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Uses and interpretations of non-word repetition tasks in children with and without specific language impairments (SLI)

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Abstract

Background—The non-word repetition task (NRT) has gained wide acceptance in describing language acquisition in both children with normal language development (NL) and children with specific language impairments (SLI). This task has gained wide acceptance because it so closely matches the phonological component of word learning, and correlates with measures of phonological working memory, a deficit in which is hypothesized to underlie SLI.

Aims/Methods & Procedures—Recent uses of the NRT seem to accept it as a measure of phonological working memory capacity in spite of the fact that researchers have consistently acknowledged that the task taps many language processes, including speech perception, phonological encoding, phonological memory, phonological assembly and articulation. This paper reviews the literature on the use of the non-word repetition task (NRT) in children with NL and children with SLI, emphasizing the component skills necessary for successful repetition.

Main Contribution—For children with NL, discussion has focused on (1) the relationship between non-word repetition ability and vocabulary, and (2) lexical and sublexical influences on repetition accuracy. For children with SLI, discussion has focused on these factors as well, but has also considered other component skills that support non-word repetition. Researchers have examined speech perception and discrimination, phonological encoding, phonological memory, phonological assembly, motor planning, and articulation, and have found evidence that children with SLI exhibit impairments in each of these supporting skills.

Conclusions—Because repetition accuracy depends on lexical and sublexical properties, the NRT can be used to examine the structural properties of the lexicon in both children with NL and with SLI. Further, because the task taps so many underlying skills, it is a powerful tool that can be used to identify children with language impairments.

Keywords

Non-word; repetition; specific language impairment; typically develeping children; vocabulary

Introduction

In recent years, researchers have begun to examine linguistic processes in various populations by having listeners repeat nonsense words. In these tasks, listeners hear a made-up word modelled after their native language, e.g. *shrib*, and are asked to repeat it back immediately. This non-word repetition task (NRT) has gained a great deal of acceptance in recent years for two main reasons. First, the NRT was adopted because it correlates so well with standardized vocabulary measures in typical populations. Children who are better able to repeat non-words after a single presentation tend to be the same children who score higher on standardized vocabulary measures. This is surely related to underlying components common to both tasks. To repeat successfully a non-word, a repeater must create an acoustic representation robust enough to support subsequent articulation. Similarly, upon hearing a novel word, a learner must create an acoustic representation robust enough to link to its real-world referent. Second, the NRT was adopted because it is quite sensitive to a wide variety of language disorders. Successful repetition of a non-word involves speech perception, phonological encoding (or segmenting the acoustic signal into speech units that can be stored in memory), phonological assembly (or formulating a motor plan that assembles the relevant speech units), and articulation. Further, it requires a robust representation of underlying speech units, and sufficient memory both to temporarily store and operate on the novel phonological string. A deficit in any of these component skills results in less accurate repetition. Indeed, NRTs have been used to explore deficits experienced by children with articulation disorders (Yoss and Darley 1974), children with reading difficulties (for a review, see Brady 1997), children with specific language impairments (SLI, e.g. Dollaghan and Campbell 1998), children with Williams syndrome (Grant *et al.* 1996, 1997), children with Down’s syndrome (Comblain 1999, Laws 1998), children with higher levels of lead exposure (Campbell *et al.* 2001), children with cochlear implants (Carter *et al.* 2002), children with fluency disorders (Hakim and Ratner 2004), and adults with acquired aphasia (e.g. McCarthy and Warrington 1984). In addition, the NRT has been adapted for speakers of many languages, including Dutch (Van Bon and Van der Pijl 1997), Finnish (Service 1992), Swedish (Sahlén *et al.* 1999a, b), Spanish (Cuetos *et al.* 1996), French (LeFoll *et al.* 1995), Italian (D’Amico 2000), Brazilian Portuguese (Santos and Bueno 2003), Greek (Maridaki-Kassotaki 2002), Cantonese (Ho and Lai 1999) and Japanese (Saito 1995). Thus, the NRT has gained wide acceptance for describing language performance in many populations.

While many recent studies have used an NRT explicitly as a measure of phonological memory (e.g. Montgomery 2004), there really is no consensus as to what the NRT actually measures. It has been used to measure the process of lexical access (e.g. Rubenstein *et al.* 1970), speech production (e.g. McCarthy and Warrington 1984), motor planning abilities (e.g. Yoss and Darley 1974), phonological processing, including phonological segmentation and assembly (e.g. Snowling 1981), and phonological memory (e.g. Gathercole and Baddeley 1989). Besides these supporting skills, repetition accuracy also relies on stored lexical knowledge, even though early versions treated it as a content-free language measure. NRTs were originally used to circumvent any word familiarity or frequency effects that would surely affect the repetition of real words. However, more recent evidence has shown that long-term lexical knowledge contributes to non-word repetition, over and above the phonological and memory processes already implicated. Indeed, repeating a non-word taps a number of underlying skills, which makes interpreting results problematic. When testing adult patients with acquired aphasia, it is reasonable to assume that they had intact linguistic systems before suffering lesions. Therefore, their representations of the underlying speech units are not in question even though their ability to process or manipulate these units may be compromised. However, when testing young children, this assumption cannot be made because these abilities develop simultaneously, along with the underlying acoustic representations. Difficulties with any or all supporting skills will result in reduced repetition accuracy.

This paper is intended to be a qualitative review of the literature on the use of NRTs in children with normal language development (NL) and in children with specific language impairments (SLI). This particular population has been used to test hypotheses about the NRT and its link to lexical development because children with SLI are known to have both memory deficits and smaller lexicons (e.g. Leonard 1998). While this population was certainly not the first to be described in terms of its non-word repetition abilities, it has been perhaps most extensively researched. Indeed, children with SLI are consistently less accurate than children with NL when repeating non-words. This finding is incredibly robust for children learning English, occurring with as few as five children per group (Gathercole and Baddeley 1990) or as few as six non-words (Edwards and Lahey 1998). The effect is so robust that researchers have suggested that the NRT might provide a quick and reliable way to identify children with SLI. Recent studies on linguistic processing by children with SLI have included versions of the NRT in language batteries for exactly this purpose (e.g. Coady *et al.* 2005, 2006, Farmer 2000, Washington and Craig 2004). For a quantitative review of studies using the NRT to examine language deficits experienced by children with SLI, see Graf Estes *et al.* (2007).

The paper is divided into four sections. The first section considers generally the evolution of NRTs for use in experimental procedures. The second section then turns to a description of how they have been used to examine linguistic development, first in children with NL, and second in children with SLI. In children with NL, discussion has focused on two factors: (1) the relationship between non-word repetition accuracy and receptive vocabulary, and (2) lexical influences on non-word repetition. The SLI literature addresses these same issues, but then offers a unique contribution. In this population, researchers have examined other underlying skills that support non-word repetition, including speech perception, phonological assembly, and articulation. The third section presents a critical review of the non-word repetition literature as a whole, including what the task actually measures, as well as how vocabulary and non-word repetition ability interact with one another. Specifically, because repetition accuracy depends on lexical and sublexical knowledge extracted from over the lexicon, the NRT is presented as a method to assess the structural organization of the phonological lexicon. The fourth section includes general conclusions, clinical implications, and future directions.

Evolution of non-word repetition tasks

In 1956, Brown and Hildum examined whether adults perceive speech units based solely on acoustic information, or if instead they are influenced by their knowledge of phonotactic structure, or rules governing the ordering of phonemic units within words. They asked English-speaking adults to write out (transcribe) monosyllabic words and non-words presented in noise. Half of the non-words began with attested consonant clusters (e.g. [skaIs]), while the other half began with consonant clusters that violate English sequence constraints (e.g. [fwaIs]). They reported that adult listeners were better able to transcribe those non-words that conformed to the phonotactic structure of English, and concluded that listeners have a perceptual bias to hear legal phonotactic sequences. Messer (1967) extended this work to young children, aged 3;1–4;5. He spoke pairs of non-words, where one member of the pair contained a legal consonant cluster while the other member contained an illegal cluster, and asked children to choose the one that sounded more like a real word. Children were much more likely to choose the non-word that conformed to English phonotactic constraints. Messer continued by examining children's repetition responses from the preference paradigm. He found that children made significantly more errors on non-words that violated English phonotactic constraints. Consistent with Brown and Hildum, he concluded that children have implicit knowledge of how phonemes can be combined in their language.

Subsequently, an NRT was used to examine motor planning deficits in children with developmental verbal dyspraxia (Snowling and Stackhouse 1983, Yoss and Darley 1974). These children were unable to repeat novel phonological sequences, presumably because of their primary articulation disorder. Snowling and colleagues (Snowling 1981, Snowling *et al.* 1986) then used an NRT to examine lexical and phonological processing in a group of children with reading impairments (RI), or dyslexia. They hypothesized that speech-motor programs would be used for familiar words, while such programs would be unavailable for non-words. Successful repetition of non-words would require 'subjects to process the auditory stimulus, to decode the sound segments, and to recode these as instructions in the form of a speech-motor program' (Snowling 1981: 226). Snowling and colleagues found that children with dyslexia experienced a greater degree of difficulty with non-words, especially at longer lengths. They concluded that children with dyslexia have difficulty with phonological analysis and articulatory assembly processes. Kamhi, Catts, and colleagues (Kamhi and Catts 1986, Kamhi *et al.* 1988) extended this work to include children with language impairments (LI) because of their low levels of phoneme awareness (Kamhi *et al.* 1985). They used an NRT to examine how children with RI, LI, or NL process phonological information. Results revealed graded performance, with highest levels of accuracy from the children with NL, significantly less accuracy from the children with RI, who in turn were significantly more accurate than children with LI. Kamhi and Catts concluded that both groups have difficulty generating accurate representations of phonological information, with children with LI exhibiting a more extreme impairment. It is worth noting that Kamhi and colleagues did not consider memory explanations for their results. They discounted any possible memory deficits by explaining that storage demands were minimized because immediate repetitions were required, even though they used non-words specifically to ensure that children would have to rely on verbal short-term memory rather than the lexicon to support accurate repetition (Kamhi and Catts 1986: 344).

Independent of this early work in developmental disorders, the NRT was added to neurological batteries used to test adults with acquired aphasia, specifically to measure speech production abilities. McCarthy and Warrington (1984) reported on an adult patient with conduction aphasia (ORF), who had preserved spontaneous speech but difficulty repeating low frequency words. They pushed this to its logical conclusion, and had ORF repeat zero-frequency words, or non-words. The accuracy with which he repeated these non-words was even less than that for the low frequency words. Based on these and other results, McCarthy and Warrington concluded that ORF's phonological memory was intact, but that he suffered an impairment in speech production. Caplan *et al.* (1986) and Caramazza *et al.* (1986) also reported on patients with aphasia who could repeat single words, but had difficulty repeating non-words. These studies were interpreted in terms of a dual-route model of repetition in which words and non-words take divergent paths. According to this model, words are repeated by accessing their articulatory specifications directly from the lexicon. Because non-words have no lexical entry specifying an articulatory plan, they must be repeated by being segmented into their constituent units, which are then assembled into novel articulatory plans. Note that this is the same mechanism originally proposed by Snowling (1981) to account for poorer non-word repetition by children with developmental dyslexia.

Baddeley *et al.* (1988) reported similar data from a patient they had been following — P.V., a 28-year-old who had suffered a left-hemisphere stroke. In her everyday life, P.V. exhibited no cognitive impairments. However, neuropsychological testing revealed a deficit in auditory short-term memory (Basso *et al.* 1982). Vallar and Baddeley (1984) subsequently showed that her phonological processing abilities were intact, suggesting a deficit in phonological *storage*. Baddeley *et al.* (1988) examined P.V.'s phonological memory capacity by asking her to recall (or repeat) nonsense words. They reported that P.V.'s recall for non-words fell off as non-word length increased. Follow-up testing revealed that she could learn to associate two unrelated real words in her native Italian, but could not learn the association between a familiar Italian word and a novel phonological string modelled after Russian. That is, she had difficulty with the phonological form of new vocabulary items. Because her stored long-term linguistic knowledge was intact, the authors concluded that P.V.'s pattern of results could best be explained in terms of a deficit in the articulatory loop component of a multi-component working memory, as originally described by Baddeley and Hitch (1974), rather than as a deficit in an all-purpose short-term memory store.

Baddeley and Hitch (1974) originally proposed the working memory model to account for deficits in unitary short-term memory models. They asked people to memorize strings of digits while performing comprehension, reasoning, or learning tasks. Presumably, when an individual's maximum digit span is reached, there will be no more memory resources for any other cognitive tasks. However, even when memory load was at its limit, performance on other cognitive tasks was better than expected. Baddeley and Hitch therefore concluded that humans are equipped with a multi-component working memory system that serves a variety of cognitive tasks. This working memory system comprises an attentional controller and two subsystems. The *central executive* is the all-purpose supervisor that deals with storage and processing. The *visuo-spatial sketchpad* deals with information about objects and locations, while the *articulatory* or *phonological loop* deals with verbal information. The phonological loop in turn comprises two components, phonological memory capacity and rehearsal processes. Memorizing a string of digits, then, involves temporarily storing the digits in the phonological loop component. The string of digits will decay unless rehearsal processes in the phonological loop actively maintain the operation of the loop. Because digits are so familiar, maintaining them in the phonological loop requires minimal effort. Even though the phonological loop may be at maximum capacity, the central executive may still have resources left over for other cognitive demands.

Baddeley *et al.* (1988) hypothesized that the phonological loop component of working memory is integral to the process of word learning. Word learners, both second language learners and children learning their first language, must associate a novel phonological string with a meaningful concept. P.V.'s ability to associate two known words was possible because their familiarity placed minimal demands on her impaired phonological storage capacity. However, her impaired ability to recall longer non-words paired with her intact phonological processing reflected limited phonological storage. Longer non-words were simply at or beyond her memory span, and because they were unfamiliar phonological strings, the central executive was also at or beyond its capacity. Therefore, the resources with which she could analyse a novel phonological string were limited.

Based on Baddeley and colleagues' findings from NRTs in adults with aphasia, Gathercole and Baddeley and colleagues embarked on a program of research using an NRT to examine the relationship between phonological memory, phonological sensitivity and language development in children with NL (Adams and Gathercole 1995, 1996, 2000, Gathercole 1995, Gathercole and Adams 1993, 1994, Gathercole and Baddeley 1989, Gathercole *et al.* 1997, 1999, 1991a, b, 1992). They reasoned that children who have more memory resources to retain novel phonological strings for immediate repetition will experience more success with language acquisition. They therefore conducted a number of multiple regression studies to provide evidence for correlations between language outcome measures and phonological memory, as measured by the NRT. Over these many studies, Gathercole and colleagues have consistently reported significant correlations between (1) non-word repetition accuracy and other measures of phonological memory (e.g. digit span), and (2) phonological memory, as measured by non-word repetition, and other areas of language (e.g. receptive vocabulary or syntax).

Snowling *et al.* (1991) criticized this line of work along two different lines. First, they took issue with the claim that the NRT is a pure measure of phonological memory. They pointed out that successfully repeating a non-word involves accurately perceiving the non-word, creating at least a transient phonological representation in working memory, segmenting the novel string into appropriate speech units, marking the temporal order of these units, formulating a motor plan for articulation, and then actually implementing that motor plan. Failure at any of these levels will result in inaccurate repetition. Further, many of these processes are assumed to take place in working memory, but classifying them all under the rubric of phonological memory misses the point. For example, creating a transient phonological representation in working memory obviously involves storage capacity, while segmenting that transient phonological representation is also assumed to take place in working memory. However, the actual storage of the material is quite a different process from the manipulation of that stored material. They concluded that interactions between all of these different phonological and memory processes need to be considered in interpreting non-word repetition results. This line of criticism provided the impetus for follow-up studies by Bowey (1996, 1997, 2001) and Metsala (1999), who conducted their own multiple regression analyses to examine the respective roles of phonological memory and phonological sensitivity in non-word repetition. Generally speaking, the three groups of researchers have all reported different sources of support for non-word repetition. Gathercole and colleagues have argued that repetition is supported by phonological memory; Metsala has argued that it is supported by phonological sensitivity; and Bowey has argued that it is supported by an underlying phonological processing factor that supports both phonological memory and phonological sensitivity.

Snowling *et al.* (1991) also questioned the assumption that non-word repetition provides a content-free measure of phonological memory. By definition, non-words are unfamiliar and have zero frequency, so there should be no lexical support for their repetition. Nevertheless, Snowling and colleagues argued that children will surely use any lexical knowledge to support non-word repetition, including knowledge of phonological, morphological and prosodic regularities. Subsequent work has examined how lexical knowledge mediates non-word repetition performance (Beckman and Edwards 2000, Coady and Aslin 2004, Dollaghan *et al.* 1993, 1995, Munson 2001, Zamuner *et al.* 2004).

Soon after its initial use, researchers recognized that the NRT might help explain the deficits experienced by a group of children with known deficits in the areas implicated in non-word repetition — phonological processing and auditory memory. Children with specific language impairments, or SLI, have difficulty acquiring and using language in spite of normal non-verbal intelligence, hearing, oral motor skills, and social/emotional development. Researchers have consistently found that children with SLI learning phonologically complex languages like English or Swedish repeat non-words less accurately than children with NL. The use of NRTs in this population appears to stem from two independent sources, reflecting the two main skills hypothesized to support repetition. First, researchers examining children with dyslexia extended this work to include children with SLI in order to measure how they process phonological information (Kamhi and Catts 1986, Kamhi *et al.* 1988). Second, memory researchers used an NRT to test the hypothesized link between vocabulary and phonological memory (Gathercole and Baddeley 1989). Gathercole and Baddeley (1990) originally justified including children with SLI based on their memory deficits (e.g. Kirchner and Klatzky 1985). In later work, Gathercole *et al.* (1991c) explained that children with LI were included because of their lexical deficits (e.g. Stark and Tallal 1981). According to their model, children with SLI have smaller lexicons because they are less able to hold novel phonological strings in working memory. Their reduced phonological working memory capacity limits the addition of new words into the lexicon.

The history of NRTs in children with SLI has followed a different trajectory than that in children with NL. Early studies used performance on NRTs to explore the mechanisms that might underlie the linguistic deficits seen in SLI (Bishop *et al.* 1996, Briscoe *et al.* 2001, Edwards and Lahey 1998, Gathercole and Baddeley 1990, Kamhi and Catts 1986, Kamhi *et al.* 1988, Montgomery 1995a, b). From very early on, researchers have attempted to tie poorer non-word repetition accuracy to poorer phonological working memory skills (Gathercole and Baddeley 1990, Marton and Schwartz 2003, Montgomery 1995a, b, 2004). However, this literature has also considered alternate explanations for the poorer non-word repetition performance by children with SLI, including problems in speech perception, phonological assembly, and articulation (Edwards and Lahey 1998, Gathercole and Baddeley 1990, James *et al.* 1994, Montgomery 1995b, Stark and Blackwell 1997). Recently, researchers have begun to focus on the relationship between non-word repetition performance and language outcomes in children with SLI (Botting and Conti-Ramsden 2001, Gray 2004, Horohov and Oetting 2004, Montgomery 1995a, Montgomery and Windsor 2006, Munson *et al.* 2005).

Because children with SLI are consistently less accurate than children with NL in NRTs, researchers have suggested that the task makes a useful tool for identifying children with language impairments (Bishop *et al.* 1996, Conti-Ramsden 2003, Conti-Ramsden *et al.* 2001, Conti-Ramsden and Hesketh 2003, Dollaghan and Campbell 1998, Ellis Weismer *et al.* 2000, Gray 2003, Horohov and Oetting 2004, Taylor *et al.* 1989). In fact, the NRT might be a particularly useful identifier because it minimizes cultural and dialectal biases, and does not over-identify children from non-standard language backgrounds (Ellis Weismer *et al.* 2000, Rodekohr and Haynes 2001, Washington and Craig 2004).

What NRTs have revealed about language development

Language development in children with NL

Table 1 provides a list of studies that have examined the non-word repetition abilities of children with NL. The use of NRTs in children with NL has revealed a great deal about aspects of typical language acquisition. Generally speaking, studies have focused on the relationship between non-word repetition accuracy and subsequent vocabulary development. A number of studies have examined directly the reciprocal influences that vocabulary growth and non-word repetition exert on one another. Other studies have examined these interrelationships more indirectly, by looking at how knowledge of words and sound patterns extracted from over the lexicon influences non-word repetition.

The first conclusion to be drawn is that non-word repetition accuracy and receptive vocabulary are significantly correlated. This is expected, as non-word repetition mimics the phonological component of the child’s task when learning a new word. Children must take in the acoustic form of the novel word and create a representation robust enough to support subsequent repetition, all while linking this acoustic representation to the real-world referent. Those children developing language normally who score higher on receptive vocabulary measures repeat non-words more accurately than do children with lower receptive vocabulary scores (Bowey 1996, 2001, Gathercole and Baddeley 1989, Metsala 1999). Further, Michas and Henry (1994) provided direct evidence for the link between repetition accuracy and vocabulary by showing that children’s ability to repeat non-words was significantly correlated with their ability to learn novel vocabulary items in their native language. Service (1992) had previously presented similar results for learning novel vocabulary items in a foreign language.

The causal direction of this relationship is not so easily described. In their earlier studies, Gathercole and colleagues (Gathercole and Baddeley 1989, Gathercole *et al.* 1991a) assumed that the NRT directly measures phonological working memory. This hypothesis was directly supported — non-word repetition abilities at age 4 predicted receptive vocabulary at age 5. However, this pattern did not hold for older children. In their 1992 study, Gathercole and colleagues replicated this earlier finding, but also found that the pattern was reversed after the age of 5. While phonological memory, as measured by non-word repetition accuracy, supports vocabulary acquisition before the age of 5, it switches to being supported by vocabulary after the age of 5. Gathercole *et al.* (1992) suggested that by this age, children's vocabularies have grown to such a size that they can use lexical and sublexical information to facilitate repetition performance. This is not to say that vocabulary exerts no influence on repetition before age 5, or that phonological memory exerts no influence on vocabulary after age 5. Indeed, there is evidence that children use sublexical information (phonotactic frequency) to facilitate non-word repetition well before the age of 5 (Coady and Aslin 2004, Zamuner *et al.* 2004), and that phonological memory continues to constrain word learning, at least through adolescence (Gathercole *et al.* 1999). The basic finding here is that the relationship between non-word repetition and vocabulary is bidirectional, with non-word repetition exerting a greater influence before age 5, but a lesser influence after age 5.

There is one potentially confusing fact about the link between non-word repetition ability and vocabulary — the link only holds for measures of receptive vocabulary, not for measures of expressive vocabulary. Briscoe *et al.* (2001) used an NRT to test the hypothesis that phonological difficulties might be causing the more pervasive language impairments experienced by children with SLI. As a control group, they included 35 children with NL, mean age 8;6. Generally, their results for children with NL replicated previous findings from other researchers. However, they reported that receptive vocabulary, but not expressive vocabulary, account for a significant portion of the variance in non-word repetition accuracy. This raises the question of why repetition accuracy correlates with receptive vocabulary, but not with expressive vocabulary.

A second conclusion to be drawn from this literature is that repetition accuracy depends on the degree to which a non-word overlaps with existing lexical entries. As Bowey pointed out, 'any manipulation that increases phonological complexity decreases non-word repetition performance' (Bowey 2001: 443). Researchers have used a number of methods to manipulate phonological complexity, including presenting non-words differing in the presence versus absence of consonant clusters, in adult ratings of subjective word-likeness, in the presence versus absence of embedded real words, in the presence versus absence of attested consonant sequences, and in the frequency of the component segments or combinations of segments. These factors are all related to one another, and can be described in terms of *phonotactics*, or rules governing how speech sounds can be arranged within a given language.

In their original study, Gathercole and Baddeley (1989) included non-words with singleton consonants, e.g. *woogalamik*, and non-words with consonant clusters, e.g. *blonderstaping*. They found that 4-year-olds with NL showed reduced accuracy for non-words containing consonant clusters, while 5-year-olds with NL did not. This sensitivity to consonant complexity was replicated in one subsequent study (Gathercole *et al.* 1991a), but not in a different follow-up study (Gathercole *et al.* 1991b). In subsequent studies, Gathercole and colleagues (Gathercole 1995, Gathercole *et al.* 1991b) explored the nature of these complexity effects by using non-words differing in adult ratings of subjective word-likeness. Some of the non-words had been judged to be very word-like (e.g. *defermication*), while others were judged to be minimally word-like (e.g. *perplisteronk*). These two variables, articulatory complexity, as measured by the presence/absence of consonant clusters, and subjective word-likeness ratings were found to be significantly negatively correlated. Gathercole *et al.* (1991b) hypothesized that non-words rated as more word-like would provide a more familiar phonological structure, thereby freeing up working memory resources to support accurate repetition. This hypothesis was supported, with children in all three age groups (4-, 5-, and 6-year olds) more accurately repeating those non-words adults had given higher word-likeness ratings. Subsequent work revealed different sources of support for different types of non-words. Gathercole (1995) found that repetition of less word-like non-words was supported by phonological memory, while repetition of more word-like non-words gained added support from stored lexical knowledge.

Dollaghan *et al.* (1993, 1995) found that children were more likely to repeat correctly non-words containing real words, e.g. *BATHesis*, as compared to non-words that did not contain embedded real words, e.g. *FATHesis* . Similarly, Beckman and Edwards (2000) and Munson (2001) asked children to repeat non-words containing attested versus unattested sequences. For example, the sequence [ft] occurs within the words *after* and *fifty*, while the sequence [fk] occurs rarely, and only in borrowed words, such as *Kafka*. They asked children to repeat non-words with attested sequences, such as *moften*, and non-words with unattested sequences, such as *mofken*. They found higher levels of accuracy for non-words containing attested sequences. Zamuner *et al.* (2004) reported that young children, mean age 2;0, repeated syllable-final (coda) consonants in CVC non-words more accurately when they occurred in high phonotactic frequency contexts (e.g. *ged*), relative to those same consonants in low phonotactic frequency contexts (e.g. *chud*). Coady and Aslin (2004) found that children repeated non-words with higher frequency phonotactic patterns (e.g. [mu·do^{w}·sa^{y}s]) more accurately than those with lower frequency phonotactic patterns (e.g. [ʃ3·ga^{w}·p3θ]). Edwards *et al.* (2004) also reported that children repeat high phonotactic frequency non-words more accurately than low phonotactic frequency non-words, but suggested that the size of this effect decreases over development, as the lexicon increases in size. As explanation, they point out that phonological development is a process in which representations of the underlying speech units become increasingly abstract or context-independent. Younger children with smaller lexicons should show larger phonotactic frequency effects because they may have reasonably abstract representations of more frequently occurring speech sounds and sound combinations, but they may not have encountered infrequently occurring sequences often enough to be able to extend them to novel phonetic contexts. Older children with larger lexicons are more likely to have encountered instances of infrequently occurring sequences, so they can more readily extend their abstracted representations to novel contexts.

The previous conclusion that repetition accuracy predicts subsequent vocabulary growth before age 5, but that vocabulary after age 5 predicts subsequent repetition accuracy might suggest that these lexical effects in non-word repetition accuracy are not significant until after the age of 5. Gathercole *et al.* (1992) did indeed find that vocabulary at age 4 failed to predict repetition accuracy at age 5. However, Metsala (1999) found a significant correlation between vocabulary and non-word repetition at age 4. Further, finding that children as young as 2;0 were more accurate repeating non-words with more frequent phonotactic patterns supports the conclusion that even very young children use knowledge extracted from over the lexicon to support non-word repetition (Zamuner *et al.* 2004).

Non-word repetition in children with SLI

Even before researchers were using NRTs to examine language development in children with NL, they were using them to explore the deficits experienced by children with language impairments. Generally speaking, NRTs were presented as content-free measures of language processing. If children were tested with real words, they would surely be influenced by a number of factors, including word frequency, familiarity, and age of acquisition. These effects would surely be exacerbated for children with language impairments. Dollaghan (1998) has pointed out that we cannot assume that the contents of the lexicons of children with SLI are comparable to their age-matched peers. Because these children have likely had different numbers and types of experiences with words, their sensitivities to word frequency, familiarity, and age of acquisition are likely to be different. Non-words, however, are non-occurring and unfamiliar, so their use is ideal for circumventing these extraneous factors. What, then, has the use of NRTs revealed about language development in children with SLI?

Consistently poorer performance by children with SLI

The first major conclusion consistently shown is that children with SLI learning phonologically complex languages such as English or Swedish repeat non-words less accurately than their typically developing peers (for a review of effect sizes, see the meta-analysis by Graf Estes *et al.* 2007). Only one study has failed to find group accuracy differences. Stokes *et al.* (2006) examined non-word repetition in a group of children with SLI learning Cantonese, a phonologically simpler language. Unlike English or Swedish, Cantonese has a small phonetic inventory, restricted syllable structure, and invariable stress. Children with SLI learning Cantonese repeated multisyllabic non-words as accurately as their age-matched peers. Stokes *et al.* (2006) suggested that children learning Cantonese can more easily reconstruct decaying phonological traces in working memory because the number of potential syllables is limited by the phonological simplicity of the language.

For the case of phonologically more complex languages, why children with SLI are significantly less accurate remains an open question. Kamhi and colleagues (Kamhi and Catts 1986, Kamhi *et al.* 1988) originally administered the NRT to children with SLI to look for possible deficits in phonological processing. They discounted potential memory deficits, stating 'storage and retrieval demands were minimized in this task because immediate repetitions were required' (Kamhi and Catts 1986: 344). Later, Gathercole and Baddeley (1990) administered the NRT to children with SLI in order to examine whether their linguistic deficits might be attributed to a primary deficit in phonological working memory. More recently, Stark and Blackwell (1997) used an NRT to look for potential deficits in oral-motor planning abilities. Thus, three groups of researchers reported similar findings, but attributed these findings to very different causes. Therefore, the question of what deficits are primary for children with SLI remains unresolved.

Relationship between non-word repetition and vocabulary

Gathercole and Baddeley (1990) included children with SLI in their studies to examine the relationship between phonological working memory and vocabulary at an extreme end of the distribution. If phonological working memory supports vocabulary acquisition, then children with SLI should score below children with NL in both of these measures, which is indeed the case. This suggests the size of these children's lexicons is actually limited by their reduced phonological working memory capacity. While all available evidence suggests that children with SLI score lower than children with NL on both NRTs and standardized vocabulary measures, few researchers have found evidence that these two factors are correlated for children with SLI. Gathercole and Baddeley (1990) reported significant group differences, but could not look for this correlation because they only included five children with LI. For those studies that included enough children for adequate statistical power, correlations between repetition accuracy and receptive vocabulary were not significant (Briscoe *et al.* 2001, Edwards and Lahey 1998). Furthermore, group differences in repetition accuracy held up even after covarying out the effects due to receptive vocabulary (Montgomery 1995a), suggesting that group differences in non-word repetition accuracy must be at least partly the result of some non-lexical factor. Botting and Conti-Ramsden (2001) reported similar findings. They examined language outcomes in two groups of children with SLI matched on non-verbal IQ, but differing in their ability to repeat non-words. Children with SLI with better non-word repetition abilities scored higher than children with poorer non-word repetition abilities on a number of language measures, but not on vocabulary. Taken together, these findings suggest that working memory and vocabulary might not be as transparently related for the population of children with SLI.

While a direct link between these factors is currently unattested, two recent studies have suggested that non-word repetition and vocabulary are indeed related for children with SLI. Gray (2004) examined the correlation between phonological memory and vocabulary as measured by a word-learning task instead of standardized measures of vocabulary knowledge that are typically used. She found that non-word repetition scores predicted a significant portion of variance in the number of trials required to learn novel vocabulary items by young children with SLI, mean age 4;10. Horohov and Oetting (2004) found no such correlation in a slightly older group of children with SLI, mean age 6;3. This apparent difference between the results of these two studies may reflect the switch in directionality that Gathercole *et al.* (1992) reported for children with NL at approximately age 5;0. They found that repetition accuracy predicted subsequent receptive vocabulary scores before the age of 5;0, while after the age of 5;0, receptive vocabulary predicted subsequent non-word repetition ability. Repetition accuracy predicted vocabulary learning for the younger children (mean age 4;10) in the Gray study (2004), but not for the older group of children (mean age 6;3) in the Horohov and Oetting study (2004).

Munson *et al.* (2005) also found a relationship between a standardized measure of receptive vocabulary and non-word repetition accuracy. They found that children with SLI and a group of younger children matched on raw receptive vocabulary scores (language age, or LA matched) did not differ in repetition accuracy. When we compare these results with those of Botting and Conti-Ramsden (2001), we see that the relationship between non-word repetition and vocabulary seems to be unidirectional in this population. Children with similar raw vocabulary scores showed similar non-word repetition accuracy, regardless of diagnosis (Munson *et al.* 2005), but children with similar non-word repetition abilities don't necessarily have similar standard vocabulary scores (Botting and Conti-Ramsden 2001). For children with SLI, vocabulary predicts repetition accuracy, but repetition ability does not predict vocabulary.

Word-likeness effects

While there is little *direct* evidence to support the hypothesized link between non-word repetition as a measure of phonological memory and receptive vocabulary, there is *indirect* evidence. Like children with NL, children with SLI more accurately repeat those non-words that reflect the properties of the lexicon. Kamhi and colleagues (Kamhi and Catts 1986, Kamhi *et al.* 1988) asked children with LI and children with NL to repeat non-words containing minimal phonetic contrasts across syllables (e.g. [səʃáfəsI]) and non-words containing easily discriminable consonants across syllables (e.g. [mákəvən]). They argued that the discriminability of the non-words' constituent consonants was actually a measure of phonological complexity, much like articulatory complexity subsequently used by Gathercole and Baddeley (1989). Kamhi and colleagues reported that both groups of children repeated phonologically simple non-words more accurately than phonologically complex ones. Further, children with LI did not differ from children with NL in the size of this effect — both groups were equally affected by phonological complexity. This finding was replicated using non-words varying in articulatory complexity (Gathercole and Baddeley 1990) and non-words differing in the frequency of their phonotactic patterns (Coady *et al.* 2007). These findings suggest that children with SLI can use phonological regularities extracted from over their lexicons to support non-word repetition in much the same way that children with NL can.

Other researchers, however, have found that children with SLI show larger articulatory complexity effects than children with NL. Bishop and colleagues (Bishop *et al.* 1996, Briscoe *et al.* 2001) had children with SLI and children with NL repeat non-words containing either singleton consonants or consonant clusters. They found a significant group by complexity interaction, in which children with SLI were more affected by increasing articulatory complexity than were children with NL. These complexity effects at least partly reflect differences in the articulatory plans required to repeat the non-words. Additionally, however, they reflect differences in subjective word-likeness and phonotactic probability. Munson *et al.* (2005) replicated this finding using non-words differing in phonotactic probability. Therefore, the question about how well children with SLI can extract distributional regularities from their input and then use them to support non-word repetition remains an open one.

Potential deficits in supporting skills

As mentioned previously, accurately repeating a non-word relies on a number of skills. Research examining non-word repetition in children with NL has focused on the phonological memory and phonological sensitivity components. Phonological memory corresponds to temporary storage in the phonological buffer, while phonological sensitivity corresponds mostly to breaking non-words down into their component parts, but may also involve assembling the phonological units for subsequent articulation. Research on children with SLI has been vital in exploring all of the component skills in order to understand why children with SLI are so much less accurate than children with NL.

In order to repeat successfully a non-word, the listener must first accurately perceive the speech stream. While recent evidence suggests that the perceptual abilities of children with SLI are intact for naturally spoken versions of real-word stimuli, all of the available evidence shows that children with SLI perceive meaningless test items such as non-words less accurately than their typically developing peers (Coady *et al.* 2005, 2007). Gathercole and Baddeley (1990) examined the possibility that a perceptual deficit might influence repetition accuracy by having their participants discriminate pairs of monosyllabic CVC words and non-words potentially differing in a single phonetic segment. Children with SLI were no less accurate than control children. Montgomery (1995b) included a similar task, except he used his own one- to four-syllable non-words as the stimuli. He found that children with SLI were less able to determine whether two non-words were identical, but there were only group differences for the longest, four-syllable non-words. He suggested that what appears to be a perceptual deficit is, in this case, another instantiation of a memory deficit. Edwards and Lahey (1998) also considered perceptual difficulties by examining errors made on stop consonants and on unstressed syllables, both of which are hypothesized to be a source of difficulty for children with SLI. They found no group differences in the error patterns on either of these variables. The non-words used by Kamhi and colleagues (Kamhi and Catts 1986, Kamhi *et al.* 1989) were also designed such that some non-words contained consonants that were relatively easy to discriminate (phonologically simple) or consonants that were harder to discriminate (phonologically complex). While this manipulation can be partly attributed to complexity or word-likeness, it also affects perception of the non-words. Kamhi and colleagues reported no group differences in the magnitude of this effect. Over all of these studies, it seems that children with SLI are able to discriminate minimal phonetic pairs when they are embedded in short words or non-words, but this ability suffers when the relevant contrast is embedded in a longer phonological string. Therefore, the possibility remains that children with SLI do have subtle speech perception deficits that compromise their ability to form precise phonological categories, and consequently learn new vocabulary items and grammatical structures.

Once a non-word has been perceived, the repeater must break the non-word down into smaller speech units, whether they are syllables, diphones, or phonemes. In this literature, this process is referred to as either *phonological encoding* or *phonological sensitivity*, which Bowey explicitly equated with more traditional measures of phonological awareness (1996). One method used to test the efficiency with which listeners encode phonological information is a memory task varying the phonological similarity of the items to be remembered. Generally speaking, children who successfully encode spoken words are less able to recall phonologically similar words because the phonological traces interfere with one another in working memory. Children with less efficient encoding strategies do not show these phonological similarity effects, making a similar number of errors on lists of phonologically similar and dissimilar words (Liberman *et al.* 1977). Gathercole and Baddeley (1990) used this methodology and found that children with SLI and children with NL were both affected by phonological similarity in shorter word lists. However, children with SLI were not affected when recalling longer word lists, suggesting that their phonological encoding processes were less efficient when memory resources are surpassed (also James *et al.* 1994). Montgomery (1995b) included a similar task, and found that children with SLI and NL were both influenced by phonological similarity among items to be remembered. However, he did not examine list length effects, so his data do not address the question of whether list length effects mediate phonological similarity effects. Edwards and Lahey (1998) also looked at phonological encoding by analysing errors from their NRT. They reported that children with SLI made more syllable structure errors and phoneme deletion errors, but fewer phoneme substitution errors. However, they did not design their experiment to differentiate between phonological memory, encoding, and representation. Thus, these group differences suggest difficulty with any or all of these phonological processes. Taken together, these studies suggest that children with SLI might have a deficit in phonological encoding, in which inefficient or inaccurate encoding of phonological material might actually result in a less robust or more quickly decaying phonological trace, thereby limiting repetition accuracy.

Once the non-word has been perceived and broken down into its constituent units, it must be stored long enough to formulate and implement an articulatory plan. Indeed, the memory component of the NRT has perhaps been the most extensively studied, so much so that the NRT is generally viewed as a measure of phonological memory capacity. All of the studies examining non-word repetition abilities in children with SLI in which non-word length is a factor have found that group differences are significant, yet small for shorter one- and two-syllable non-words, and larger for longer three- and four-syllable non-words (Bishop *et al.* 1996, Briscoe *et al.* 2001, Dollaghan and Campbell 1998, Ellis Weismer *et al.* 2000, Gathercole and Baddeley 1990, Montgomery 1995a, b). Gathercole and Baddeley (1990) cited these length effects as evidence for a phonological memory deficit. A caveat put forward by Snowling *et al.* (1991) is that longer non-words tax other phonological processes besides memory.

In follow-up tasks specifically designed to measure memory, Gathercole and Baddeley (1990) had children with SLI and NL recall lists of words differing in phonological similarity, but also lists of words differing in syllable length. Words to be remembered are assumed to be stored in the phonological loop and actively maintained by subvocal rehearsal. One-syllable words can be repeated more quickly, so they should be easier to maintain in the phonological loop. Over both conditions (similarity and word length) the group with SLI recalled fewer items overall, but this difference was only significant in one of ten conditions. Van der Lely and Howard (1993) questioned the conclusion of a memory deficit, pointing out the conspicuous lack of group memory effects. They hypothesized that children with SLI might perform poorly on measures of immediate recall because of reduced facility with phonological materials rather than reduced memory capacity. They therefore examined immediate recall using three different manipulations (semantically related versus unrelated, word versus non-word, and phonologically similar versus dissimilar) in two different response conditions (verbal recall and pointing). After covarying out language abilities, they found no significant differences between children with SLI and age-matched controls, and concluded that any potential memory deficits resulted from difficulty with the linguistic nature of the materials to be remembered. Gathercole and Baddeley (1995) replied by arguing that Van der Lely and Howard based their conclusions on the results of non-standard memory procedures. Chief among their criticisms was that Van der Lely and Howard attempted to maximize children's performance by having each item to be remembered associated with a puppet in an array. In this procedure, the experimenter said the first word while pointing to the first puppet, the second word while pointing to the second puppet, and so on. Gathercole and Baddeley worried that this associative step added another degree of difficulty to the memory procedure. They suggested that a child might succeed by ignoring the syllable rime, and just remembering the syllable onset. Howard and Van der Lely (1995) issued a rebuttal justifying the use of their experimental procedures. While their procedures are reasonable, it is curious that they covaried raw language scores out of their statistical analyses. Both groups of researchers agree that phonological memory capacity and language skills are related. Gathercole and Baddeley argue that phonological memory determines language abilities, while Van der Lely and Howard argue that phonological memory is instead a consequence of language abilities. It is consistent with both positions that group memory differences should be mediated by language scores.

Montgomery (1995b) included more children than these previous studies, and found that children with SLI recalled fewer items than did children with NL, replicating previous findings of a memory deficit in SLI (e.g. Kirchner and Klatzky 1985). To relate this memory deficit to deficits in language abilities, Montgomery (1995a) had children with SLI and NL participate in a grammatical understanding task. Children heard spoken sentences that either did or did not contain extra redundant words. As an example, a non-redundant sentence was 'the girl chases the horse,' while the redundant version was 'the pretty little girl quickly chases the big fast horse.' Children then indicated which of four pictures matched that spoken sentence. Montgomery reported no group differences for sentences without redundant words, but significant differences for sentences containing redundant information. Finally, Edwards and Lahey (1998) examined error patterns from their non-word repetition task to see if there were hints to which underlying processes were impaired. Children with SLI did not differ from children with NL in the rates with which they turned nonsense syllables into real words. However, the children with SLI made significantly more syllable structure and phoneme deletion errors and significantly fewer phoneme substitution errors, indicating impaired phonological memory processes. However, Edwards and Lahey acknowledged that their task was not designed to differentiate phonological memory explanations from phonological sensitivity explanations.

Yet another potential cause of difficulty in non-word repetition tasks is motor planning. Children with SLI might have difficulty assembling the speech units to recreate an accurate version of the target non-word. Gathercole and Baddeley (1990) examined this possibility by including non-words with singleton consonants and non-words with consonant clusters, which presumably require a more elaborate articulatory plan. All children repeated non-words with consonant clusters less accurately, but group interactions were not significant, indicating no group differences in articulatory planning. Edwards and Lahey (1998) obtained inconclusive results when they considered how complexity affects motor planning. They found no group differences on the percentage of errors on non-words with consonant clusters. They found that children with SLI made significantly more errors than children with NL on production of liquids, but significantly fewer errors on production of fricatives, both of which are later acquired and more difficult to produce. Bishop *et al.* (1996) found a significant complexity by group interaction, indicating that children with SLI were more affected by the presence of consonant clusters. Likewise, Briscoe *et al.* (2001) reported that children with SLI were inordinately affected by articulatory complexity.

Stark and Blackwell (1997) directly measured the role of motor planning abilities in the non-word repetition performance of children with SLI. They measured both non-word repetition ability and the ability to make isolated, repeated and sequential oral volitional movements. Children with SLI were as able as their typically developing peers to make isolated and repeated oral volitional movements. However, children with SLI were less able to perform sequences of oral movements, implicating a subtle deficit in motor planning. These subtle deficits in oral volitional movements are consistent with the more pervasive, yet subtle, motor deficits experienced by children with SLI (Hill 2001). These results from articulatory complexity and oral volitional movements suggest that children with SLI also exhibit deficits in articulatory motor planning.

Finally, researchers have considered that children with SLI might also have subtle deficits in articulation. Of course, those deficits attributed above to motor planning might instead be errors in articulation. The question of potential articulation deficits has also included measures of fluency and timing. Slower articulation rates should result in slower subvocal rehearsal, thereby limiting recall, while slower articulation latencies would indicate difficulty executing the motor act. Gathercole and Baddeley (1990) examined articulation durations and latencies for one- and three-syllable familiar words, but found no significant group differences. Montgomery (1995b) measured articulation durations for correct repetitions of his non-words, and found no group differences after age was entered as a covariate. Edwards and Lahey (1998) also measured articulation durations and latencies for their non-words. They found no group differences in articulation latencies, but significant group differences in articulation durations. They reported that these articulation durations did not correlate significantly with accuracy, which they interpreted as a non-effect. That is, the slowest children were not the least accurate. However, increased articulation durations might instead indicate the speed-accuracy trade-off. Perhaps children with SLI articulate more slowly to enhance accuracy. In this case, a group difference in articulation duration is a relevant statistical finding. Therefore, there is also evidence that children with SLI have subtle deficits in articulation, as measured by articulation durations.

Therefore, children with SLI have difficulty repeating non-words relative to children developing language typically. Even though repetition accuracy and vocabulary are related for children with NL, there is a lack of convincing direct evidence that they are related for children with SLI. However, children with SLI are affected by word-likeness, although it is not clear whether they are similarly or differently affected. Furthermore, the difficulty experienced by children with SLI in repeating non-words appears to stem from difficulty with all components of the task, including speech perception, phonological encoding, phonological memory, phonological assembly, and articulation.

Current issues in the use of NRTs

What does non-word repetition measure?

NRTs have been used to measure a variety of language skills, including lexical access (e.g. Rubenstein *et al.* 1970), motor planning abilities (e.g. Yoss and Darley 1974), phonological processing (e.g. Snowling 1981), and phonological memory (e.g. Gathercole and Baddeley 1989). The task additionally taps speech perception, phonological assembly, and articulation processes. In spite of the fact that this is a complex task with many components, researchers have focused on phonological memory and phonological sensitivity explanations of performance. A list of studies examining the non-word repetition abilities of children with SLI is provided in Table 2. Both of these factors are obviously related to repetition performance. Children with greater phonological memory capacity experience greater success in repeating novel phonological strings. Similarly, children with greater facility with the phonological structure of their language will also experience more success in repeating non-words. The question then becomes, which of these is primary? Do children gain facility with the sound structure of their language because of their phonological memory capacity? Or instead, does their facility with the sound structure of their language determine phonological memory capacity?

Gathercole and colleagues (Adams and Gathercole 1995, 1996, 2000, Gathercole 1995, Gathercole and Adams 1993, 1994, Gathercole and Baddeley 1989, Gathercole *et al.* 1991a–c, 1992, 1997, 1999) have argued that non-word repetition is a measure of phonological working memory, separate from other phonological processes. They based this conclusion on the fact that non-word repetition is significantly correlated with another measure of phonological memory, digit span. They found that measures of phonological memory and receptive vocabulary were significantly correlated, while measures of phonological sensitivity and receptive vocabulary were not (Gathercole *et al.* 1991a). This may be the result of the particular phonological sensitivity measure used. In this study they used a rhyme oddity task in which children were presented with pictures of three familiar objects that were named by the experimenter. Two of the objects had rhyming names, while the third did not. Children were asked to pick the non-rhyming object. Based on the results of a single word reading measure, children from the age 5 group were separated into subgroups. When age and non-verbal intelligence were entered as covariates, there were no significant reading group differences in the phonological sensitivity measure. That is, the phonological sensitivity measure used in this study failed to differentiate between the reading groups, at least for this sample of children.

Metsala (1999) argued that phonological sensitivity, not phonological memory, mediates non-word repetition and vocabulary acquisition. She found that phonological memory and phonological sensitivity both contributed unique variance to non-word repetition scores in a group of 4–5-year-old children with NL, but only phonological sensitivity accounted for unique variance in the scores of younger children, aged 3–4 years. So this finding is at least partly based on the lack of a relationship between memory and vocabulary measures in younger children. Gathercole and Adams (1993) also found that vocabulary and digit span were not correlated in a younger group of children. However, they attributed this to the fact that digit span measures are notoriously unreliable in very young children. They suggested that for very young children, digits have not yet become the highly familiar phonological sequences that they are for older children and adult subjects.

Alternatively, Bowey (1996, 1997, 2001) has argued that phonological memory and phonological sensitivity are not separable, but rather are both surface manifestations of an underlying phonological processing ability (also MacDonald and Christiansen 2002). She collected non-word repetition and digit span scores as measures of phonological memory, and rhyme oddity and rime matching scores as measures of phonological sensitivity. Factor analysis extracted a single factor, with non-word repetition, phonological memory and phonological sensitivity all loading on that single factor. Bowey (1996) interpreted this as evidence of a single underlying general phonological processing factor. Next, she entered the results into stepwise multiple regression analyses. Both phonological memory and phonological sensitivity accounted for unique portions of the variance in the vocabulary measure. Three of the four phonological variables, rhyme oddity, phoneme identity and digit span, accounted for significant portions of the variance when entered in the last step of separate multiple regression analyses. That is, these three factors accounted for independent, significant portions of the variance in receptive vocabulary. However, the variance due to non-word repetition was largely redundant with that due to digit span, and did not account for a significant portion of the variance when entered after the other phonological variables. Bowey (1996, 1997) argued that these factors entered as the last steps of the various stepwise multiple regression analyses only accounted for small portions of the variance, and could therefore be considered redundant. However, if these variables accounted for truly redundant portions of the variance, then we would expect that none of them would account for significant portions of the variance when entered in the final steps of the multiple regression analysis. This was only the case for non-word repetition, the variance for which was redundant with that for the other phonological measures. The other three phonological variables accounted for significant portions of the variance in receptive vocabulary when entered in the final steps of the analyses, and therefore cannot be considered redundant. Therefore, while all four phonological variables loaded with receptive vocabulary onto a single factor in the factor analysis, three of them accounted for unique portions of the variance in receptive vocabulary. Thus, the evidence for a single underlying phonological processing factor is mixed.

Taken together, all of the results using the NRT bring into question whether phonological working memory (phonological loop) is a construct distinct from phonological knowledge. Performance on NRTs appears to be tightly linked to phonological information available to the child for any given non-word being repeated. In their original model, Baddeley and Hitch

(1974) argued that the phonological loop is separate from extant language knowledge. In the more recent version of this model, Baddeley (2003) suggested that the phonological loop does not function independently of extant knowledge, even though it remains a separate construct. In recent models of adult working memory, MacDonald and Christiansen (2002) argue that the distinction between working memory and language knowledge is an artificial one. Specifically, they argue that differences in performance on working memory tasks can be explained entirely in terms of differences in language experience and architectural biological differences. It may also be the case that there is no distinct phonological working memory at all. Differences in performance on phonological working memory tasks such as the NRT may be an artefact of the size of the child's lexicon, the degree to which non-words reflect the properties of the lexicon (i.e. word-likeness), and biological constraints the child brings to the task (such as the precision of underlying phonological representations).

Case for using the NRT as a window on the phonological structure of the lexicon

For both children with NL and children with SLI, repetition accuracy is better for phonologically and articulatorily simple non-words, and for non-words that most closely match existing lexical entries (Beckman and Edwards 2000, Bishop *et al.* 1996, Briscoe *et al.* 2001, Coady and Aslin 2004, Coady *et al.* 2006, Dollaghan *et al.* 1993, 1995, Edwards *et al.* 2004, Gathercole 1995, Gathercole and Baddeley 1989, 1990, Gathercole *et al.* 1991a, b, 1992, Kamhi and Catts 1986, Kamhi *et al.* 1988, Munson 2001, Munson *et al.* 2005, Zamuner *et al.* 2004). To the extent that these manipulations reflect differences in word-likeness and phonotactic frequency, they can be used to measure how well the language learner is able to extract phonological regularities from the corpus of language that they hear. On one hand, understanding the process by which regularities are extracted from language input has important implications for understanding developmental changes in the level of phonological detail within lexical representations, or lexical specificity. Developmental changes in lexical specificity have been implicated as a necessary precursor for beginning literacy in typically developing children (Fowler 1991, Metsala and Walley 1998). On the other hand, understanding how phonological regularities are extracted may help elucidate the underlying cause of SLI. Chiat (2001) has made the first steps toward a formal model explaining how difficulty extracting phonological regularities might cause the higher level morphosyntactic deficits experienced by children with SLI. Joanisse and Seidenberg (2003) have provided similar evidence from connectionist simulations.

The evidence concerning the specificity, or level of acoustic detail in children's earliest lexical representations is sparse, but it is likely that their earliest words are represented as whole units (e.g. Ferguson 1978, Menyuk and Menn 1979). After the naming spurt, however, children gradually begin to incorporate more phonetic detail into their lexical representations. Still, the exact nature of these representations is controversial. Some researchers have argued that lexical representations are holistically stored only until the onset of the naming explosion at approximately 19 months, when the rapid acquisition of many new words forces children to attend to phonetic detail (Boysson-Bardies 1999, Ferguson 1986, Studdert-Kennedy 1987). Based on younger children's apparent insensitivity to phonological materials, others have suggested that holistic lexical representations continue until the early school years (e.g. Treiman and Baron 1981). As infants begin to speak, they often make errors in both speech perception and speech production (Eilers and Oller 1976, Garnica 1973, Shvachkin 1973, Stager and Werker 1997). Also, young children group spoken words based on overall similarity, while older children and adults group them based on shared phonemes (Treiman and Baron 1981, Treiman and Breaux 1982, Walley *et al.* 1986). That is, when presented with the spoken syllables /bIs/, /diz/, and /bun/, for example, young children group /bIs/ and /diz/ because they are quite similar overall, while older children and adults group /bIs/ and /bun/ based on shared phonemic content. Furthermore, when perceiving and producing fricative-vowel syllables, young children appear to rely more on the vocalic formant transitions than on the fricative noise spectra, using information that spans the syllables rather than information within individual phonetic segments (Nittrouer and Studdert-Kennedy 1987, Nittrouer *et al.* 1989). Young children also have fewer similar sounding words in their lexicons, reducing the need for sophisticated perceptual abilities (Charles-Luce and Luce 1990, 1995, Logan 1992). Based on these and other findings, a number of researchers (e.g. Jusczyk 1986, Fowler 1991, Walley 1993) have concluded that children store words in their lexicons as holistic, syllable-based units rather than sequences of phonetic segments, and that these holistic representations gradually become segmentally based over the course of early childhood.

Of course, these claims are by no means uncontroversial. Children acquire a remarkable amount of information about the sound structure of their input language during their first postnatal year, before they ever produce a single word. By six months of age, infants have the ability to discriminate virtually any phonetic contrast that could be relevant in any of the world's languages (for a review, see Aslin *et al.* 1998). By 12 months of age, they have honed their discriminative capacities to concentrate on those speech sounds used phonemically in their native language (Hillenbrand 1983, 1984, Holmberg *et al.* 1977, Jusczyk *et al.* 1992, Kuhl 1979, 1983, Werker and Tees 1984), how often they occur (Jusczyk *et al.* 1994), how they are combined to form the words of their language (Friederici and Wessels 1994, Jusczyk *et al.* 1993), how they differ depending on their position in a word (Jusczyk *et al.* 1999), and how those differences signal syllable and word boundaries (Mattys and Jusczyk 2001, Mattys *et al.* 1999). These sophisticated perceptual skills and distributional sensitivities suggest that children are quite sensitive to phonological materials. Indeed, when tested with simpler, more sensitive methods, children do show evidence of more segmental (less holistic) representations, at least after the naming explosion (Coady and Aslin 2003, 2004, Dollaghan 1994, Gerken *et al.* 1995, Swingley and Aslin 2000, 2002, Swingley *et al.* 1999). Whatever the acoustic form, young children's lexical representations cannot be fully detailed simply by virtue of the fact that phonological development continues until about the age of 9;0 (e.g. Templin 1953). Children's sensitivity to phonological materials must therefore be changing over development, as must its contribution to both vocabulary acquisition and non-word repetition. More recent models of non-word repetition have taken these developing sensitivities into account (Bowey 2001, Coady and Aslin 2004, Metsala 1999, Zamuner *et al.* 2004).

Understanding the process by which phonological regularities are extracted is particularly important in the case of children with SLI, who exhibit a variety of lexical deficits. Children with SLI typically show later acquisition of first words, relative to children with NL (e.g. Trauner *et al.* 1995). In word-learning tasks, children with SLI can succeed, but typically require more presentations to adequately learn novel words. For example, when children with SLI are given only three presentations of novel words, their comprehension suffers relative to children with NL (Ellis Weismer and Hesketh 1993, 1996, Rice *et al.* 1992, 1994). But when given multiple presentations over multiple sessions, their comprehension matches that of age-matched children with NL (Leonard *et al.* 1982, Rice *et al.* 1994). However, in all of these cases, their productions of novel words are significantly less accurate than those of children with NL (also Dollaghan 1987). Children with SLI also exhibit word-finding deficits in a variety of tasks (e.g. Kail and Leonard 1986). They are slower than CA-matched children with NL in auditory lexical decision tasks (Edwards and Lahey 1996). In gating tasks, they can identify familiar words with as little acoustic information as children with NL, but they need more acoustic information to identify less frequent words (Dollaghan 1998, Montgomery 1999). Based on all of this evidence, Dollaghan (1998) has argued that it may be incorrect to assume that the *content* of the lexicons of children with SLI is the same as those of children with NL.

Given that children with SLI learn words slowly, that their lexicons are smaller at any point in development, and that they have difficulty accessing words in their lexicons, then it may also be incorrect to assume that the *structure* of their lexicons is the same as those of children with NL. Two additional factors may characterize the lexicons of children with SLI. First, even if they are matched on vocabulary size to younger children with NL, then it may be the case that their lexicons will contain different words. If their lexicons contain different words, then the neighbourhood densities and phonotactic probabilities for children with SLI will differ from those for children with NL. Second, even if the lexicons contain exactly the same words, then the specificity with which the underlying lexical and phonological units are stored is still likely to be different. Given that the NRT is sensitive to the size of the lexicon, the words in the lexicon, and the robustness with which the phonological units are represented, that makes it an even more powerful tool for characterizing the nature of the lexicons of children with SLI, and how they may differ from those of children with NL.

This discussion raises an interesting point about the phonological information being extracted. Besides the skills already implicated, researchers have acknowledged that successfully repeating a non-word requires robust representations of the underlying speech units. However, it is notoriously difficult to measure underlying phonological representations, so they have not been directly explored. Wells (1995) has cautioned that children’s underlying representations cannot be inferred from their repetitions of non-words. Nevertheless, researchers have suggested that children with SLI might not have robust representations of the underlying speech units. For example, Edwards and Lahey (1998) explain that what appears to be a deficit in phonological working memory might actually be a problem with the nature of the representation being stored. That is, memory for novel phonological strings will fail for those children for whom the acoustic forms of the underlying speech units are less robustly specified. Bishop (2000) and Evans (2002) have suggested that children with SLI might have fragile underlying linguistic representations. Given that children with SLI show pervasive linguistic deficits, perhaps they have not had the opportunity to develop robust, precise phonological representations. In this case, measuring children’s surface behaviour (repetition accuracy) is not as important as the underlying representations used to encode language. However, it may be impossible to separate processes that operate on underlying representations from the representations themselves. MacDonald and Christiansen (2002) have argued for exactly this point. They argue that working memory per se does not exist. Rather differences in what are traditionally called memory measures are simply the result of differences in language experience and architectural (biological) differences. According to this view, children with SLI experience difficulties repeating non-words because they have less linguistic experience and an unspecified biological difference that results in less precisely specified phonological representations. Along these lines, Leonard (1989) has suggested that children with SLI receive 'filtered' input, thereby distorting their linguistic experience. Similarly, as explained above, children with SLI show phonological processing difficulties, calling into question the precision of their underlying representations. According to MacDonald and Christiansen, these two factors explain group differences in phonological memory.

What is the relationship between vocabulary and non-word repetition for children with SLI?

For children with NL, non-word repetition accuracy and receptive vocabulary are significantly correlated, and the direction of causality appears to change over development. For younger children with NL, those skills that support non-word repetition also support vocabulary knowledge. For older children with NL, vocabulary knowledge supports non-word repetition. These studies were extended to include children with SLI because of their previously attested memory deficits (Gathercole and Baddeley 1990) and their previously attested lexical deficits (Gathercole *et al.* 1991c). These children with SLI were hypothesized to have reduced phonological memory capacity, causing both poorer performance on NRTs and reduced vocabulary size. While there is evidence of poorer non-word repetition ability and poorer performance on standardized vocabulary measures by children with SLI, there is no evidence that these two variables are related for this population of children. If these two factors are indeed related, the correlation between them should remain strong at extreme ends of the continuum. There are three potential explanations for the lack of a correlation.

The first potential explanation has to do with how groups were chosen for inclusion in the studies. Children with SLI were chosen to have normal non-verbal intelligence, but to fall at least one standard deviation below the mean on language measures. The control group, on the other hand, are chosen to cluster around the mean on all measures if non-verbal intelligence and language. If we then consider a scatterplot of receptive vocabulary scores and non-word repetition scores, we should see two distinct clusters. Children with NL will cluster around the centre of the graph, while children with SLI will cluster in the lower left quadrant. If we consider that these two groups are drawn from the same underlying population, we can compute the correlation statistic over the entire set of data. This would most certainly be a significant positive correlation. However, we must assume that SLI has its own underlying distribution. Therefore, correlations must be calculated for each cluster separately. Because the analysis is limited to values at the extreme end of the distribution, perhaps there is not enough variance in the reduced distribution to be able to find the predicted effect.

A second possibility is that the lack of a correlation may result from the standardized measures of receptive vocabulary being insufficient for capturing the relevant variance. There are three reasons this might be the case. First, the vocabulary measures used in these studies, the British Picture Vocabulary Scale (BPVS; Dunn and Dunn 1982) and the Peabody Picture Vocabulary Test — Revised (PPVT-R; Dunn and Dunn 1981), measure static vocabulary knowledge rather than the process of word learning, or even vocabulary size. The words contained in these standardized receptive vocabulary tests consist of a finite set of words known by some percentage of children at any given age. They are not measures of the number of words in a child's vocabulary or of the process by which new words are added to the lexicon.[1] Second, the vocabulary measures have been normed on large samples of children, and are quite useful in capturing normal variation in the population of children with NL. However, as stated above, we must assume that the population of children with SLI represents a separate distribution. Because there are not separate norming statistics for this population, it could be that these measures fail to capture the normal variation of the SLI population. The normal variation in this population might be masked, thereby masking a valid correlation between these two factors. Third, the correlation between repetition accuracy and receptive vocabulary might rely on intact speech perception and motor planning abilities, which are probably impaired in these children with SLI. Indeed, Bishop and colleagues (Bishop *et al.* 1999, Briscoe *et al.* 2001) have argued that SLI likely results from a constellation of factors rather than a single underlying factor (also James *et al.* 1994). They suggest that language acquisition is such a robust process that it may be impervious to a single deficit. It may require a double hit to impede its progress. That is, perhaps a deficit in phonological memory only leads to SLI in those children who already have a genetic predisposition to language impairment. Because these children have deficits at all levels — pre-lexical, lexical, and post-lexical, perhaps other factors that support non-word repetition in the population of children with NL fail to do so in the population of children with SLI.

The third possibility that must be considered is that repetition accuracy and standardized assessment measures of receptive vocabulary (i.e. the BPVS or PPVT) are simply not related in this population. This presents a problem because the NRT so closely matches the phonological component of the task children face when learning new vocabulary items. Children must take in a novel phonological string and hold it in memory long enough to both create a robust representation of the sound pattern and link it to a real-world referent. Thus, the task has a great deal of face validity. However, the task of word learning diverges from the task of non-word repetition once we consider the number of times novel phonological strings are presented for both tasks. In the NRT, children have but one opportunity to hear each non-word. If their attention wavers or they misperceive part of the non-word, repetition accuracy will be affected. When they are learning a new word, children likely have many chances to hear the novel phonological string. With enough presentations of each novel word, children with SLI can develop age-appropriate vocabularies (Gray *et al.* 1999). Even

[1]After this manuscript was accepted for publication, Alt and Plante(2006) reported a statistically significant first-order correlation between nonword repetition and word learning for a group of children both with and without SLI. Potentially confounding effects due to age or nonverbal intelligence were not partialled out of the analysis. Further, results were collapsed across groups, which likely exaggerated the strength of the correlation. Even so, this is the first evidence that there is a relationship between vocabulary and nonword repetition for children with SLI.

so, their overall language skills, including non-word repetition, will still lag behind those of their peers.

General discussion

The use of NRTs has revealed a great deal about the process of lexical development, and language development more generally, but also raises a number of interesting questions. From studies of children with NL, we know that repetition accuracy and *receptive* vocabulary are significantly correlated, although evidence suggests that non-word repetition and *expressive* vocabulary are unrelated. Further, non-word repetition is supported by both memory and lexical mechanisms. Accuracy is correlated with other measures of phonological memory, such as digit span. In addition, accuracy depends on how much non-words overlap with known words. From studies of children with SLI, we know that a number of processing and cognitive skills support repetition accuracy, including speech perception, phonological encoding, phonological memory, phonological assembly, and articulation. There is evidence that children with SLI have deficits in each of these underlying skills. Any attempts to ascribe accuracy differences to one or two underlying skills to the exclusion of other supporting skills are doomed to fail. Nevertheless, the NRT remains a valuable research tool for both children with NL and children with SLI.

First, the NRT can be used to explore the structural organization of the developing lexicon. As stated above, children's accuracy is better for non-words with singleton consonants (Gathercole and Baddeley 1990, Gathercole *et al.* 1991a), higher word-likeness ratings (Gathercole 1995, Gathercole *et al.* 1991b), embedded real words (Dollaghan *et al.* 1993, 1995), attested consonant sequences (Beckman and Edwards 2000, Munson 2001), and higher frequency phonotactic patterns (Coady and Aslin 2004, Zamuner *et al.* 2004). Furthermore, all of these variables are related (Bailey and Hahn 2001, Frisch *et al.* 2000). In order to examine the structural organization of the developing lexicon, non-words can be created that exploit different sources of phonotactic frequency information that are known to change over development. For example, if children's lexical representations change from holistic to more segmental, then over development, children should show decreasing sensitivity to larger phonetic units, such as syllables or biphones, with increasing sensitivity to smaller phonetic units, such as phonemes. Instead, Coady and Aslin (2004) found evidence of increasing sensitivity to phonemes without the decreasing sensitivity to larger phonetic units, suggesting that children's lexical representations contain considerable phonetic detail, at least after the naming spurt.

When using the NRT to examine the structural properties of the lexicon, researchers must take into account that the acoustic nature of children's lexical representations is changing over development (e.g. Metsala 1999, Walley 1993). That is, we should consider the child's state of linguistic development at the time of testing. As stated above, it is quite common for children beginning the process of lexical acquisition to make speech perception and speech production errors. When children are presented with novel objects with novel labels differing in a minimal phonetic contrast, they often fail to discriminate these newly taught words (e.g. Eilers and Oller 1976). However, young children can easily discriminate two words that they use productively, e.g. *bear–pear* (Barton 1976, 1978). Similarly, when children are beginning the process of syntactic development, they often omit function morphemes, which signal grammatical relationships within sentences (Bloom 1970, Brown and Bellugi 1964). Even though they omit them, however, there is evidence that function morphemes are represented in children's speech (Carter and Gerken 2004, Gerken *et al.* 1990). Stated another way, when children are undergoing lexical and morphosyntactic development, their productions of words and function morphemes, respectively, are variable. The same can be argued of phonological development. As the phoneme emerges as a perceptual unit over early and later childhood, we would expect production of phonemes to be characterized by a great deal of variability (also Sosa and Stoel-Gammon 2006). As children gain facility with the phonemes of their native language, it should become easier to use them to create transient phonological representations to support non-word repetition. This, of course, will be a graded phenomenon, as it should be easier to manipulate more frequent sounds and sound combinations, thereby resulting in the lexical and sublexical effects in NRTs. However, these phonological effects will be difficult to separate from already attested lexical effects. Phonological development occurs in the context of lexical development (Ferguson and Farwell 1975). That is, children do not learn individual sounds, but rather learn words that contain the various sounds.

Second, because the NRT taps so many underlying skills that are problematic for children with SLI, it does make a good diagnostic tool. Many researchers have considered that the NRT provides a quick, reliable marker to differentiate children with language difficulties from children without such problems (Bishop *et al.* 1996, Conti-Ramsden *et al.* 2001, Dollaghan and Campbell 1998, Ellis Weismer *et al.* 2000, Taylor *et al.* 1989). Dollaghan and Campbell (1998) pointed out that their version of the NRT can be administered in less than two minutes, and provides a content-free measure of linguistic knowledge, if non-words are constructed to have minimal overlap with lexical items. Further, because it is a content-free measure, cultural and racial biases are minimized (Ellis Weismer *et al.* 2000). Consequently, its validity as a behavioural marker is currently being explored (e.g. Bishop *et al.* 1996, Conti-Ramsden *et al.* 2001). While using the NRT as an identifying tool says nothing about the nature of underlying deficits, it does provide a way to group children so that these deficits can be explored.

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What this paper adds

The non-word repetition task (NRT) has become accepted as a measure of phonological working memory capacity, even though accurate repetition of non-words taps a variety of underlying processes, including speech perception, lexical and phonological knowledge, motor planning, and articulation. Two facts about the NRT make it a useful measure: (1) there is a strong relationship between non-word repetition accuracy and standardized vocabulary measures, at least for children acquiring language typically, and (2) children with many different language disorders, including specific language impairments (SLI), consistently repeat non-words less accurately than their age-matched peers. These facts make the NRT a powerful tool for describing language performance in both typical and impaired populations. First, because the accuracy with which non-words are repeated depends on the degree to which they reflect the properties of the lexicon, the NRT provides a window into the structural organization of the phonological lexicon. Second, because the NRT depends on language knowledge, a separate phonological memory capacity becomes an extraneous construct. Finally, because the NRT taps so many underlying skills that present difficulty for children with SLI, it can be used as a tool to identify children with or at risk for language impairments.

Table 1

Studies using non-word repetition tasks (NRTs) in children developing language typically

Study	Purpose	Participants	Primary results
Gathercole and Baddeley (1989)	Correlate phonological memory (non-word repetition and digit span) with receptive vocabulary	104 children with NL, tested as they were entering school (age 4—5) and again a year later	(1) Accuracy increased with age. (2) Accuracy decreased as non-word length and complexity increased. (3) Accuracy at age 4 predicted vocabulary at age 5
Gathercole *et al.* (1991a)	Correlate phonological working memory and sensitivity with receptive vocabulary	57 children with NL, age 4, and 51 children with NL, age 5	Phonological memory predicted vocabulary, but phonological sensitivity did not
Gathercole *et al.* (1991b)	Correlate phonological memory and sensitivity with receptive vocabulary, and consider lexical influences on repetition accuracy	103 children with NL, tested as they entered school (age 4—5), then one year later, and again 2 years later	(1) No accuracy differences due to complexity. (2) Higher accuracy for more word-like non-words
Gathercole *et al.* (1992)	Longitudinal study examining the reciprocal influences of vocabulary and repetition accuracy by comparing cross-lagged partial correlations	80 children with NL, tested over a 4-year period (ages 4, 5, 6, and 8)	Repetition accuracy at age 4 predicted receptive vocabulary at age 5, but vocabulary at ages 5 and 6 predicted repetition at ages 6 and 8, respectively
Gathercole and Adams (1993)	Use NRT to measure phonological memory in very young children, for whom memory measures are typically unreliable	54 children with NL, aged 2;10 to 3;1	Repetition accuracy correlated significantly with receptive vocabulary, but digit span did not
Dollaghan *et al.* (1993)	Examine lexical effects on repetition accuracy by having children repeat non-words varying in the lexical status of stressed syllables	11 boys with NL, aged 9;10 to 12;0	Non-words containing real words were repeated more accurately than those non-lexical stressed syllables
Michas and Henry (1994)	Examine the relationship between phonological memory and vocabulary, and how phonological; memory affects the acquisition of new words	48 children with NL, aged 5;2 to 6;2	Non-word repetition ability predicted the ability to learn new words, providing direct evidence for the phonological memory-word learning link
Gathercole and Adams (1994)	Examine the relationship between phonological working memory and vocabulary, and betweern phonological working memory and other cognitive skills	70 children with NL, tested first at age 4;1 (3;11–4;4), and again at age 5;3 (4;10–5;7)	Non-word repetition accounted for variance in receptive vocabulary, but not in children's knowledge of number
Gathercole (1995)	Compare phonological working memory and lexical knowledge influences on non-word repetition accuracy	70 children with NL, tested first at age 4;1, and again at age 5;3	Long-term lexical knowledge supports repetition of more word-like non-words, while phonological memory supports repetition of less word-like non-words
Adams and Gathercole (1995)	Examine the relationship between phonological memory and spoken language development	38 children with NL, aged 2;10 to 3;1, separated into high- and low-phonological memory groups	Children in the high-phonological memory group (better non-word repetition ability) produced longer, more grammatically complex sentences
Dollaghan *et al.* (1995)	Replicate their 1993 study with a larger group of children	30 boys with NL, aged 9;10 to 12;5	Lexical knowledge influences non-word repetition accuracy, replicating their previous study
Adams and Gathercole (1996)	Replicate their 1995 study using a more constrained narrative (*The Bus Story*; Renfrew 1966)	89 children with NL, aged 4;10 to 5;8	Non-word repetition ability predicted narrative recall and grammatical complexity
Bowey (1996)	Examine the role of phonological memory and phonological sensitivity in receptive vocabulary	205 children with NL, mean age 5;5	Phonological memory and sensitivity measures accounted for variance in vocabulary. Factor analyses extracted a single factor — a latent phonological processing factor

Study	Purpose	Participants	Primary results
Gathercole *et al.* (1997)	Examine the role of phonological memory in a word-learning task	65 children with NL, aged 5;1 to 6;3	Learning new words was predicted by repetition accuracy, but learning to associate two familiar words was not
Gathercole *et al.* (1999)	(1) Examine if the link between vocabulary and non-word repetition arises from articulation or from encoding and memory. (2) Examine the relationship between phonological memory and vocabulary in older adolescents	(1) 18 children with NL, aged 4;0 to 4;3. (2) 65 children with NL, aged 5;1 to 6;3 and 60 adolescents with NL, aged 13;4 to 14;5	(1) Non-word repetition taps phonological encod ing and/or memory skills rather than output variables. (2) The link between phonological memory and vocabulary continues into adolescence
Metsala (1999)	Examine changes in non-word repetition accuracy resulting from developmental changes in phonological representations	In Experiment 1, 32 children with NL, aged 3;11–4;11, and 29 children with NL, aged 5;0 to 6;4. In Ex. 3, a third group of 36 children with NL, aged 3;0 to 4;8	Memory and phonological awareness correlated with repetition accuracy, but only phonological awareness correlated with vocabulary. Repetition did not account for variance in vocabulary over that accounted for by phonological awareness
Adams and Gathercole (2000)	Examine the role of phonological working memory on grammatical complexity	Two groups of 15 children with NL, aged 4;6 to 5;0, matched on non-verbal IQ, but differing in non-word repetition ability	Children in the high-repetition group produced longer, more grammatically complex sentences using a wider variety of lexical items
Beckman and Edwards (2000)	Examine lexical effects on non-word repetition accuracy by comparing non-words containing attested sequences to those containing unattested sequences	16 children with NL, aged 3;2 to 5;0. Replicated with 24 children with NL, aged 3;2 to 5;4	Children more accurately produced attested CV and CC sequences, relative to unattested sequences. There was no difference between attested and unattested VC sequences
Simkin and Conti-Ramsden (2001)	Provide norms for the CNRep and two morphological-marking tasks	100 children with NL in their final year of primary school, aged 10;5–11;6	Children's median score was 38 of 40 non-words repeated accurately, indicating that 10.5-year-old children are at ceiling in non-word repetition accuracy
Munson (2001)	Compare accuracy and fluency of non-words differing in phonological pattern frequency	Nine children with NL, aged 3;5 to 4;6, and nine older children with NL, aged 7;4 to 8;11	Attested sequences in non-words were repeated more accurately and with shorter durations than unattested sequences
Bowey (2001)	Longitudinal study examining the link between non-word repetition and subsequent vocabulary	71 children with NL tested longitudinally, first at age 5;11 and again at 9;7	Repetition accuracy and vocabulary predicted each other at subsequent time frames. Replicates previous finding of a latent phonological processing ability that supports phonological memory and sensitivity
Edwards *et al.* (2004)	Examine how vocabulary size and phonotactic frequency affect repetition accuracy	22 adults and 104 children with NL, divided into three age groups: (1) 43 children, mean age 4;2; (2) 38 children, mean age 5;6; and (3) 23 children, mean age 8;1	All children repeated non-words with higher frequency phonological patterns more accurately than those with lower frequency, but this effect decreased with age, possibly mediated by increasing vocabulary size
Zamuner *et al.* (2004)	Examine whether phonotactic frequency influences repetition accuracy in a group of very young children	29 children with NL, aged 1;8 to 2;4, mean age 2;0	Children repeated coda consonants in CVC non-words more accurately when they occurred in high phonotactic frequency non-words rela tive to the same consonants in low phonotactic frequency non-words
Coady and Aslin (2004)	Examine lexical influences on repetition accuracy by manipulating frequency of smaller and larger phonological units	Three groups of 24 children with NL. Each group contained a younger cohort, aged 2;4 to 2;8, and an older cohort, aged 3;4 to 3;8	By the age of 2;6, children are sensitive to the frequency of individual segments, and sensitivity to all aspects of sound structure increase over development

Table 2

Studies using non-word repetition tasks (NRTs) in children with specific language impairments (SLI). All children are learning English as a native language unless otherwise noted

Study	Purpose	Participants	Primary results
Kamhi and Catts (1986)	Examine how children with LI and children with process phonological information	Three groups of 12 children, aged 6;2–9;2 (LI, RI, and NL)	LI<RI<NL. Accuracy correlated with sentence repetition and morphological awareness, but not with phonological awareness
Kamhi *et al.* (1988)	Examine how children with LI and children with process phonological information and spatial information	Three groups of ten children, aged 6;8–8;10 (LI, RI, and NL)	LI<RI<NL. Children with LI repeated multi syllabic non-words less accurately, but per formed comparably with children with RI on spatial tasks
Taylor *et al.* (1989)	Examine phonological processing in children with learning disabilities	24 children with learning disabilities(LD) aged 7–12 (probably some with LI) and 20 children with NL	NRT has good sensitivity and specificity in identifying children with LD. Children with LD repeated less accurately than children with NL, even after IQ was partialled out
Gathercole and Baddeley (1990)	Examine phonological memory capacity in children with LI	Six children with LI, aged 7;2–8;10, six language-matched controls, and six IQ-matched controls. One child with LI did not participate in the NRT	Children with LI were less accurate than both LA-and IQ-matched controls, with larger group differences for longer non-words. Follow-up tasks showed no group differences in speech perception, rate of articulation, or phonological encoding
James *et al.* (1994)	Examine phonological working memory and phonological processing in children with SLI with 'central auditory processing difficulties (CAPD)'	Six children with CAPD, aged 8;6–10;8, six CA-matched children, and six LA-matched children	Children with CAPD were less accurate than CA-matched and LA-matched controls. There were no group differences in phonological encoding or rate of articulation, but children with CAPD showed deficits in phoneme discrimination
Montgomery (1995a)	Examine the influence of phonological memory on sentence comprehension in children with SLI	14 children with SLI, mean age 8;2, and 13 children with NL matched on language abilities, mean age 6;9	Children with SLI repeated less accurately, even after receptive vocabulary was partialled out. They also had trouble comprehending sentences containing extraneous words
Montgomery (1995b)	Examine phonological memory and related language abilities in children with SLI	13 well-defined children with SLI, mean age 8;5, and 13 LA-matched children, mean age 6;9	Children with SLI were less accurate when repeating longer non-words, in spite of no group differences in articulation and phonological encoding. Children with SLI were less able to discriminate longer non-words, probably because of poorer memory abilities
Bishop *et al.* (1996)	Use the NRT to examine the heritability of language impairments	39 children with LI, 13 children with resolved LI, and 79 controls, all aged 7—9	Children with SLI (including resolved LI) repeated less accurately than controls. The NRT may be a behavioural marker of language impairment
Stark and Blackwell (1997)	Use an NRT to examine speech production, in terms of volitional oral movements (VOM)	15 children with LI and articulation impairments (LI-A), mean age 7;1, 16 children with just LI (LI-0), mean age 7;10, and 19 age-matched control children with NL	For the NRT and VOM tasks, NL>LI-0>LI-A Further, for all children with LI, repetition accuracy significantly correlated with both isolated and repeated VOMs, suggesting potential deficits in oral movements
Stothard *et al.* (1998)	Follow-up adolescents who had been diagnosed at age 4 with LI	30 children with persistent SLI, 26 with resolved SLI, and 15 with general delay; mean age for all groups was 15;7	Children with resolved SLI had age-appropriate vocabulary and language comprehension skills, but still experienced problems with phonological processing. Children with persistent SLI had difficulties in all

Study	Purpose	Participants	Primary results
			areas of language, and continued to fall behind their peers
Edwards and Lahey (1998)	Explore why children with SLI are less accurate when repeating non-words	54 children with SLI, aged 4;6–9;8, CA-matched controls, and LA-matched controls	Children with SLI were less accurate. Error analyses revealed potential problems in encoding, representation, or memory
Dollaghan and Campbell (1998)	Develop an NRT with minimal lexical influences to be used as a quick measure of phonological memory to identify children with SLI	20 children with SLI, aged 6;0–9;9, and 20 CA-matched children	NRT provided good sensitivity and specificity and can be administered in less than 2 minutes
Sahlén *et al.* (1999a)	Examine prosodic influences on word and non-word repetition accuracy	27 children with SLI learning Swedish, aged 4;11–5;11	Swedish children with SLI repeated words more accurately dian non-words, and were more likely to omit or reduce unstressed syllables in pre-stressed versus post-stressed position
Sahlén *et al.* (1999b)	Examine the relationship between non-word repetition and receptive measures of vocabulary, syntax, and narrative	Same 27 children with SLI learning Swedish, aged 4;11—5;11, who participated in their previous study (Sahlén *et al.* 1999a)	Partial correlations revealed significant relationship between non-word repetition accuracy and receptive syntax, but not receptive vocabulary or narrative
Ellis Weismer *et al.* (2000)	Use likelihood ratio analyses to examine how the NRT might be used to assist in ruling in or ruling out language disorders	581 second-grade children, aged 7;1—8;11, separated into four groups differing in language and cognitive abilities: [1] high language, high cognition; [2] high language, low cognition; [3] low language, high cognition (SLI); and [4] low language, low cognition (non-Specific language impairment, or NLI)	Children with SLI were less accurate, even for shorter non-words. The NRT provides good sensitivity and specificity, and does not over-identify children from non-standard linguistic backgrounds
Briscoe *et al.* (2001)	Examined language outcomes in children with known phonological difficulties: children with SLI and children with mild-to-moderate sensori-neural hearing loss(SNH)	19 children with SNH, mean age 8;7, 20 children with SLI: younger group, mean age 9;0, older group, mean age 12;1, 20 CA-matched children and 15 LA-matched children	Children with SNH and children with SLI show similar levels of accuracy on NRTs, but only children with SLI show deficits at higher linguistic levels
Rodekohr and Haynes (2001)	Compare different processing tasks, including the NRT, in terms of potential cultural or dialectal biases	40 children, aged 7;0–7;3, either white or African-American, and with either NL or LI	Children with LI repeated non-words less accu rately than children with NL, regardless of race
Conti-Ramsden *et al.* (2001)	Examine different processing tasks, including morphological-marking tasks and sentence and non-word repetition tasks, in order to compare their validity as psycholinguistic markers for LI	160 children with SLI, mean age 10;9, and 100 children with NL, mean age 10;9	NRT provided very good sensitivity and specificity, However, the sentence repetition task provided even better sensitivity and specificity
Botting and Conti-Ramsden (2001)	Compared the language abilities of children with good non-word repetition ability to children with poor non-word repetition ability	Two groups of 14 children with SLI, mean age 10;11, matched on non-verbal IQ	Children with SLI with better repetition abilities scored higher than those with lower repetition abilities on all language measures, except for vocabulary measures
Gray (2003)	Examine the validity and reliability of the NRT in identifying preschool children with SLI	22 children with SLI, aged 4;0–5;11, and 22 CA-matched children with NL	NRT provided good sensitivity and specificity, and good test-retest reliability for children with SLI, but not as good for children with NL
Conti-Ramsden and Hesketh (2003)	Use the NRT to identify preschool children at risk for SLI	32 children with SLI, aged 4;4–5;10, and 32 LA-matched children with NL, aged 2;4–3;7	Children already identified at risk for SLI scored lower than children with NL on the NRT
Conti-Ramsden (2003)	Use the NRT to identify preschool children at risk for SLI	32 children with SLI, aged 4;4–5;10, and 32 CA-matched children with NL	NRT (and a past-tense-marking task) provided good sensitivity and specificity in identifying children with SLI

Study	Purpose	Participants	Primary results
Marton and Schwartz (2003)	Examine the interaction between working memory and language comprehension in children with SLI	13 children with SLI, aged 7;0–10;0, and 13 CA-matched children with NL	Children with SLI repeated non-words less accurately than children with NL which they took as evidence for a deficit in phonological memory rather than phonological sensitivity
Horohov and Oetting (2004)	Compare different types of presentation methods in word learning by children with SLI	18 children with SLI, aged 5–7, 18 CA-matched children with NL, and 18 LA-matched children	NRT differentiated groups, but did not account for unique variance in word learning
Montgomery (2004)	Examine the effects of working memory and input rate on sentence comprehension by children with SLI	12 children with SLI, mean age 8;9, 12 CA-matched children with NL, and 12 LA-matched children with NL, mean age 6;10	Children with SLI showed deficits in both non-word repetition and sentence comprehension However, input rate did not correlate with working memory, as tested by the NRT
Hansson *et al.* (2004)	Explore the roles of phonological working memory and complex working memory in a word-learning task	Three groups of Swedish-speaking children: (1) 27 children with SLI, aged 8;6–11;4; (2) 18 children with SNH, aged 9;1–13;3; and (3) 38 children with NL, aged 9;5–12;4	Children with SLI and SNH did not differ in non-word repetition accuracy. For both groups, complex working memory accounted for variance in novel word learning, while phonological short-term memory, as measured by an NRT, did not
Gray (2004)	Examine the role of phonological memory and semantic knowledge in word learning	20 preschoolers with SLI, aged, 4;0—5;11, and 20 age-matched children with NL	NRT predicted variance in the number of trials required to learn words
Munson *et al.* (2005)	(1) Examine the role of vocabulary size in non-word repetition accuracy. (2) The relative contributions of phonotactic probability and subjective word-likeness ratings to repetition accuracy	16 children with SLI, mean age 11 ;3, 16 CA-matched children with NL, and 16 LA-matched children with NL, mean age 7;6	Children with SLI were less accurate than CA matches, but not LA matches, indicating vocabulary size mediates accuracy. Also, children with SLI show a larger phonotactic frequency effect than children with NL
Stokes *et al.* (2006)	Examine an NRT and sentence repetition task as a potential clinical marker for SLI in children learning Cantonese, a phonologically less complex language	14 children with SLI learning Cantonese, aged 4;2—5;7, 15 age-matched children with NL, and 15 younger language-matched children with NL, aged 2;11—3;6	Cantonese children with SLI did not significantly differ from age-matched controls in the NRT, possibly because reintegration processes are more successful in the phonologically simpler language
Montgomery and Windsor (2006)	Examine the interrelations between speed of processing, working memory, non-verbal IQ, and broad-based language measures in children with SLI	48 children with SLI, aged 6;8–11;0, and 48 CA-matched children with NL	Phonological working memory (NRT) correlated with broader measures of language knowledge and experience (as opposed to real-time language processing)
Coady *et al.* (2006)	Examine the role of phonotactic frequency in an NRT by children with SLI to see how well they are able to extract phonological regularities from their language input	18 children with SLI, mean age 9;2, and 18 CA-matched children with NL	Children with SLI were less accurate overall, but showed the same phonotactic frequency sensitivity as children with NL