (c) an inhibitory N effect in the RVF (i.e. a significant inhibitory simple main effect of N)². If, however, our failure to replicate the N effects in either visual field in Experiment 1 was the result of presentation mode, then we

² Note that our predictions were separate for the two VHF paradigms and we did not set out to directly compare performances across the two tasks.

should only expect N effects under unilateral presentation. Finally, if our failure to replicate the N effects in either visual field in Experiment 1 was the result of stimuli selection then we would predict null effects of N for both unilateral and bilateral presentation.

Methods

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the experiment.

Participants. As with Experiment 1, our final sample size was based on the a priori power analyses reported in Experiment 1. That is, we looked to recruit 55 participants in total. This would theoretically provide sufficient power (i.e. 80%) to detect a -25 ms facilitatory N effect in the LVF and a 15 ms N effect in the RVF.

To reach this sample, 105 native English speakers were recruited through Prolific (<https://www.prolific.co/>). Participants were right-handed, 18- to 45-years old, had normal or correct-to-normal vision, no significant hearing loss, history of neurological disease, head injury, epilepsy, or diagnosis of language and/or reading impairment. The final sample is described under the *Data Analysis* section below.

Online tasks. In addition to the five tasks administered in Experiment 1, participants completed a unilateral VHF task. The stimuli were identical to those used in Experiment 1. To reduce effects of fatigue, participants completed two sessions. For session 1, participants completed the demographics, Edinburgh Handedness Inventory, and the LexTALE. They then completed two blocks of either the unilateral or bilateral VHF task. Before each block, participants complete a single block of the dichotic listening such that they completed two blocks per session (four blocks in total). For session 2, participants completed two blocks of the remaining VHF task which was preceded by a block of the dichotic listening each time. For brevity's sake, we only describe the VHF tasks here.

Visual half-field task. We administered two VHF tasks to study lateralised orthographic neighbourhood effects: one using unilateral presentation and the other using

bilateral. Participants completed 2 blocks of each task. Each block comprised 120 word and 120 non-word targets; in half the trials the target was in the LVF, and in half it was in the RVF. Trial order within the block was randomised and block order was pseudorandomised for each participant.

Stimuli. Word and non-word targets were identical to those used in Experiment 1.

Bilateral presentation. All conditions reported for Experiment 1 were maintained.

Unilateral presentation. At the start of a trial, a fixation cross was presented centrally for 400 ms. Participants were instructed to keep their eyes on the central fixation point. Then, a target string was shown for 150 ms to the left or right of fixation. Under unilateral presentation there was no masking at stimulus offset and no centrally presented arrow to indicate where to allocate attention.

Stimuli were presented in black lower case Courier font on a white background. Gorilla's scaling tool was used to ensure that stimulus size and position were kept consistent across participants' experimental setup. Font was scaled to 250% equating to 28pt font, and stimuli were presented at a displacement of 2.5 deg. of visual angle when presented to the left or right of fixation. Participants were instructed to press one of two buttons on the keyboard to indicate whether the string was a legitimate English word or not (*Y* for word or *N* for non-word). They were instructed to do so as quickly and accurately as possible. The next trial started contingent on the participant's response. Stimuli were divided into two counterbalanced lists with each participant responding to 120 words and 120 non-words in a random order. Across the two blocks, participants responded to 240 words and 240 non-words.

General Procedure. The current experiment implemented a within-subjects design. Both *N* (high or low) and visual field (left or right) in the lexical decision task were within-subjects as was presentation mode (all participants completed unilateral and bilateral versions of the task).

Data analysis.

Data cleaning and final sample. Of the 105 participants initially recruited, 86 participants (81.9%) completed both sessions. 30 participants were then removed following pre-registered criteria. Six participants were removed due to scores on the Edinburgh Handedness Inventory falling below 80 (i.e. participants were not extreme right-handers). A further 5 participants were removed due to lower than an advanced level of English vocabulary knowledge on the LexTALE (i.e. <80).

For the remaining 75 participants, the following data cleaning procedures were applied to data from each VHF task: (1) we removed reaction times shorter than 200 ms; (2) we removed reaction times longer than 2000 ms; (3) we applied Hoaglin and Iglewicz's (1987) outlier identification procedure to reaction times. Under this procedure outliers are defined as response times that are 1.65 times the difference between the first and third quantiles ($1.65 * (Q3 - Q1)$) below or above the first and third quantile values (e.g: lower limit = $Q1 - 1.65 * (Q3 - Q1)$; upper limit = $Q3 + 1.65 * (Q3 - Q1)$). This criterion was applied to all responses. This was performed separately for each experimental condition. Following outlier removal procedures, we removed 19 participants who had more than 50% of their data removed due to these procedures.

After applying data cleaning procedures, we were left with usable data from 56 participants (31 females, 25 males). The mean age of participants was 28.14 years ($SD_{years} = 7.27$).

Mixed-effects analysis. We aimed to examine the nature of the N effect in the LVF and RVF under both bilateral and unilateral presentation. To examine our experimental hypotheses, we fitted a series of linear mixed-effects models to the reaction time data using the same procedures as Experiment 1. These analyses considered word targets only. To assess hypothesis 1a and 1b, we fitted a model to left and right visual field data for the bilateral task: $lmer(dv \sim N \times VF + (1/participant) + (1/item))$. Using treatment

coding, high-N words in the LVF became the intercept to which the remaining conditions were compared. Thus, the fixed N effect would statistically examine the N effect in the LVF (i.e. hypothesis 1a). The interaction term of N x VF would statistically examine whether the effect differed in the RVF relative to LVF (i.e. hypothesis 1b). Hypothesis 1c was examined via a supplemental model fitted to data for the RVF only: $lmer(dv \sim N + (1/participant) + (1/item))$. The fixed N effect would statistically examine the N effect in the RVF. An identical model was fitted to unilateral data to assess hypotheses 2a, 2b, and 2c .

For each model, we report regression coefficients (b), standard errors (SE), and t -values. We consider as statistically significant those cases where $|t| > 1.96$. We then report Bayes Factors for these analyses.

Results

The proportion of correct answers and reaction times across each experimental condition under bilateral and unilateral presentation are reported in Table 5. Reaction time data is visualised in Figure 4. Of interest is the inhibitory effect of N under bilateral presentation.

Table 5

Proportion of correct responses and reaction times for word targets under bilateral and unilateral presentation. Conditions means are shown across visual fields and neighbourhood sizes (N).

		LVF		RVF	
		High N	Low N	High N	Low N
Bilateral	Prop. correct	0.63 (0.48)	0.63 (0.48)	0.76 (0.43)	0.77 (0.42)
	Reaction time (ms)	751 (199.4)	744 (194.2)	717 (195.9)	712 (201.0)
Unilateral	Prop. correct	0.75 (0.43)	0.8 (0.40)	0.81 (0.39)	0.85 (0.36)
	Reaction time (ms)	670 (164.6)	688 (151.7)	672 (152.2)	661 (144.0)

Figure 4. Mean reaction time (ms) under (A) bilateral and (B) unilateral presentation across the four within subjects conditions. Pink points indicate condition means for words in the LVF and blue points indicate condition means word in the LVF. Error bars indicate the 95% confidence interval around the mean.

Bilateral presentation. Under bilateral presentation, Model 1A indicated that that the N effect was not significant in the LVF (see Table 6). The N x VHF interaction was not significant, indicating that the N effect did not differ across visual fields. Model 1B confirmed that the N effect was not significant in the RVF. Bayes Factors provided support for the suggestion that under bilateral presentation, N has little influence on reaction times. This pattern of results is strikingly similar to those observed in left-handers in Experiment 1.

Table 6

Linear mixed-effects results for reaction times analysis in typically lateralised participants.

Presentation	Fixed.effect	Model 1A: NxVHF+(1 participant)+(1 item)				Model 1B: N+(1 participant)+(1 item)			
		b	SE	t	BF10	b	SE	t	BF10
Bilateral	(intercept)	6.600	0.022	297.430	-	6.543	0.023	287.703	-
	N	-0.010	0.009	-1.171	0.018	-0.009	0.009	-1.034	0.015
	VHF	-0.061	0.007	-8.649	1.072e+145	-	-	-	-
	N x VHF	0.001	0.010	0.059	0.010	-	-	-	-
Unilateral	(intercept)	6.485	0.017	389.035	-	6.485	0.017	389.035	-
	N	0.032	0.010	3.275	1.595	-0.015	0.009	-1.613	0.032
	VHF	0.003	0.006	0.500	0.006	-	-	-	-
	N x VHF	-0.048	0.008	-6.131	2.012e+15	-	-	-	-

Unilateral presentation. Under unilateral presentation, Model 2A indicated that for words in the LVF reaction times were longer for low N words relative to high N words; thus there was a facilitatory N effect in the LVF. The N x VHF interaction was statistically significant, indicating that the N effect differed across visual fields. Model 2B indicated that the N effect was not significant in the RVF. Bayes Factors were largely in support of the conclusions drawn. Importantly, in terms of replicating prior research, we were able to replicate the strong N effect in the LVF and replicate the interaction whereby effects of N differ across visual fields. However, we did not replicate the N effect in the RVF. This is not so surprising given previous reports of this effect being small but inhibitory.

Discussion

Experiment 2 set out to examine why we had previously failed to replicate a facilitatory N effect in the LVF and an inhibitory N effect in the RVF. Specifically we examined whether the failure to replicate was due to selecting a sample of left-handers, the stimuli used, or whether it stemmed from the use of bilateral presentation. This was accomplished by recruiting a sample of right-handers who completed a lateralised lexical decision task under unilateral and bilateral presentation. We predicted three scenarios: (1) if the failure to replicate the typical pattern of N effects was due to increased variability of lateralisation in left-handers, then we should find evidence of N effects under both bilateral and unilateral presentation in right-handers; (2) if the failure to replicate the typical pattern of N effects was due to the selection of different stimuli, then we should fail to observe N effects across both the unilateral and bilateral tasks; and (3) if the failure to replicate the typical pattern of N effects was due to the use of bilateral presentation, then we should observe N effects only when using unilateral presentation.

The data is conclusive on the above matter. We observed N effects only under unilateral presentation. As such, it seems as though our failure to observe N effects in a sample of left-handers when using bilateral presentation was likely due to the selection of bilateral presentation. We say more on this in the General Discussion.

General Discussion

Here we present two experimental studies aimed at understanding why participants vary in the extent to which they show facilitatory or inhibitory effects of neighbourhood size (N) in the LVF and RVF respectively. Experiment 1 examined lateralised N effects in typically and atypically lateralised left-handers. The study yielded null results in both typically and atypically lateralised participant groups. Given that the N effect has previously been reported as robust, at least in the LVF (Lavidor & Ellis, 2002, Lavidor et al., 2006, Parker et al., 2021, Perea et al., 2008; Whitney & Lavidor, 2005), we conducted

Experiment 2 to examine why the null results may have been observed in Experiment 1. In a sample of right-handers, we again reported null effects under bilateral presentation conditions but confirmed a facilitatory N effect under unilateral presentation in the LVF which reliably differed from the N effect in the RVF. The N effect in the RVF was numerically inhibitory but was not statistically significant. Thus, Experiment 2 replicated a number of previous studies when unilateral presentation was used (Lavidor & Ellis, 2001, 2002, Parker et al., 2021, Perea et al., 2008; Whitney & Lavidor, 2005). We consider the implications of these findings below.

We theorised that the failure to observe N effects in Experiment 1 may have stemmed from functional differences in left-handers as it is known that left-handers show a greater variability in language lateralisation and a greater incidence of atypical lateralisation than right-handers (e.g. Bruckert et al., 2021; Carey & Johnstone, 2014; Woodhead et al., 2020). Testing a group of right-handers and observing highly similar results under bilateral presentation provided evidence to the contrary. Instead, it appeared that our failure to replicate the typical patterns of N effects was due to the task used. The fact that we observed N effects under unilateral presentation confirms that the failure to replicate the basic pattern of N effects under bilateral presentation was not a result of stimulus selection.

The use of bilateral presentation may have had unanticipated consequences on the N effect. Sentence reading studies have reported that orthographically related words presented in the parafovea facilitate lexical access in the fovea (Dare & Shillcock, 2013; Snell, Vitu, & Grainger, 2017). This indicates that orthographic information is integrated, to some extent, across multiple words in parallel. Of course, making comparisons between sentence reading studies and lateralised lexical decision paradigms is limited by the fact that two words in sentence reading are separated by a characters length whereas the space between two stimuli under bilateral presentation is much greater, as stimuli are placed at 2.5 degrees eccentricity.

In a more directly relevant VHF paradigm, Jordan and Patching (2003) examined the effect that bilateral presentation had on perceived word identity. On every trial, orthographic neighbours were briefly presented to each VHF (e.g. romp - ramp). Participants were then shown 2 letters (e.g. a/u) and had to report the letter previously shown and in which VHF it appeared. Jordan and Patching reported a perceptual interaction in 24% of trials, whereby the RVF word altered the perceived identity of the LVF word, but not vice versa. These results suggest that orthographic information from the RVF can influence the processing of orthographic information in the LVF. It may be possible that during bilateral presentation, orthographic processing of words presented in the LVF is altered by processing of the distractor in the RVF. This could explain why under bilateral presentation we continually observed inhibitory effects of N that are characteristic of RVF presentation. Such an argument may have a place within Grainger, Dufau and Ziegler's (2016) model of multi-word reading, which theorizes that orthographic processing pools information from adjacent words into a single processing channel. While this would be helpful during sentence reading (allowing adjacent, orthographically related words to exert a mutually facilitatory influence), this process would also disrupt lateralised N effects during bilateral presentation.

From the above evidence it is clear that lateralised lexical decision paradigms with bilateral presentation may not be a robust method for examining lateralised N effects. Instead, because of pooling of information across the whole visual field, it seems unilateral presentation is perhaps the preferred method. Indeed, unilateral presentation in Experiment 2 resulted in a -18.2 ms facilitatory effect in the LVF and a 11.3 inhibitory effect in the RVF. Compared to a recent meta-analysis (Parker et al., 2021) the estimate in the LVF is smaller than previously observed and the estimate in the RVF is larger (-31.8 ms and 10.8 ms respectively). Despite the small differences in the estimate of the N effect between studies, it will be essential for future studies of lateralised N effects to employ unilateral presentation when examining individual differences in lateralised N effects. Such

studies should still employ a number of the criteria for a good VHF task as defined by Hunter and Brysbaert (2008), such as (1) an acceptable number of observations; (2) matched stimuli sets. Under such a task it may be possible for future studies to examine the effects of hemispheric dominance for language on estimates of lateralised N effects.

It is important to note that in addition to bilateral presentation, Experiment 1 also employed a mechanism to control fixation at the beginning of each trial and backwards masking, whereas Experiment 2 did not. These differences may have also had consequences for the measurement of lateralised N effects. It is possible that by not controlling for fixation participants may have fixated away from central vision; distorting N effects across visual fields. However, the effects of controlling for central fixation appear somewhat minimal in VHF paradigms. Van der Haegen, Cai, Seurinck, and Brysbaert (2011) reported data for two VHF tasks where eye tracking was used to monitor fixation. Two sets of laterality indices were calculated; one that controlled for fixation error and one that did not. Laterality indices were highly correlated for both word naming, $r = .94$, and picture naming $r = .98$, indicating that implementing eye movement control minimally influences reaction time measures under lateralised presentation. The observation that we failed to observe N effects when employing backwards masking is interesting. Hunter and Brysbaert (2008) argued that backwards masking prevents iconic memory of a stimulus and any possibility of afterglow on the monitor and retina. As such, this may suggest that the observation of N effects is dependent upon the ability to continually perceive orthographic information after stimulus presentation. While this may be plausible, we see the most parsimonious explanation as the pooling of information across visual fields that occurs as a result of hemispheric transfer. To firmly conclude this, future studies will need to examine how N effects are influenced under unilateral presentation when further control for central fixation and backwards masking is employed.

Further research using unilateral presentation will also be required to test our original

hypothesis, of whether lateralised N effects are affected by the direction of hemispheric dominance for language. Unfortunately, the costs and time associated with testing this are beyond the scope of our preregistered protocols and our current resources. Hence, this question will remain open for future studies.

Conclusion

Two decades of research has indicated consistent facilitatory N effects in the LVF. The picture for N effects in the RVF is somewhat less consistent; some studies report N effects to be facilitatory in the RVF (e.g., Lavidor et al., 2006) while others report them to be inhibitory (e.g., Mano et al., 2010; Perea et al., 2008). A recent meta-analysis raised the hypothesis that inconsistencies in the literature may be due to individual differences, specifically the direction of hemispheric dominance for language (Parker et al., 2021). Experiment 1 sought to test this by recruiting a sample of left-handers, who were categorised as typically or atypically lateralised on a dichotic listening task, to complete a bilateral VHF lexical decision task where N was manipulated. While N effects did not differ between laterality groups, interpreting these findings was difficult as we failed to replicate the basic pattern of N effects in those who were typically lateralised. This led us to examine N effects in a sample of right-handers under both unilateral and bilateral presentation in Experiment 2. While we established N effects under unilateral presentation, we again failed to replicate N effects under bilateral presentation. Together, these results indicate that our failure to replicate the standard N effects in Experiment 1 stemmed from the use of bilateral presentation. We suggest that studies which look to examine individual differences in lateralised N effects should rely on unilateral presentation while using a sufficient number of stimuli and balancing stimuli across visual fields.

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