Clinical Linguistics & Phonetics
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713693308

Neighbourhood density effects in auditory non-word processing in aphasic listeners

Esther Janse [a]
[a] Utrecht Institute of Linguistics OTS, Utrecht, the Netherlands

Online Publication Date: 01 March 2009

To cite this Article Janse, Esther(2009)'Neighbourhood density effects in auditory non-word processing in aphasic listeners',Clinical Linguistics & Phonetics,23:3,196 — 207

To link to this Article: DOI: 10.1080/02699200802394989

URL: http://dx.doi.org/10.1080/02699200802394989

Clinical Linguistics & Phonetics, March 2009; 23(3): 196–207

informa
healthcare

Neighbourhood density effects in auditory non-word processing in aphasic listeners

ESTHER JANSE

Utrecht Institute of Linguistics OTS, Utrecht, the Netherlands

(Received 16 September 2006; accepted 30 June 2007)

Abstract
This study investigates neighbourhood density effects on lexical decision performance (both accuracy and response times) of aphasic patients. Given earlier results on lexical activation and deactivation in Broca's and Wernicke's aphasia, the prediction was that smaller neighbourhood density effects would be found for Broca's aphasic patients, compared to age-matched non-brain-damaged control participants, whereas enlarged density effects were expected for Wernicke's aphasic patients. The results showed density effects for all three groups of listeners, and overall differences in performance between groups, but no significant interaction between neighbourhood density and listener group. Several factors are discussed to account for the present results.

Keywords: *Spoken word processing, aphasia, lexical neighbourhood density*

Introduction

In spoken word processing, listeners have to map sound onto stored mental representations. Lexical competition is an important part of this mapping. The Neighbourhood Activation model (NAM; Luce and Pisoni, 1998) proposes that words in the mental lexicon are organized into similarity neighbourhoods. Thus, the auditory presentation of a word or non-word yields automatic activation of all words in the mental lexicon that sound similar. It is relatively easy to find a match between an incoming speech signal and a stored representation if that stored representation is dissimilar from other entries in the lexicon. However, if there are a number of similar entries, a match is less easily found, since the best match has to be found by weighing the goodness of fit of several representations to the incoming sound. The NAM suggests that both the number (neighbourhood density) and the frequency (neighbourhood frequency) of entries within a word's neighbourhood will affect recognition of that word. Experimental results with unimpaired listeners on a lexical decision task showed that non-words with dense lexical neighbourhoods led to slower responses and lower accuracy rates than non-words with sparse neighbourhoods: the non-word must be compared against existing entries, which takes more time when there are more neighbours.

Correspondence: Esther Janse, Janskerkhof 13, 3512 BL Utrecht, The Netherlands. Tel: +31-30-2536110. Fax: +31-30-2536406. E-mail: esther.janse@let.uu.nl

ISSN 0269-9206 print/ISSN 1464-5076 online © 2009 Informa Healthcare USA, Inc.
DOI: 10.1080/02699200802394989

The ability to suppress or inhibit co-activated neighbours is a central function to allow this mapping between sounds and words, but inhibitory control may be decreased in certain populations. In the non-pathological domain, inhibitory control has been claimed to decline with age (Hasher and Zacks, 1988; Hasher, Stoltzfus, Zacks, and Rypma, 1991). As a result, apart from the fact that age-related hearing problems may play a role, age-related cognitive decline means that older adults are particularly disadvantaged in identifying words that are phonetically similar to many other high-frequency words. Sommers (1996) showed larger effects of neighbourhood structure on lexical identification for older than younger adults, even when performance for a set of easy words was made equal for younger and older listeners. In the pathological domain, inhibitory deficits were found to be greater in individuals with Dementia of the Alzheimer's type (DAT) than in healthy older adults: and indeed, increased neighbourhood density effects were found in older individuals with more advanced DAT (Sommers, 1998). In yet another 'special' population, listeners with schizophrenia, enlarged lexical difficulty effects were found (Titone and Levy, 2004), and these were also attributed to inhibitory dysfunction. Spoken word identification, or the ability to cope with lexical competition, has thus been shown to depend on inhibitory function.

The present study examined the effect of neighbourhood density on auditory lexical decision performance with three groups of listeners: Broca's aphasic patients, Wernicke's aphasic patients, and age-matched non-brain-damaged participants. Broca's and Wernicke's aphasic patients have been claimed to be differentially impaired in lexical access. A number of auditory lexical access studies have suggested that lexical activation levels are reduced in Broca's aphasic patients (Milberg, Blumstein, and Dworetzky, 1988; Utman, Blumstein, and Sullivan, 2001). In non-aphasic subjects, acoustic manipulations of word-initial plosives (such as manipulation of voice onset time in *c*at*) produce a small, short-lived reduction in semantic priming (*c*at - dog*), relative to undegraded presentation of the prime target pair (*cat-dog*). This reduction in priming was found regardless of whether the prime had a voiced lexical competitor (*coat-goat*) or not (*cat-gat*), which suggests that the effect is due to poorer bottom-up mapping from acoustics to the lexical entry, rather than to lexical competition. At longer prime-target intervals, differences in semantic priming between good (*cat*) and poor phonetic exemplars (*c*at*) disappear. The results obtained for Broca's aphasics (Utman et al., 2001) were clearly different from those obtained with normal subjects. Broca's aphasics did not activate words such as *coat* when presented with an acoustically distorted form (VOT-manipulated *c*oat*) if there was a lexical competitor (such as *goat*), neither with a short nor with a long interstimulus interval. This indicates that, if there is a lexical competitor, the modified prime fails to produce sufficient lexical activation to prime the semantically-related target. Similar differences between Broca's aphasics and control subjects were found by Misiurski, Blumstein, Rissman, and Berman (2005). Misiurski et al. showed mediated priming for non-brain-damaged subjects with acoustically altered stimuli. VOT-manipulated stimuli (*t*ime*) were presented which activated the lexical entry *dime*, which in turn facilitated recognition of *penny*. Misiurski et al. (2005) found semantic priming from *dime* to *penny* for Broca's aphasics, but no mediated priming from *t*ime* to *penny*. Misiurski et al. (2005) suggest that bottom-up activation levels for acoustically manipulated prime items are not sufficient to overcome lexical competition, so that semantic priming is lost. If the lexical processing deficit in Broca's aphasia can be characterized by an overall reduction in lexical activation, the lexical competition difference between (non-) words from dense neighbourhoods and from sparse neighbourhoods may be reduced as well.

Conversely, there are some indications that lexical activation levels are increased in Wernicke's aphasic patients. In Wernicke's aphasia, less appropriate acoustic forms seem to be able to activate lexical items almost to the same extent as exact-match items (Milberg et al., 1988). Furthermore, a more recent study showed impaired deactivation of no longer appropriate word candidates in Wernicke's aphasia (Janse, 2006). Upon presentation of e.g. the word *hammock*, listeners will initially activate multiple lexical entries, such as *hammer* and *hammock*. If the target word turns out to be *hammock*, the remaining word candidates (such as *hammer*) are deactivated below resting level activation. This deactivation can be seen in competitor priming studies: if the word pair *hammock–hammer* is presented, listeners will be slower to perform lexical decisions on the second item than if the word *hammer* is preceded by an unrelated word. In Janse (2006), this deactivation or negative priming effect was found for non-brain-damaged control participants, whereas facilitation was found for Wernicke's aphasics. This reversed priming effect in the Wernicke's aphasic patients was attributed to impaired suppression of once-activated candidates. Given these inhibitory problems in Wernicke's aphasia, neighbourhood density may exert an enlarged influence in this population, as was found for the healthy elderly (Sommers, 1996) compared to younger listeners, elderly with dementia of the Alzheimer type (Sommers, 1998), and for schizophrenic listeners (Titone and Levy, 2004). Or, in other words, based on the assumption that the magnitude of the neighbourhood density effect is influenced by the overall level of lexical activation, smaller neighbourhood density effects on task performance were expected for Broca's aphasic patients, whereas enlarged density effects were expected for Wernicke's aphasic patients, compared to age-matched control participants.

An earlier study on neighbourhood density effects in aphasia is that of Boyczuk and Baum (1999), who investigated the effect of neighbourhood density on phonetic categorization by fluent aphasics, non-fluent aphasics, and age-matched controls. It is important to note, however, that phonetic categorization may tap a different (i.e. later) type of processing than the priming and lexical decision studies mentioned above. Boyczuk and Baum (1999) carried out phonetic identification experiments in which subjects were required to label syllable-initial stop consonants varying along a continuum. The endpoints of the continuum differed in terms of lexical status and neighbourhood density values. Given that Broca's aphasics showed a heavier reliance on lexical strategies in an earlier study (i.e. a larger lexical effect than controls on a phonetic categorization task; Blumstein, Burton, Baum, Waldstein, and Katz, 1994), Boyczuk and Baum (1999) initially expected a larger neighbourhood density effect for non-fluent aphasics than for fluent aphasics and control participants. Although no significant interactions between density effect and participant group were found, the density effect was numerically largest for the fluent patients. Boyczuk and Baum (1999) then suggest that neighbourhood density in fact exerts a greater influence on the fluent aphasics' performance because they tend to 'over-activate' the lexicon. Thus, even though the authors expected heavier reliance on (post-hoc) lexical strategies to be influenced by neighbourhood density, the numerically largest density effect for the fluent patients seemed more in accordance with initial lexical over-activation.

In the present study, lexical decision was chosen as the task to investigate lexical competition in perceptual processing. Non-words were chosen as test items because the density effect on accuracy seemed somewhat larger for non-words than for words (in Luce and Pisoni, 1998; Vitevitch and Luce, 1999). This may be due to the nature of the lexical decision response. A lexical decision response will be initiated when activation for a unique lexical item has reached some criterion or threshold. When an item fails to receive sufficient activation (within the subject's self-imposed time limit), decisions will be based on the overall level of lexical activity in the recognition system. Thus, for words, even though competition slows down processing for the high-density items, there is a lexical match to the input. Given that there is no lexical match for the non-words, the effects of competition may be more difficult to overcome. An additional point to take into account is that recognition of real words is determined not only by neighbourhood characteristics, but also by the lexical frequency of the item itself. The use of non-words may therefore provide a clearer picture of neighbourhood effects than the use of words.

The hypothesis tested in the present study is that neighbourhood density effects on task performance will be relatively weak for Broca's aphasic patients, but enlarged for Wernicke's aphasic patients, compared to age-matched control participants.

Method

Stimulus materials

Eighty monosyllabic Dutch CVC non-words were constructed: 40 with a high number of real-word neighbours (16 or more neighbours) and 40 with a low number of real-word neighbours (10 or less neighbours). In addition, 80 Dutch monosyllabic real words were chosen to balance for lexical status. The words and non-words were spoken in isolation by a male native speaker of standard Dutch with a clear speaking style. Additionally, 10 practice items (also balanced for lexical status) were recorded to familiarize the participants with the speaker's voice and with the task of lexical decision. The materials were recorded on digital audiotape with a Sennheiser microphone. They were fed as digital input into the computer, and downsampled to 16 kHz. Each word was stored as a separate sound file.

Procedure

The experimental software program TEMPO (Motta et al., 2000) was used to present the subjects with the materials. The programme randomized the order of presentation of the words and non-words for each participant. Participants were seated at a table, wearing closed earphones. The speech material was presented at a comfortable loudness level. They were asked to provide a lexical decision response after each auditory presentation by pressing either of two buttons (labelled YES and NO) on a response box as quickly and accurately as possible. There was a 3 second window during which the response could be given. Even if no response was given, the experiment proceeded following a 1 second pause before the next trial. During the practice session, meant to familiarize participants with the task, each participant's performance was monitored. Participants were told that they could not correct their response once given. The experiment lasted about 30 minutes. Participants were given a short break half-way through the experiment.

Participants

Participants included 27 aphasic patients: almost all of them had become aphasic following a CVA. Aphasic patients were recruited via several rehabilitation centres in the Netherlands and volunteered for the study after giving informed consent. The design and procedure for this multicentre experiment were approved by the Medical Ethics Committee of the Groningen University Medical Centre. There were 15 patients with a non-fluent type of aphasia, most of them classified as Broca's aphasic patients (on the basis of the Dutch version of the Aachen Aphasia Test; Graetz, de Bleser, and Willmes, 1992); and 12 patients with a fluent type of aphasia, most of them classified as Wernicke's aphasic patients. Patient information (age, sex, post-onset time, etc.) is given in Table I. Additionally, 12 age-matched non-brain-damaged control listeners (five female, seven male) participated in the study. Mean age of the non-fluent aphasics was 54.7 years; mean age of the fluent aphasics was 60.6 years. Mean age of the control participants, who were age-matched to the oldest, i.e. the fluent, aphasic patient group, was 60.2 years.

Results

Lexical decision response times were measured from target onset. Low density non-words were, on average, somewhat shorter (595 ms) than high density non-words (616 ms), although the duration difference between the item sets was not significant ($t(78)<1$, ns). To account for different item durations, each item's duration was subtracted from the response times. Subsequently, the mean item duration of 606 ms was added again to avoid negative response times. The obtained mean response times (collapsed over correct NO-responses) are presented in Figure 1. Accuracy percentages are given in Table II.

Table I. Patient information.

Patient	Age	Sex	Aetiology	Months post-onset	Language Comprehension Score AAT (0–120)
NF1–Broca	57	F	CVA-L	9	60
NF2–Global	77	F	CVA-L (arteria cerebri media)	16	75
NF3–Broca	51	F	CVA-L (frontoparietal)	20	82
NF4–Broca	56	M	CVA-L (parietal)	17	110
NF5–Broca	54	M	CVA-L	48	102
NF6–Broca	53	M	CVA-L	11	74
NF7–Global	70	M	CVA-L	8	80
NF8–Broca	36	F	CVA-L (arteria cerebri media)	3	62
NF9–Broca	39	F	CVA-L (arteria cerebri media)	5	111
NF10–Global	57	F	CVA-L	6	53
NF11–Global	43	F	CVA-L (arteria cerebri media)	14	77
NF12–Global	53	F	CVA-L	15	57
NF13–Broca	53	M	CVA-L	4	96
NF14–Broca	58	M	CVA-L	12	83
NF15–Broca	63	F	Politrauma-L	13	97
F1–Wernicke/Amn.	53	F	CVA-L	11	93
F2–Wernicke	60	M	CVA-L	4	14
F3–Wernicke	39	F	CVA-L (arteria communicans posterior)	15	90
F4–Amnestic	63	F	CVA-L	8	111
F5–Amnestic	48	F	CVA-L (parietal)	10	103
F6–Wernicke	68	M	CVA-L	7	94
F7–Wernicke	76	F	CVA-L	7	79
F8–Wernicke	67	M	CVA-L	3	86
F9–Wernicke	72	M	CVA-L (parietal)	3	107
F10–Wernicke	59	F	CVA-L	6	53
F11–Wernicke	57	M	CVA-L (arteria cerebri media)	6	107
F12–Wernicke	65	M	CVA-L	5	86

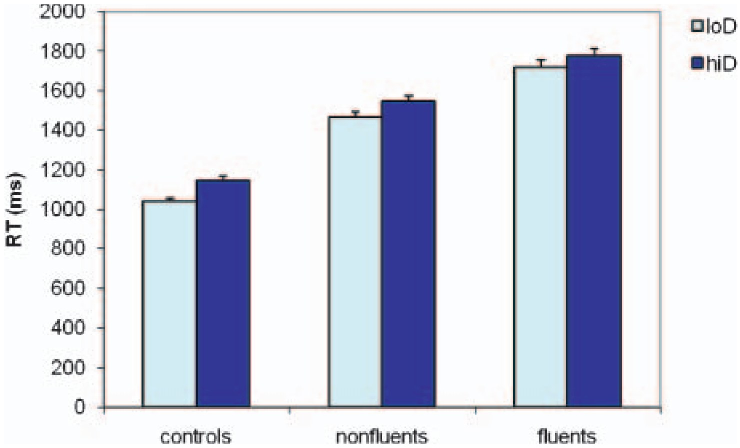

Figure 1. Mean response time for correct non-word decisions to Low and High Neighbourhood Density non-words for the three participant groups (controls vs non-fluent and fluent aphasics).

ANOVAs were run on accuracy rate (arcsine transformed) and response times, testing the effects of Neighbourhood Density (High vs Low) and Subject Group (Controls/Non-fluent aphasics/Fluent aphasics).

Accuracy rates (Repeated Measures ANOVA) showed a main effect of Neighbourhood Density: accuracy scores were significantly lower for the High Density non-words (overall 89% correct) than for the Low Density non-words (overall 84% correct; $F_1(1,36)=14.72$, $p<.001$; $F_2(1,78)=3.67$, $p=.059$). The effect of Subject Group was also significant (overall accuracy was 92% for the controls; 88% for the non-fluents, and 79% for the fluent aphasics; $F_1(2,36)=4.59$, $p=.017$; $F_2(2,77)=53.71$, $p<.001$). The Density by Subject Group interaction was not significant ($F_1(2,36)<1$, ns; $F_2(2,77)=1.73$, $p>.1$).

Within the group of aphasic participants, it was investigated whether the effect of Density on accuracy was greater for either patient group (as the accuracy rates in Figure 1 suggest). The same accuracy analyses were run, but now only on the patient data. The results showed a main effect of Density ($F_1(1,25)=8.48$, $p=.007$; $F_2(1,78)=3.96$, $p=.050$). The effect of Patient Group approached significance ($F_1(1,25)=3.30$, $p=.081$; $F_2(1,78)=45.65$, $p<.001$). The interaction between Density and Patient Group approached significance only by items, however ($F_1(1,25)<1$, ns; $F_2(1,78)=3.47$, $p=.066$).

The lexical decision response times (only for correct NO-responses, transformed to 1/RT values to make the data distribution less skewed; Ulrich and Miller, 1994) were analysed with Univariate ANOVAs to investigate Density and Subject Group effects. There were significant main effects of Density (overall slower response times to High (1521 ms) than to

Table II. Accuracy percentages for correct NO-responses to non-words for three groups of participants.

	Low density	High density
Controls (n=12)	94 (1.5)	89 (1.8)
Non-fluents (n=15)	90 (1.8)	87 (1.9)
Fluents (n=12)	84 (3.5)	75 (6.4)

Standard errors are given in brackets.

Table III. Lexical decision performance on non-words for control listeners and a sub-set of the aphasic patients.

	Low density		High density	
	Mean RT (SE)	Accuracy (SE)	Mean RT (SE)	Accuracy (SE)
Control listeners (n=12)	1043 ms (14)	94% (1.5)	1147 ms (20)	89% (1.8)
Broca's patients (n=10)	1383 ms (28)	88% (2.0)	1521ms (33)	85% (2.1)
Wernicke's patients (n=10)	1709 ms (35)	86% (3.3)	1783 ms (38)	79% (6.9)

Low Density (1433 ms) non-words: $F_1(1,36)=37.10$, $p<.001$; $F_2(1,78)=5.34$, $p=.023$) and Subject Group (slower response times for the aphasic patients than for the control participants: $F_1(2,36)=17.88$, $p<.001$: $F_2(2,77)=511.20$, $p<.001$), but no significant interaction between Density and Subject Group ($F_1(2,36)=1.76$, $p>.1$; $F_2(2,77)=1.78$, $p>.1$). Post-hoc analyses showed that response times of all three listener groups (mean RT was 1093 ms for the controls; 1506 ms for the non-fluent aphasics; and 1748 ms for the fluent aphasics) differed significantly from each other (for all comparisons $p<.001$ both by subjects and items).

Note that the aphasic patients were initially grouped in a fluent and non-fluent group, rather than in stricter aphasia types. The results were also analysed by restricting the patient data to those of the Broca's and Wernicke's patients. Since the hypotheses on reduced lexical activation vs increased lexical activation mainly concerned those specific Broca and Wernicke diagnostic groups, the results should also be presented for those sub-types. Table III shows the results for the Broca's and Wernicke's patients (control listener results of Figure 1 are repeated in this table). Note that mean ages in the Broca's and Wernicke's patient group were 52.0 and 61.6 years, respectively (control listeners had a mean age of 60.2 years).

Analyses on accuracy were run again for this group of listeners, testing the effects of Density (High vs Low) and Subject Group (Controls vs Broca's vs Wernicke's aphasics). The data showed an effect of Density by subjects only ($F_1(1,29)=8.60$, $p=.006$; $F_2(1,78)=2.45$, $p=.12$) and a significant effect of Subject group ($F_1(2,29)=3.22$, $p=.055$; $F_2(2,156)=32.5$, $p<.001$). Post-hoc comparisons showed that this effect was due to the overall difference between controls and patients only ($p=.06$; all other comparisons ns). The interaction between Density and Subject Group was not significant ($F_1(2,29)<1$, ns; $F_2(2,156)=1.7$, ns).

Response time analyses (testing the effects of Density and Subject Group: Controls vs Broca's vs Wernicke's) showed a significant effect of Density ($F_1(1,29)=39.82$, $p<.001$; $F_2(1,78)=7.38$, $p=.008$) and Subject Group ($F_1(2,29)=15.23$, $p<.001$; $F_2(2,78)=436.63$, $p<.001$). The interaction between Density and Subject group was not significant ($F_1(2,29)=1.36$, ns; $F_2(2,78)=1.68$, ns). Post-hoc analyses (Bonferroni) showed that all comparisons between subject groups were significant ($p<.001$ by subjects and items).

The statistical analyses by subjects clearly fail to show an interaction between Neighbourhood Density and Subject Group. The failure to find larger density effects for the fluent/Wernicke's aphasics than for the non-fluent/Broca's aphasics is due to the effect of size variability within both patient groups. This variability within groups is present, regardless of a classification in fluent vs non-fluent patients or in Broca's vs Wernicke's patients. Either way, the effect of neighbourhood density is not consistently larger in either group.

Table IV. Non-word performance for the two control listener groups.

	Low density		High density	
	Mean RT	Accuracy	Mean RT	Accuracy
Listeners mean age 22 (n=18)	864 ms (7.2)	97% (0.4)	904 ms (8)	96% (0.9)
Listeners mean age 60 (n=12)	1043 ms (14)	94% (1.6)	1147 ms (20)	89% (1.8)

Note, however, that the two patient groups do not differ only in terms of aphasia type. Aphasia researchers often find their fluent or Wernicke's patients to be, on average, older than the non-fluent or Broca's patients. This was also the case in the present study. Note that the control group was age-matched to the oldest patient group. Inasfar as there is a small difference between the patient groups in (overall) non-word performance, could this be attributed to this age difference, rather than to an underlying lexical activation/speech perception difference between the two diagnostic groups? There are two approaches to investigate this possibility. The first is to investigate the size of an age effect in non-brain-damaged control listeners by comparing the performance of the age-matched control group to that of a younger healthy control group. The second approach is to investigate whether, within the aphasic patients group, there is a correlation between non-word accuracy score and age.

Performance of the present (non-brain-damaged) control group was compared to performance of a young healthy listener group. This younger group comprised 18 listeners, all aged below 30, with a mean age of 22 years. Materials and procedure were the same as before. Non-word performance for these two listener groups is presented in Table IV.

Accuracy analyses show a main effect of Density by subjects ($F_1(1,28)=7.20$, $p=.012$; $F_2(1,78)=2.07$, $p>.1$), and an effect of Age Group ($F_1(1,28)=10.59$, $p=.003$; $F_2(1,78)=15.37$, $p<.001$). The interaction between Density and Age Group is not significant ($F_1(1,28)=2.80$, $p>.1$; $F_2(1,78)<1$, ns).[1] Response times of the correct non-word decisions were also analysed (1/RT values) and these showed a significant effect of Density ($F_1(1,28)=36.51$, $p<.001$; $F_2(1,78)=3.16$, $p=.079$) and of Age ($F_1(1,28)=12.35$, $p=.002$; $F_2(1,78)=363.12$, $p<.001$). The interaction between Age and Density was not significant ($F_1(1,28)<1$, ns; $F_2(1,78)<1$, ns).

This comparison between the age-matched control group of the present study and a younger control group shows that overall performance declines with age, but not too drastically (<5%). The difference in high-density condition performance between the control group and the younger control group (89% correct for the control group vs 96% for the young controls) is roughly equal in size to the difference between the Wernicke's and Broca's patients (79% vs 85%), whereas the age difference in years between the latter two participant groups (6 years) is much smaller than for the control groups. It should be noted, however, that there may be no linear relationship between the size of the density effect and age.

Therefore, a better way to investigate whether age, rather than aphasia type, might be responsible for the difference in performance between Broca's (or non-fluent) and Wernicke's (or fluent) patients is to investigate the corrrelation between age and non-word performance among the aphasic patients. Non-word accuracy (collapsed across the two density conditions) was computed for all 27 aphasic patients mentioned in Table I. There was only a very weak relationship between age and non-word accuracy ($r=.23$). Given the results of these two approaches, it seems rather unlikely that the difference in non-word performance should be attributed to an age difference, rather than to a difference in aphasia type.

Apart from density effect size, language comprehension also differs greatly among the aphasic patients. Therefore, the relationship between a patient's language comprehension score (taken from the Aachen Aphasia Test) and performance on the non-words of the present study was investigated. Language comprehension and non-word performance were only weakly related (r=.16). However, this comprehension test investigates auditory and written language, and within each modality both word comprehension and sentence comprehension. The auditory word score of the AAT language comprehension test is the most appropriate one to correlate the present results with. For a number of patients, the sub-scores of this auditory word comprehension test were available. The correlation coefficient r was computed for the relation between the auditory word score and accuracy performance on the non-words in the present study (for the 11 patients for which these sub-scores were available), and r had a value of .37. This is still a weak relation, but somewhat stronger than the relation with the *overall* comprehension score.

Discussion

The results of this study show some important points. First, neighbourhood density affects accuracy rates and lexical decision response times for all three participant groups: non-words with many neighbours were more difficult to reject than non-words with fewer neighbours. This is an important finding because it shows that this task measured what it was supposed to measure, namely lexical activation upon presentation of auditory input. Secondly, there were listener group effects in that the aphasic population made more errors than the control participants. Within the aphasic population, slightly more errors were made by the fluent patients than by the non-fluent patients. This difference cannot be attributed to an age difference between the two patient groups. The main question of the present study was whether either patient group would display a greater density effect. There was no strong evidence for such an interaction.

Similar results were reported in Janse (2005) for a smaller group of aphasic patients: even after the inclusion of more aphasic patients, performance within both aphasic groups is too variable to find consistent differences between groups with respect to neighbourhood density. The results do agree with the Boyczuk and Baum (1999) study, mentioned in the introduction, who also found that neighbourhood density affected performance of the same three groups of participants equally. It must be noted again that their study was not designed to investigate initial lexical activation, but heuristic processes used in phonetic categorization.

Given the inhibitory impairments the Wernicke's aphasics in Janse (2006) had, and given the fact that a number of those Wernicke's aphasics also participated in the present study, the present failure to establish a link between such inhibition impairments and an increased density effect is puzzling. Another puzzling finding is that each patient's performance is not strongly related to his or her overall language comprehension score, but note the somewhat higher correlation between non-word performance and patients' sub-score on comprehension of auditory words.

Three possible factors might account for the present results. A first possibility is that the task of lexical decision is less sensitive to differences in inhibitory capabilities than word identification. The greater neighbourhood density effects for special populations were all obtained with real word identification, rather than with lexical decision. Identification was not an option, however, given the problems in speaking or writing the aphasic patients might have.

A second account is that inhibitory deficits in the Wernicke's aphasic patients become evident only when a certain threshold of activation has been surpassed. The stimuli used in the present experiment were short CVC non-words which evidently yielded lexical activation, but there was no converging evidence for specific word candidates. Deactivating word candidates with a relatively high activation/probability may be impaired in Wernicke's aphasia, but these deficits may be less obvious as long as a greater pool of word candidates is involved.

A third possibility might be the non-word materials. Only the number of neighbours (neighbourhood density) was manipulated; not the (weighed) neighbourhood frequency (as e.g. in Sommers, 1996). The accuracy rate difference in the 'easy' vs 'difficult' condition in the present materials was not too large to begin with. This could also have played a role in the failure to find an interaction.

It is impossible, at present, to establish which of these three factors may in fact be largely responsible for the results. The somewhat better performance of the non-fluent aphasics patients than the fluent patients, combined with the weak correlation between non-word performance and auditory word comprehension score, is in line with non-fluent aphasics' generally better language comprehension. Still, the variability within the aphasic populations presents researchers with more of a challenge. Grouping patients along the dimensions of fluency measures or classic aphasia syndromes may not be very useful as long as variability within groups, particularly in the fluent/Wernicke's group (cf. Tables II and III) is so large. One could reasonably argue that amnesic and Wernicke's patients should not be grouped together, given their different language perception abilities. However, after exclusion of the amnesic patients, the Wernicke's group was still highly variable (cf. Table III). Since there are not so many speech processing studies which included Wernicke's patients, it is difficult to establish whether the variability in the present study was larger than in other studies.

More definitive answers regarding lexical processing impairments may come from research in the neuroimaging domain. One recent fMRI study on which brain areas correspond to activation and to deactivation processes in auditory word processing is reported in Prabhakaran, Blumstein, Myers, and Hutchison (2004) and in Prabhakaran, Blumstein, Myers, Hutchison, and Britton (2006). In this study, fMRI research is combined with the behavioural task of lexical decision. Prabhakaran et al. (2004: 193) suggested that frontal area activation, which was increased for high density compared to low density items, may reflect 'greater executive control required in making a lexical decision under conditions of maximal lexical competition'. In Prabhakaran et al. (2006) it is hypothesized that posterior regions (left supramarginal gyrus) will also show increased activation under high neighbourhood density conditions because it is engaged in activating phonologically similar lexical neighbours. Accessing a word from a high-density neighbourhood should require greater phonological processing than accessing one from a low-density neighbourhood. If greater phonological processing places a burden on posterior structures and selection between (more) competing alternatives is in fact performed by frontal structures, the results of the present study are not that surprising after all. Exact lesion sites of the patients involved in the present study were unfortunately not available. If we assume, however, for the sake of simplicity, that the non-fluent/Broca's patients had frontal lesions and the fluent/Wernicke's patients had more posterior lesions, it is not clear whether differences in terms of neighbourhood density effects between fluent and non-fluent patient groups should still be anticipated. If a lesion in either anterior or posterior regions may interact with neighbourhood density effects, albeit perhaps during different stages required for lexical decision, the present lack of differences between aphasic patient groups can be accounted for. However, this account may be tentative as long as the time course of neural activity is unknown. Therefore, further research, and specifically the combination of studies into timing and localization aspects of lexical activation, competition, and deactivation, may provide more insight into the relation between specific lesion sites and the subsequent word processing impairments that aphasic patients may encounter.

Acknowledgements

The Netherlands Organization for Scientific Research (NWO) is gratefully acknowledged for funding this project. This research was conducted while the author was supported by a grant from the division of Humanities of this organization (360-89-003).

***Declaration of interest*:** The author reports no conflicts of interest. The author alone is responsible for the content and writing of the paper.

Note

1. Note that this interaction was significant if untransformed accuracy scores were analysed ($F_1(1,28)=4.76$, $p=.038$).

References

Blumstein, S. E., Burton, M., Baum, S. R., Waldstein, R., & Katz, D. (1994). The role of lexical status on the phonetic categorization of speech in aphasia. *Brain and Language*, *46*, 181–197.

Boyczuk, J. P., & Baum, S. R. (1999). The influence of neighborhood density on phonetic categorization in aphasia. *Brain and Language*, *67*, 46–70.

Graetz, P., de Bleser, R., & Willmes, K. (1992). *Akense Afasietest (AAT)*. Lisse, The Netherlands: Swets and Zeitlinger.

Hasher, L., & Zacks, R. T. (1998). Working memory, comprehension and aging: A review and a new view. In G. H. Bower (Ed.), the psychology of learning and motivation (Vol. 22, pp. 193–225). San Diego, CA: Academic Press.

Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 163–169.

Janse, E. (2005). Neighbourhood density effects in auditory nonword processing in aphasia. *Brain and Language*, *95*, 24–25 (Proceedings of the Academy of Aphasia meeting 2005, Amsterdam).

Janse, E. (2006). Lexical competition in aphasia: deactivation of lexical candidates in spoken word processing. *Brain and Language*, *97*, 1–11.

Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: the neighborhood activation model. *Ear and Hearing*, *19*, 1–36.

Milberg, W., Blumstein, S., & Dworetzky, B. (1988). Phonological processing and lexical access in aphasia. *Brain and Language*, *34*, 279–293.

Misiurski, C., Blumstein, S. E., Rissman, J., & Berman, D. (2005). The role of lexical competition and acoustic-phonetic structure in lexical processing: evidence from normal subjects and aphasic patients. *Brain and Language*, *93*, 64–78.

Motta, G., Rizzo, F., Swinney, D., & Piñango, M. M. (2000). Tempo: A software for psycholinguistic and neuroimaging testing. Brandeis University (Dept of Computer Science), University of California San Diego (Dept of Psychology) & Yale University (Department of Linguistics).

Prabhakaran, R., Blumstein, S. E., Myers, E. B., & Hutchison, E. (2004). An event-related fMRI investigation of phonological-lexical competition. *Brain and Language*, *91*, 193–194.

Prabhakaran, R., Blumstein, S. E., Myers, E. B., Hutchison, E., & Britton, B. (2006). An event-related fMRI investigation of phonological-lexical competition. *Neuropsychologia*, *44*, 2209–2221.

Sommers, M. S. (1996). The structural organisation of the mental lexicon and its conribution to age-related declines in spoken-word recognition. *Psychology and Aging*, *11*, 333–341.

Sommers, M. S. (1998). Spoken word recognition in individuals with dementia of the Alzheimer's type: changes in talker normalization and lexical discrimination. *Psychology and Aging*, *13*, 631–646.

Titone, D., & Levy, D. (2004). Lexical competition and spoken word identification in schizophrenia. *Schizophrenia Research*, *68*, 75–85.

Ulrich, R., & Miller, J. (1994). Effects of truncation on reaction time analysis. *Journal of Experimental Psychology: General*, *123*, 34–80.

Utman, J. Aydelott, Blumstein, S. E., & Sullivan, K. (2001). Mapping from sound to meaning: reduced lexical activation in Broca's aphasics. *Brain and Language*, *79*, 444–472.

Vitevitch, M. S., & Luce, P. A. (1999). Probabilistic phonotactics and neighborhood activation in spoken word recognition. *Journal of Memory and Language*, *40*, 374–408.