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NOTE

**Phonological neighbourhood density: effects in a rhyme awareness task in five-year-old children\***

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ABSTRACT

Phonological awareness skills are critical for reading acquisition, yet relatively little is known about the origins of phonological awareness. This study investigates one plausible source of the emergence of phonological awareness, phonological neighbourhood density. As vocabulary grows, the number of similar-sounding words in the child's mental lexicon increases. This could create developmental pressure to develop awareness of sub-units within words such as syllables, rhymes and phonemes. If this is the case, then neighbourhood density effects should be discernible in phonological awareness tasks. Children should be more successful in these tasks with words from dense phonological neighbourhoods, as they should show greater awareness of sub-units within these words. We investigated this hypothesis in a group of 48 five-year-old children, most of whom were pre-readers. The five-year-olds with a high vocabulary age showed neighbourhood density effects in a rhyme oddity task, but five-year-olds with lower vocabulary ages did not. This suggests that vocabulary acquisition and consequent neighbourhood density effects are indeed one source of the emergence of phonological awareness skills in pre-readers.

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## INTRODUCTION

Although the development of phonological awareness is widely recognized to be important for reading development across orthographies (e.g. Bradley & Bryant, 1983; Lundberg, Frost & Petersen, 1988; Schneider, Kuespert, Roth, Vise & Marx, 1997), surprisingly little work has been done on the origins of phonological awareness and on the language acquisition factors that may help to determine the development of phonological awareness. In this paper, we investigate whether phonological neighbourhood density affects the emergence of phonological awareness. The child's mental lexicon increases rapidly in size between 1;0 and 6;0. This could lead him or her to become increasingly aware of phonological units shared between many words, such as syllables, onsets and rhymes. It is therefore possible that children's accuracy in phonological awareness tasks will depend in part on the size of the phonological neighbourhoods within which target words reside, and on the overall size of children's vocabularies.

The idea that young children add phonological information to lexical representations in order to differentiate among phonologically similar items has been around for a long time, although it has different developmental interpretations (Aslin & Smith, 1988; Walley, 1993). There is also extensive developmental evidence from studies of speech perception and production showing that young children have access to fine-grained levels of phonological representation in certain circumstances, including syllable, segment and feature-level information (e.g. Gerken, Murphy & Aslin, 1995; Gierut, 1998; Gierut, Morrisette & Champion, 1999). Such studies appear to challenge the notion that young children's lexical representations differ from those of adults in being more holistic (e.g. Ferguson & Farwell, 1975; Charles-Luce & Luce, 1990; Walley, 1993). The assumption behind the holistic view is that children's primary goal in language acquisition is to recognize and produce whole words, not to learn phonemic contrasts. Hence, children represent early words in terms of holistic properties such as prosodic structure rather than in terms of particular phonemic contrasts. This view is supported by data showing that children are less likely to use segmental information in making similarity judgements than adults (e.g. Treiman & Breaux, 1982) and from speech gating studies showing that children need significantly more acoustic information than adults to identify highly familiar words (Walley, 1988). Studies focusing more on production, however, suggest that the segmental representations of young children are very similar to those of adults. Slips of the tongue in young children involve whole segments (e.g. Stemberger, 1989), and detailed case studies of phonetic inventories show that by 3;0 children with large lexicons have large inventories of individual phonemes, syllable shapes and stress placements (Stoel-Gammon, 1998).

Perception and production tasks hence yield somewhat conflicting information concerning the degree of segmental specificity of very young children's

phonological representations. However, this broad distinction between perception tasks (apparent evidence for more holistic representation) and production tasks (apparent evidence for fine detail in representations) is itself too simple. For example, recent work using a visual fixation task with infants suggests that fine detail is indeed coded in their perceptual lexical representations. In a study by Swingley & Aslin (2002), infants aged 1;2 and 1;3 were shown pairs of pictures of familiar items while either the correct referent (e.g. 'ball'), or a close mispronunciation (e.g. 'gall'), was presented. Swingley & Aslin found that the infants spent significantly more time fixating the correct picture for the correctly-pronounced target words, and therefore argued that infants encode words in fine detail. Fixation of the pictures for the incorrectly-pronounced target words was also significantly greater than chance, however (looking at the ball when hearing 'gall'), suggesting that a degree of mispronunciation is tolerated in the drive to extract meaning. Gierut *et al.* (1999) point out further that the productive traits of a child's representations may not match identically their perceptual characteristics, and note that the task of attempting to integrate data from perception and production into a coherent theoretical account of the links between phonological and lexical structure is currently a challenging one.

An alternative route of investigation has been to examine the vocabularies of young children to ascertain whether lexical entries are indeed more unique than those of adults, with fewer phonologically similar neighbours. Dollaghan (1994) indexed by hand the phonemic similarity between monosyllables thought to be known by one- to three-year-olds. She found a relatively high degree of phonologically similar entries. From this, she argued that phonological 'neighbourhood density' effects might be found in young children as well as in adults. For example, young children might be expected to demonstrate more fine-grained auditory discrimination skills in processing words from larger 'similarity neighbourhoods'. The proposal that the phonological properties of words are organized into phonological similarity neighbourhoods derives from work in adult word recognition. In this work, a phonological neighbourhood is defined as all words differing from a target in terms of a one-phoneme addition, substitution or deletion in any word position (Luce & Pisoni, 1998). For example, the neighbours of *rat* include the words *brat*, *rot* and *at*. Studies employing neighbourhood density manipulations typically find that adults recognize words from dense neighbourhoods more slowly and less accurately than words from sparse neighbourhoods, and produce words from dense neighbourhoods more slowly than words from sparse neighbourhoods. In developmental studies, in contrast, density seems to facilitate word recognition (Jusczyk, 1997, for review). Normally developing infants and children perceptually attend to, and accumulate, phonetically similar forms, biasing the development of high density neighbourhoods (see for example Gierut *et al.*, 1999). In production, on the other hand, Gierut *et al.*

(1999) found that word frequency was most salient in promoting productive sound change, with neighbourhood structure least salient.

Given the range of views concerning the nature of early phonological representations, it is perhaps unsurprising that theoretical attempts at linking the emergence of phonological awareness to developments in phonological and lexical structure have proved controversial. The most comprehensive theory of how lexical acquisition might affect the development of phonological awareness has been put forward by Walley and her colleagues. They have proposed that phonological awareness may emerge partly as a result of 'lexical restructuring' processes that are an intrinsic part of language acquisition ('lexical restructuring theory' or LRT, see Walley, 1993; Metsala & Walley, 1998; Metsala, 1999; Garlock, Walley & Metsala, 2001). Lexical restructuring is thought to be intimately connected to vocabulary development. In line with a holistic view of early lexical representation, Metsala & Walley proposed that early word representations represented fairly global phonological characteristics. As vocabulary grows, these holistic representations were thought to be gradually RESTRUCTURED, so that smaller segments of sound such as syllables were represented, and ultimately, phonemes. Neighbourhood density was thus argued to be a critical factor in the emergence of phonological awareness. The view that phonemic awareness emerges as a natural result of language acquisition is at variance with most current theories of reading acquisition. Such theories conceptualize phonemic awareness as a PRODUCT of reading rather than as a precursor (see Morais, Alegria & Content, 1987; Goswami & Bryant, 1990; Ehri, 1998; Goswami, 2002*a*, for overviews of this position). According to such theories, lexical restructuring to the phoneme level occurs BECAUSE OF the acquisition of literacy.<sup>1</sup> The development of phonemic awareness is thought to be driven by the feedback provided by graphemic information as reading is acquired, coupled with the explicit tuition in letter-sound relationships provided by the reading teacher.

In the developmental reading literature, it is generally agreed that phonological awareness follows a sequence, from the awareness of 'large' units like syllables, onsets and rhymes to the awareness of 'small' units (phonemes) at all sequential positions in the word (see Goswami & Bryant, 1990; Treiman & Zukowski, 1996; Goswami, 2002*a*; for overviews). This sequence seems to be language-universal, at least for all languages studied so far (Goswami, 2002*b*). It is important to note that this developmental sequence refers to accessible levels of phonological knowledge. Clearly many auditory processing skills are required to accurately segment and recognize incoming speech, and these are active from infancy onwards. However, in themselves these processing skills do not constitute phonological awareness, and they are not available to

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[1] Further, the effects of literacy on lexical restructuring might vary with the transparency of the language being acquired (Goswami, 2000).

conscious inspection, although they may contribute to phonological organization (e.g. Jusczyk, Goodman & Baumann, 1999) and to the development of accessible phonological knowledge. It is a child's accessible levels of phonological knowledge rather than their speech recognition and production skills that researchers aim to measure in phonological awareness tasks.

Studies designed to explore the effects of phonological neighbourhood density on phonological awareness (and speech recognition) have to date produced mixed results. Consistent with their LRT, Metsala (1999) found that three- to four-year-old children performed better in a phoneme blending task with target words from dense neighbourhoods. She also reported that older children showed neighbourhood density effects in a speech gating task, requiring less information to recognize words from dense neighbourhoods (Metsala, 1997). Garlock *et al.* (2001) reported an effect of phonological neighbourhood density on word repetition by five- and six-year-old children. Words from SPARSE neighbourhoods were repeated more accurately, although this effect was restricted to early acquired words. In a speech gating task used in the same study, however, no effects of phonological neighbourhood density on word recognition were found, and no effects of phonological neighbourhood density were found on phonological awareness as measured by initial phoneme isolation and deletion tasks. This clearly goes against the claims of LRT. Nevertheless, Garlock *et al.* (2001) argued that 'developmental changes in the nature of basic speech representations play a crucial role in THE EMERGENCE OF PHONEME AWARENESS and early reading ability' (Garlock *et al.*, 2001 : 469, our emphasis).

One reason for these mixed results could be that the phonological awareness tasks employed by Garlock and her colleagues measured phonemic awareness. If it is accepted that phonemic awareness depends on literacy, then it follows that factors such as phonological neighbourhood density will not exert their effects at the phoneme level. Rather, they will operate at the level of larger units such as rhymes and syllables (and possibly also smaller units such as features, see Storkel, 2002). An issue raised by Dollaghan (1994) may also be useful in explaining the mixed findings concerning phonological awareness and phonological neighbourhood density. Dollaghan pointed out that the one-phoneme different criterion classically used to define a target's phonological neighbours may not be appropriate for young children. If young children do not use phonemes to organize the mental lexicon, then neighbourhood similarity metrics might depend on different units, such as syllables and rhymes. Dollaghan found that the one-phoneme different criterion led to many intuitively dissatisfying exclusions when she was calculating phonological neighbourhoods (Dollaghan, 1994). For example, the criterion excludes many rhyme neighbours, even though rhyme is an important phonological similarity relation for young children (e.g. *clock* and *sock* would not count as phonological neighbours by the one-phoneme different criterion).

This intuition is supported by a recent empirical paper by De Cara & Goswami (2002). We presented an alternative analysis of the distribution of phonological similarity relations among monosyllabic spoken words in English, based on the assumption that the mental lexicon has psycholinguistic structure. Statistical analyses of the nature of phonological neighbourhoods in terms of RHYME neighbours (e.g. *hat/cat*), CONSONANT neighbours (e.g. *hat/hit*), and LEAD neighbours (e.g. *hat/ham*) were reported for all monosyllabic words in the CELEX corpus (4086 words; Baayen, Piepenbrock & Gulikers, 1995), and for a number of smaller lexicons controlled for age of acquisition. These analyses showed that most phonological neighbours in English are rhyme neighbours (e.g. *hat/cat*). A possible implication of this demonstration is that rhyme neighbourhood density should be more important than phonemic neighbourhood density in exploring the developmental effects of increasing vocabulary size on the emergence of phonological awareness. As a direct test of this implication, the effect of rhyme neighbourhood density on performance in the rhyme oddity task is investigated in this paper. In the oddity task, children must select the 'odd word out' from a triple of words, one of which has a different rhyme (e.g. *pit*, *hit*, *got*). Our hypothesis was that the sub-syllabic level of onset/rhyme may be that most affected by phonological similarity relations, especially prior to literacy. We predicted that children would perform more accurately in the oddity task with words from dense rhyme neighbourhoods than with words from sparse rhyme neighbourhoods.

## EXPERIMENT

### *Participants*

A group of 48 five-year-olds took part in the study. All children enrolled in the participating school whose parents returned a consent form allowing them to take part in the study were tested. The mean age of the group was 4;11 (S.D. 5 months, 26 girls). Mean group performance on a standardized vocabulary test (British Picture Vocabulary Scales, mean = 100, S.D. = 15) was 106.0, S.D. 14.5. Of the 48 children, 18 were able to read at least one word on a test of standardized word reading (British Ability Scales Single Word Reading Test). For these 18 children (11 girls; hereafter beginning readers), the mean reading age was 5;4, S.D. 7 months. Although race and social class data were not systematically collected, the majority of participants were of Caucasian descent and were from a middle-class neighbourhood.

## METHOD

### *Procedure*

Each child received 3 different tasks spread across 2 short testing sessions. The tasks were the oddity task, the British Picture Vocabulary Scales (Dunn,

Dunn, Whetton & Pintilie, 1982) and the word reading subtest of the British Ability Scales (Elliott, Smith & McCulloch, 1996). In session 1, the children received the standardized vocabulary and word reading tests. In session 2, they received the oddity task. The sessions were run in the same order within the same week. Many of the children (30 out of 48) could not attempt the single word reading test.

### *Oddity task*

This was based on 36 triples of words. The words for each oddity trial were recorded by a native female speaker of British English and then digitized for computer presentation using Cool Edit TM 96 (Syntrillium Software Corporation). Each word was recorded in citation form and not excised from sentences. The stimuli were presented to the child from a laptop computer (DELL Latitude with an ESS Maestro Sound Card.). Recordings were verified by two independent adult listeners to ensure accurate and interpretable renditions. Before each trial, the children saw a row of asterisks in the centre of the computer screen, which disappeared when the trial began. The stimuli were presented through headphones. For each oddity trial, the children had to press the space bar and say the odd word when they knew the answer. The space bar press was intended to yield reaction time data. Children were told that the odd word would not rhyme with the others. Eighteen experimental trials consisted of 9 trials for words from dense rhyme neighbourhoods and 9 trials for words from sparse rhyme neighbourhoods (the other 18 trials were filler trials based on a sonority manipulation [chill, fill, bowl] and are not reported here, see Appendix). Within each of these neighbourhood categories (dense vs. sparse), we varied whether the triples were based on a vowel change (e.g. pit, hit, *got*), on a coda change (e.g. meat, *weak*, seat), or both a vowel and coda change (e.g. *peak*, dot, not). Trials were not blocked by density, but varied in a semi-random order which also varied the position of the odd word systematically across the experiment. Six different semi-randomized sequences of the 36 trials were created for this purpose. Detailed feedback was provided prior to the experimental trials in the training trials, which consisted of 5 trials using different words to the experimental words (leg, peg, shop; doll, top, hop; bun, sun, hut; bat, hut, cat; pin, bun, gun). In these trials, the experimenter reinforced the correct response ('That's right, 'shop' is the odd word out'). Ninety percent of children selected the non-rhyme within 2 training trials and no child required more than 5 training trials. No feedback was given in the experimental trials.

### *Stimuli*

The words were selected from an earlier version of the auditory database reported in De Cara & Goswami (2002). This version contained 3619



monosyllabic words. Monosyllables with either no onset or with a complex onset or coda (i.e. with a CCC structure) were excluded because they were relatively rare, and because the sonority of CCC structures is unusual. This left 3072 monosyllables (85% of total) with the following distribution: CVC 44.3%, CCVC 24.4%, CVCC 15.7%, CCVCC 6%, CV 5.9%, CCV 3.8%. To vary neighbourhood density, we initially aimed to select stimuli from neighbourhoods that were either 1 s.d. above or below the mean of 12 rhyme neighbours (s.d. = 8, these were also dense or sparse phonological neighbourhoods overall as the correlation between rhyme neighbourhood density and neighbourhood density is 0.89). In practice, this strict selection criterion did not yield sufficient stimuli for either the sparse or dense comparisons. This was because most words with fewer rhyme neighbours than 5 are unfamiliar to young children and so could not be selected (e.g. *daub*, *lour*, *moll*). We therefore selected the best contrast in rhyme neighbourhood possible in view of the necessity for item familiarity, yielding a mean rhyme neighbourhood density for dense stimuli of 20.4 (s.d. 1.8) and a mean rhyme neighbourhood density for sparse stimuli of 7.6 (s.d. 3.2),  $t(52) = 18.2$ ,  $p < 0.001$ . Mean overall neighbourhood size for these stimuli was dense neighbourhood 36.4 (s.d. 4.5) and sparse neighbourhood 22.9 (s.d. 8.1),  $t(52) = 7.6$ ,  $p < 0.001$ . Words selected were judged to be familiar to young children, and had a familiarity ranking of 6.5 or above out of a maximum ranking of 7 according to the Luce & Pisoni (1998, adult) norms. One third of the stimuli we selected also had published AoA norms from the Age of Acquisition data reported in Gilhooly & Logie (1980). These norms were based on a 7-point scale (1: age 0;0–2;0; 7: age 13;0 and older) for 1944 words. All stimuli for which AoA data were available had AoA norms of 5;0 or below, mean 3;0, s.d. 0.7. Words were matched across dense versus sparse neighbourhoods for spoken frequency using figures from Celex (CobSMIn; occurrence per million within a 17.9 million spoken word corpus). We also computed neighbourhood density for our stimuli with AoA controlled, by restricting the database reported in De Cara & Goswami (2002) to words known to be acquired by the age of 5;0 (565 words), according to Gilhooly & Logie's AoA norms. The dense/sparse manipulation was still significant, yielding a mean rhyme neighbourhood density for dense stimuli of 3.3 (s.d. 1.3) and a mean rhyme neighbourhood density for sparse stimuli of 1.0 (s.d. 0.8),  $t(17) = 4.28$ ,  $p < 0.001$ . The number of vowels used was limited in order to avoid large disparities in vowel format between categories, and the same vowels were used as far as possible. Note that perfect matching is not possible because the nature of vowels and codas in dense versus sparse neighbourhoods varies systematically (see De Cara & Goswami, 2002). Vowel quality (short, long, diphthong) and consonantal features (manner, place of articulation, voicing) were matched between target and distractor words across stimuli as far as possible. The items and summary statistics for the variables of interest are shown in the Appendix.

## RESULTS

Performance is analysed in terms of accuracy of selecting the non-rhyming item rather than reaction time (RT), as the RT data were extremely noisy. The few occasions on which children requested to hear the stimuli again were accepted as correct unless the subsequent response was incorrect (2.6% of data). Initial analysis of the data for the whole group of five-year-olds by subjects ( $F_1$ ) and by items ( $F_2$ ) showed no significant main effect of rhyme neighbourhood density,  $F_1(1, 47) = 1.74$ ,  $F_2(1, 12) = 0.69$  (dense neighbourhood word triples = 64.4% correct, sparse neighbourhood word triples = 60.9% correct). There was a main effect of type of change,  $F_1(2, 94) = 22.08$ ,  $p < 0.001$ ,  $F_2(2, 12) = 9.28$ ,  $p < 0.01$  (coda change, 50% correct; vowel change, 70% correct; rhyme change, 68% correct), but no interaction between type of change and neighbourhood density,  $F_1(2, 94) = 1.86$ ,  $F_2(2, 12) = 0.62$ .

In order to see whether a rhyme neighbourhood density effect would be present for children whose vocabulary development was more advanced (as would be predicted by LRT), we divided the group by vocabulary age using a median split.<sup>2</sup> The HIGH VOCABULARY GROUP ( $N = 24$ ) had a mean chronological age of 5;0 (4 months); a mean reading age of 5;4 (8 months); and a mean vocabulary age of 6;4 (17 months). The LOW VOCABULARY GROUP ( $N = 24$ ) had a mean chronological age of 4;10 (6 months); a mean reading age of 5;2 (3 months); and a mean vocabulary age of 4;8 (15 months). Chronological age was not significantly different across the two vocabulary groups  $t(46) = 1.36$ , and nor was reading age,  $t(16) = 0.70$ . Only vocabulary age differed significantly between the two groups,  $t(46) = 4.22$ ,  $p < 0.001$ . Table 1 shows performance for each of the 3 versions of the oddity task. There appears to be an effect of rhyme neighbourhood density for the high vocabulary group only, restricted to the coda change and rhyme change trials.

In order to explore whether this was significant, a (2) vocabulary age (high, low)  $\times$  (2) neighbourhood density (dense, sparse)  $\times$  (3) type of change (vowel change, coda change, rhyme change) ANOVA was run by subjects ( $F_1$ ) and by items ( $F_2$ ), taking the mean number of correct responses as the dependent variable. The analysis showed a main effect of type of change ( $F_1(2, 92) = 21.76$ ,  $p < 0.001$ ;  $F_2(2, 12) = 9.28$ ,  $p < 0.01$ ), an interaction between neighbourhood density and vocabulary age ( $F_1(1, 46) = 7.41$ ,  $p < 0.01$ ;  $F_2(1, 12) = 5.68$ ,  $p < 0.05$ ), and a triple interaction between neighbourhood density, type of change and vocabulary age ( $F_1(2, 92) = 4.81$ ,  $p < 0.05$ ;  $F_2(2, 12) = 3.25$ ,

[2] We also explored the effects of a median split by age and of dividing the group by reading ability. Division of the sample into younger ( $N = 24$ ) and older ( $N = 24$ ) children (mean ages of 4;8 and 5;3 respectively) did not yield an interaction with rhyme neighbourhood density ( $F_1(1, 46) = 1.77$ ,  $p > 0.10$ ;  $F_2(1, 12) = 1.03$ ,  $p > 0.10$ ). Comparison of the 18 beginning readers with the 30 non-readers also failed to yield an interaction with rhyme neighbourhood density ( $F_1(1, 46) = 3.03$ ,  $p = 0.085$ ;  $F_2(1, 12) = 2.95$ ,  $p > 0.10$ ).

TABLE 1. *Number of correct responses (max. = 3) in the oddity task by rhyme neighbourhood density (RND) and type of change (vowel, coda, rhyme) as a function of vocabulary age*

Type of change	Dense RND			Sparse RND		
	Vowel	Coda	Rhyme	Vowel	Coda	Rhyme
Low-vocabulary						
<i>M</i>	2.00	1.25	2.00	2.08	1.50	1.96
<i>S.D.</i>	0.88	0.68	0.93	0.83	0.88	0.91
%	66.7	41.7	66.7	69.4	50.0	65.3
High-vocabulary						
<i>M</i>	2.13	2.00	2.21	2.21	1.25	1.96
<i>S.D.</i>	0.61	0.78	0.72	0.72	0.90	0.69
%	70.8	66.7	73.6	73.6	41.7	65.3

$p < 0.10$ ). Focusing on the density effect, the interaction between neighbourhood density and vocabulary age arose because items from dense neighbourhoods (70.4% correct) were processed more accurately than items from sparse neighbourhoods (60.2% correct) by children with higher vocabulary scores ( $F_1(1, 23) = 9.31$ ,  $p < 0.01$ ;  $F_2(1, 12) = 10.08$ ,  $p < 0.01$ ). For the children with lower vocabulary scores, the difference between dense and sparse phonological neighbourhoods did not reach significance (58.3% correct versus 61.6% correct,  $F_1(1, 23) = 0.80$ ;  $F_2(1, 12) = 0.26$ ). The triple interaction between neighbourhood density, type of change and vocabulary age arose because the neighbourhood density  $\times$  type of change interaction was only significant for the children with higher vocabulary scores ( $F_1(2, 46) = 7.41$ ,  $p < 0.01$ ;  $F_2(2, 12) = 6.33$ ,  $p < 0.05$ ). For these children, neighbourhood density effects were strongest for the coda change trials (dense = 66.7% correct, sparse = 41.7% correct,  $F_1(1, 23) = 13.80$ ,  $p < 0.005$ ;  $F_2(1, 4) = 18.00$ ,  $p < 0.025$ ), with a strong trend in the same direction for the rhyme change trials (dense = 73.6% correct, sparse = 65.3% correct,  $F_1(1, 23) = 4.06$ ,  $p = 0.053$ ;  $F_2(1, 4) = 1.80$ ,  $p > 0.10$ ), but non-significant for the vowel change trials,  $F_1(1, 23) = 0.32$ ;  $F_2(1, 4) = 0.40$ . There was no interaction between neighbourhood density and type of change in children with lower vocabulary scores ( $F_1(2, 46) = 0.63$ ;  $F_2(2, 12) = 0.20$ ).

#### DISCUSSION

Our study was designed to investigate whether phonological neighbourhood density affects the emergence of phonological awareness. This is a core proposal of LEXICAL RESTRUCTURING THEORY or LRT (Metsala & Walley, 1998), derived from the basic claim that phonological awareness emerges primarily as the result of growth in spoken vocabulary. LRT proposes that changes in the

familiarity of individual lexical items and inter-item phonological similarity relations with increasing vocabulary size creates developmental pressure for the representation of PHONEMES. Accordingly, children's performance in phonemic awareness tasks should be most accurate for words in dense phonological neighbourhoods. On the basis of the developmental finding that phoneme awareness in children depends on literacy, we argued that the effects of phonological similarity relations between vocabulary items might be most marked for the emergence of ONSET-RHYME processing in children. On this hypothesis, children's performance in rhyme (and possibly onset) tasks should be most accurate for words in dense RHYME neighbourhoods. We already know that inter-item phonological similarity relations in English make rhymes very salient neighbours in dense phonological neighbourhoods (see De Cara & Goswami, 2002).

In our rhyme awareness (odddity) task, five-year-old children with larger vocabularies made significantly fewer errors in making similarity judgements about rhymes from dense rhyme neighbourhoods compared to rhymes from sparse rhyme neighbourhoods (with as much as a 25% accuracy advantage for the coda change trials). This finding suggests that the rhymes of words in dense neighbourhoods are indeed represented with greater specificity than the rhymes of words in sparse neighbourhoods, at least prior to the development of literacy. This effect was found most strongly for the relatively difficult 'coda change' oddity trials, with a marked trend in the same direction for the 'rhyme change' trials ( $p = 0.053$ ). Stimuli for this study were selected on the basis of rhyme neighbourhood density. However, the number of rhyme neighbours and the total number of neighbours according to the one-phoneme-different criterion are highly correlated,  $r = 0.89$ ,  $p < 0.001$ . An interesting direction for future work would be to examine whether phonological neighbourhood density effects in phonological awareness tasks in children depend on rhyme neighbourhood density (as argued here) or on overall neighbourhood density.

However, our rhyme neighbourhood density findings were mediated by unexpected variations in the difficulty of the different versions of the oddity task. In Bradley & Bryant's original oddity tasks (Bradley & Bryant, 1978, 1983), there were two rhyme oddity conditions, a coda change condition (e.g. doll, hop, top) and a vowel change condition (e.g. cot, pot, hat). Performance in these two versions of the tasks was equivalent for four- and five-year-old children in both studies. In later work, Kirtley, Bryant, Maclean & Bradley (1989) also found no differences in performance for vowel change versus coda change oddity triples for five-, six- and seven-year-old children. As we used digitized speech stimuli in our experiment, the linguistic cue to the odd word out (the different coda) comprised a relatively small portion of the overall syllable. This change was in either voicing or place, with a voicing change occurring once and a place change occurring twice for both the dense and the sparse stimulus triples. In the vowel change and rhyme change trials, the

linguistic cue (a vowel or rhyme) was relatively large. As the participants were unsupported by lip cues and any inadvertent social cueing on the part of the experimenter in our procedure, the linguistic demands of the oddity judgement were possibly more dominant, making the coda change task particularly difficult. Some prior studies of the development of phonological awareness have only used the coda change version of the oddity task (e.g. Snowling, Hulme, Smith & Thomas, 1994). Given that this seems to be the most difficult version of the oddity task, it may also be the most discriminative with respect to phonological development.

Finally, our data add support to the notion that the phonological unit of the rhyme has a special role to play in the development of phonological awareness prior to literacy (Goswami & Bryant, 1990). The lexical statistics of English, which show an over-representation of rhyme neighbours in dense phonological neighbourhoods, coupled with speech perception factors that make the vowel dominant in the syllable, could give rhymes the special psycholinguistic salience illustrated in many studies of phonological processing in adults and children (see e.g. Treiman, 1988). The significant effects of phonological neighbourhood density on rhyme processing reported here may also be important with respect to subsequent reading and spelling development. If words in denser phonological neighbourhoods have more segmented representations at the onset-rhyme level, this may facilitate reading and spelling acquisition of these words by a process of lexical analogy (Goswami, 1986). Alternatively, the early onset-rhyme segmentation that appears to characterize denser phonological neighbourhoods might enable more rapid restructuring of words in these neighbourhoods to the phonemic level when letter-sound relations are taught. The lexical database reported in De Cara & Goswami (2002) shows that rhymes in dense phonological neighbourhoods tend to have a greater variety of spellings than rhymes in sparse phonological neighbourhoods, in an approximate ratio 4:1. It is possible therefore that reading acquisition alerts the child to different orthographic conventions for spelling the same rhyme, for example 'stair', 'where', 'their', 'share' – 'feedback' inconsistency (from sound to spelling, see e.g. Ziegler, Stone & Jacobs, 1997). Further studies of phonological development attempting to disentangle the overlapping effects of phonological neighbourhood density, rhyme neighbourhood density and orthographic congruency (stair – chair) and incongruency (stair – where) are required to examine these possibilities.

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# APPENDIX 1

## LIST OF STIMULI AND FILLERS

### *Stimuli*

	Target 1					Target 2					Distractor						
	RND	ND	Fam.	AoA	Freq.	RND	ND	Fam.	AoA	Freq.	RND	ND	Fam.	AoA	Freq.		
<b>Dense RND</b>																	
Vowel change	pit	19	42	7.00	3.1	12	hit	19	39	7.00	64	got	23	36	7.00	abs	
	date	20	32	7.00	3.1	90	wait	20	35	7.00	161	lit	19	41	6.75	abs	
	hot	23	37	7.00		77	lot	23	38	7.00	1220	wait	20	35	7.00	161	
Coda change	bag	19	36	7.00	2.2	29	rag	19	36	7.00	2	jack	23	29	7.00	4.1	71
	lick	19	45	6.75		0	sick	19	41	7.00	30	chip	22	33	6.92	22	
	meat	19	33	7.00		15	seat	19	39	7.00	53	weak	19	31	7.00	35	
Rhyme change	fit	19	40	7.00		66	hit	19	39	7.00	64	jack	23	29	7.00	4.1	71
	cheek	19	29	7.00	2.7	2	leak	19	44	6.75	3.4	nip	22	31	7.00	3.0	5
	dot	23	36	7.00	2.2	38	not	23	38	7.00	4678	peak	19	38	7.00		26
												<i>M</i>	20.4	36.4	6.97	3.1	280
												<i>S.D.</i>	1.8	4.5	0.08	0.7	947
<b>Sparse RND</b>																	
Vowel change	bird	5	24	7.00	2.1	33	word	5	22	7.00	701	mud	9	30	7.00	2.4	6
	kid	11	31	7.00		99	rid	11	33	7.00	abs	heard	5	20	7.00		abs
	thud	9	13	6.50		2	bud	9	37	6.83	3.3	rid	11	33	7.00		abs
Coda change	mike	8	22	6.17		32	bike	8	22	7.00	13	wipe	7	18	7.00		12
	pig	13	27	7.00	2.3	10	dig	13	24	6.92	21	lid	11	38	7.00		1
	soot	2	12	6.58		0	foot	2	10	7.00	160	could	5	14	6.42		abs
Rhyme change	bird	5	24	7.00	2.1	33	third	5	7	6.50	173	ripe	7	23	6.92		1
	wood	5	18	7.00	2.7	39	good	5	14	7.00	1857	big	13	29	6.92		472
	like	8	29	7.00		3032	bike	8	22	7.00	13	word	5	22	7.00		701
												<i>M</i>	7.6	22.9	6.88	2.5	323
												<i>S.D.</i>	3.2	8.1	0.23	0.5	724
												<i>t</i> test Dense vs. Sparse	18.2	7.6	1.91	1.90	0.19
												<i>p</i> value	0.000	0.000	ns	ns	ns

RND = number of rhyme neighbours; ND = number of overall neighbours (both based on 3072 monosyllabic words from Luce & Pisoni's (1998) lexical database); Fam. = item familiarity (ranking out of a maximum of 7 according to the Luce & Pisoni's (1998) adult norms); AoA = age of acquisition [ranking from a 7-point scale (1: age 0-2 years; 7: age 13 years and older) from Gilhooly & Logie's (1980) adult norms]; Freq. = Celex (Baayen, Piepenbrock & Gulikers, 1995) measure for spoken frequency of lemmas (occurrence per million within a 17.9 million spoken word corpus); abs = information absent from the corpus. As these experimental trials were interspersed with 18 filler trials, the repetition of some of the items was not apparent to the children.



LIST OF STIMULI AND FILLERS (CONTD)

*Fillers*

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Vowel change	chill	fill	bowl	pearl	girl	dull
	tail	rail	bill	full	pull	curl
	mole	goal	nail	gull	dull	wool
Coda change	tell	yell	pear	dial	pile	wire
	hall	ball	raw	howl	fowl	sour
	hill	mill	cheer	full	bull	poor
Rhyme change	pill	will	dare	curl	hurl	fire
	sail	whale	jaw	wool	pull	sour
	bowl	goal	dear	mile	file	sure

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