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The link between infant speech perception and phonological short-term memory

Bywater, Tracey-Jane

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The Link Between Infant Speech Perception and Phonological Short-Term Memory

By

Tracey-Jane Bywater

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Summary

At the end of the first year infants begin to focus on their familiar-sounding native language, and begin to build a receptive and productive vocabulary. Phonological short-term memory has been proposed as an indicator of an individual's later vocabulary (Gathercole and Baddeley, 1989). This research is an attempt to bring together these different strands of language development by investigating the relationship between word form recognition, word production, comprehension and phonological short-term memory in a longitudinal study.

Word form recognition was determined by the amount of time infants spent looking towards auditorily presented familiar words using the head-turn preference procedure at 10 months. Previous research demonstrated that 11-month-olds look longer towards familiar words versus unfamiliar words (Depaolis, Vihman & Bywater, 1998). This research begins by replicating these findings (Experiment 1a) and extending them by testing 10-month-olds (Experiment 1b). This age group was found to recognise familiar word patterns. Word production was measured in two ways; by observing and videotaping infants in free play interacting with a caregiver for 30 minutes at 14 and 18 months of age (Experiment 2), and by parental report (the Oxford Communicative Development Inventory was used) at 10, 14, 18 and 24 months (Experiment 3). Speech comprehension was also assessed at these ages with the parental report (Experiment 3). Phonological short-tem memory was measured at 24 months of age using a non-word repetition task (Experiment 4).

An interesting developmental overview of language development emerged, suggesting that sensitivity to phonological patterns is an important implicit skill, leading to the formation of stable word representations, and early accurate word productions. The ease at which infants repeat non-words appears to reflect an infant's sensitivity to word forms and early word production. That is, if an infant was sensitive to phonological patterns and recognised familiar words at 10 months, they were found to be effective, and early, word producers with high non-word repetition scores at 24 months. From these findings it is feasible to propose that sensitivity to phonological patterns could predict later language development.

Acknowledgements

The writing of this thesis has taken me, over the last four years, on a roller-coaster ride of emotions, not all of them pleasant. However, with much friendly support I have managed to overcome the usual difficulties of writer's block, lack of motivation and desperation. Support has come from a variety of people and it is here that I would like to thank those individuals.

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Thank you all.

Dedications

I dedicate this thesis to my patient children, Charlotte and Oliver.

I love you both, let's party!

Table of Contents

Chapter 1

Steps Towards Language Acquisition

If you can look into the seeds of time,

And say which grain will grow and which will not...

William Shakespeare, *Macbeth*

In childhood or infancy is it possible to identify those children who will become superior language learners? Language learning can be affected by many influences, both external and internal. The internal influences, such as individual differences in certain linguistic skills, are of interest here. Gathercole and Baddeley (1989a) found that nonword repetition tasks at five years of age could measure phonological short-term memory span, and that this, in turn, could predict later vocabulary growth. However, it is possible that another factor or linguistic skill is (partly) responsible for vocabulary growth. Sensitivity to word forms or sound patterns could have a great impact on language learning and may even be the basic, unconscious skill that underlies phonological short-term memory. It is possible that if an individual is an effective learner of co-occurring sound sequences, these stable lexical representations could facilitate early receptive vocabulary and word productions, culminating in an effective repeater of nonwords. If this is the case then a child's later vocabulary could be predicted at an earlier age.

The goal of this thesis is to bring together the different strands of language learning, that is, speech perception in the context of word form recognition, receptive and productive vocabulary, and phonological short-term memory within one longitudinal study. The main aim is to examine the relationship between word form recognition and the role of phonological short-term memory, as this has not yet been examined. The secondary aim is to examine the relationships between word form recognition, comprehension, production and phonological short-term memory to provide a developmental overview of language development between 10 and 24 months of age.

This thesis is divided into three main sections. The first, Chapters 1 to 3, presents research on the development of infants' speech perception abilities from a prosodic and segmental perspective, progressing to word form recognition. This section continues by examining the areas of speech comprehension and production and the tools used to measure these abilities. Phonological short-term memory and the working memory model will be presented in more detail and the importance of phonological short-term memory in vocabulary acquisition will be discussed. This section will end with an overview of the present study.

The second section includes Chapters 4 to 7. These chapters report the experimental studies of individual differences in word form recognition, receptive and productive vocabulary and phonological short-term memory.

Chapter 4 focuses on the first variable, word form recognition. This chapter describes the research paradigm used here to test an infant's sensitivity to word forms, namely, a modified version of the head-turn preference procedure devised by Hallé and Boysson-Bardies (1994). Hallé and Boysson-Bardies found that French 11-month-olds listened longer to familiar words than to unfamiliar words. Familiar words are words used frequently within the home. This thesis begins by replicating this study with English 11-month-old infants, and then proceeds to test 10-month-olds to establish at what age familiar word forms are recognised.

Chapter 5 focuses on the second variable, the speech production abilities of infants as measured with observational studies. As a basis for measurement of production infants at 14 and 18 months of age will be videotaped in free play with a parent.

Chapter 6 examines the relationship between speech production and comprehension at 10, 14, 18, and 24 months of age as measured by the Oxford Communicative Development Inventory (CDI, adapted for British English by Hamilton, Plunkett and Schafer, 2000). This chapter will also compare the two productive measures, both observational and parental reports, to assess their reliability and validity.

Chapter 7 examines phonological short-term memory using nonword repetition at 24 months of age, and Chapter 8 presents the general results, examining the relationships between all the above variables, that is, word form recognition, receptive and productive vocabulary and phonological short-term memory. The third and final section, chapter 9, discusses the findings as regards the relationships between the four strands of language learning and presents a developmental picture of the linguistic processes used when acquiring a native language.

Speech Perception Leading to Word Form Recognition

In speech perception research it has been a priority to discover which aspects of the sound pattern are essential to identify a given unit of speech. The critical stimulus patterns in a perceived event are called cues. Speech cues are the acoustic patterns of speech that facilitate identification of a given sentence, phrase, word, syllable or phoneme (Pickett, 1999).

At birth infants possess acute auditory discrimination for the acoustic cue differences used to differentiate phonemes of all languages. However, during the first few months of hearing the native language infants begin to lose the ability to discriminate between, or begin to lose the ability to pay attention to, non-native contrasts and concentrate more on the native language, in readiness for word comprehension and production (Werker & Pegg, 1992).

Before being able to communicate via language infants must recognise and discriminate between meaningful and less important sounds. Exposure to a particular language environment affects speech perception capacities in the first year of life (Jusczyk, Houston, & Goodman, 1998). This section chronologically reviews what is known about segmental and perceptual prosodic abilities in pre-natal and very young infants, culminating in the recognition of word forms. Infants have been found to pay attention initially to prosody, and then to vowels and then to consonants (Vihman, 1996), the following subsections will reflect this order where possible.

The Prenatal Period

When the foetal auditory system becomes functional (after 22-24 weeks), the maternal voice and external speech located near the mother are clearly audible over background uterine noises (Querleu, Renard, Versyp, Paris-Delrue, and Crépin, 1988). Querleu et al. (1988) found that both the mother's and others' speech was muffled and attenuated in the high-frequency components, but had well-preserved prosodic characteristics. Infants are already acquiring knowledge for storage in their long-term memory to aid recognition of future heard sound patterns. Indeed towards the final weeks of gestation foetuses have been shown to demonstrate responsiveness to habituation, conditioning and mere exposure to sound and speech stimuli (for example, Hepper, Scott, & Shahidullah, 1993; DeCasper, Lecanuet, Busnel, Granier-Deferre, & Maugeais, 1994).

Newborn Infants

At birth infants prefer both the prosody of their native language to another language (Mehler, Juscyzk, Lamberz, Halsted, Bertoncini, & Amiel-Tison, 1988) and their mother's voice versus that of another female (DeCasper & Fifer, 1980). It has been suggested that these preferences may derive from prenatal familiarisation (Moon, Panneton-Cooper, & Fifer, 1993). Infants appear to prefer what is familiar to them. Infants especially favour the more prosodically enhanced infant-directed speech (motherese), which is higher in pitch and has wider pitch excursions, shorter utterances, longer pauses, and more repetition than adult-directed speech (Cooper & Aslin, 1990; Fernald, 1985).

Newborns can respond to habituation techniques. Newborns are highly sensitive to the acoustic cues that signify different basic elements of speech such as between the consonants in syllables /ba/ versus /da/ or /ba/ versus /pa/ (Eimas, Siqueland, Jusczyk, & Vogorito, 1971). The habituation paradigm is used to measure infants' attention through high amplitude sucking rate (HAS). The HAS technique is appropriate for small babies with limited movement. The paradigm assumes that the infant's level of attention remains high to events that are perceived as new or novel. Infants are exposed to a certain sound repeatedly until they are no longer stimulated by it; they recognise it after some time to be previously encoded and lose interest in it. A new sound is then presented. For the HAS technique a sucking base rate must first be obtained; this is the rate the baby will return to when habituated to the stimulus. If an increase in responsive sucking rate is noticeable, it is considered that the infant recognises the new sound as different to the one previously heard.

For older babies a different technique must be used as they have a growing behavioural repertoire. The technique most often used to test perception is the head turn procedure. The fact that an infant will turn towards stimuli that they find interesting is utilised in this technique. An infant will turn towards auditorily or visually presented stimuli. Studies of perception, or sensitivity to sound pattern, show that an infant does not need to be able to produce the sound distinctions in order to discriminate between the sounds.

Two Months of Age

Nazzi, Bertoncini, and Mehler (1998) showed that French newborns could discriminate filtered sentences in English and Japanese. And Christophe and Morton (1998) showed that English 2-month-olds could discriminate between English and Japanese, but not Japanese and French. A possible interpretation is that while newborns may attempt to analyse every segment of sound, 2-month-olds have enough knowledge of their native language to be able to filter out utterances in a foreign prosody as irrelevant (Mehler & Christophe, 2000).

Infants between 2 and 4 months can perceive vowel identity across many contexts. For example, the vowel /i/ will be recognised as the same sound by infants whether produced by a child, female or male speaker and the infants will be able to distinguish it from the vowel /a/ (Kuhl, 1979). This perception of stable vowels involves what Kuhl (1991) labelled as the 'magnet effect'. It has been suggested that as early as 2 months of age infants begin reorganising their perceptual responses as a result of exposure to speech. Jusczyk, Kemler Nelson, Hirsh-Pasek, Kennedy, Woodward, and Piwoz (1992) demonstrated that 2-month-olds could discriminate between [fa] and [θ] in addition to prosody.

Four Months of Age

By 4 months infants prefer uninterrupted clauses (Jusczyk et al., 1992), as reflected in the English language, and also at this age infants begin to explore vocal sounds by spontaneously producing, and imitating, vowels (Kuhl & Meltzoff, 1988). At 4 months infants can match the sounds of a vowel to the correct visual mouth movements for that vowel (Kuhl & Meltzoff, 1988).

From a segmental point of view Trehub (1976) demonstrated that 1- to 4-month-old infants (exposed only to English) could successfully discriminate between certain sounds in French, such as [pa] versus [pã] even though such contrasts do not occur in the English language.

Six Months of Age

In a series of studies Jusczyk and colleagues demonstrated that by 6 months of age infants listen longer to words that correspond to the rhythm and intonation patterns of the native language. At approximately 6 to 7 months of age infants begin to produce canonical babbling (Oller, 1980), that is, production of consonant vowel (CV) syllables, suggesting an awareness of segmental changes. Werker, Gilbert, Humphrey and Tees (1981) found that 6- to 8-month-olds were more capable of discriminating non-native consonantal contrasts than adults.

Eight Months of Age

Recently research has focused on infants' capacities for segmenting fluent speech into word-sized units (Echols, Crowhurst, & Childers, 1997; Aslin, Jusczyk, & Pisoni, 1997). Jusczyk and colleagues studied infants' perception of strings of isolated nonsense syllables to establish which units of a syllable, if any, are more salient to the infant. At 8 months of age infants have the ability to perceive and recognise familiar, repeated sound sequences embedded within continuous, monotone, synthesised speech (Saffran, Aslin, & Newport, 1996) and also within natural speech (Johnson & Jusczyk, 2001). Additionally, Johnson and Jusczyk (2001) found that when the stimuli contained stress and speech cues produced by coarticulation, pitted against statistical cues as diagnostic tools to identify repeated, familiar segments of sound, stress and coarticulation were more influential than statistical cues.

Nine Months of Age

At 9 months infants show a preference for listening to words that correspond to the phonetic and phonotactic rules of the native language (Jusczyk, 1997). Jusczyk Cutler and Redanz (1993a) found a preference for trochaic accentual patterns over iambic patterns by 9-month-olds, but not by 6-month-olds. The English language has a higher percentage of trochees than iambs, which may render them more familiar and salient to the older group. Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk (1993b) found that at 9 months of age English-learning infants listen significantly longer to unfamiliar English word lists than to unfamiliar Dutch word lists. Plausibly, the unfamiliar native words were still more familiar in their structure than the Dutch words. Jusczyk, Luce, & Charles-Luce (1994) demonstrated that English-learning 9-month-olds listened significantly longer to lists of CVCs containing phonotactic patterns that occur frequently within English words than to lists with infrequently occurring phonotactic patterns.

Jusczyk, Goodman and Bauman (1999) have shown that some infants as young as 9 months of age are able to direct attention towards word beginnings and are also capable of segmenting pre-trained 'familiar' words, or word patterns, from fluent speech (Echols et al., 1997; Morgan & Saffran, 1995; Saffran et al., 1996). Indeed, beginnings of words may give some clues to word boundaries. The ability to attend to the way words begin may be a prerequisite for developing a lexicon. Word endings are also important in early language learning to establish word boundaries (Echols & Newport, 1992; Slobin, 1973).

Ten to Eleven Months of Age

When infants have learnt which phonological information is relevant to their native language they can begin to attach meaning to the sound patterns. Studies have demonstrated that by 11 months infants possess a mental representation of familiar words (used in the home) in the absence of any referential cues (Hallé & Boysson-Bardies, 1994; DePaolis, Vihman & Bywater, 1998).

Twelve Months of Age

At this age, towards the end of the first year, infants can no longer discriminate unfamiliar, foreign phonemic contrasts. This effect is probably due to active attendance to the native language and a lack of exposure and experience with non-native sounds (Werker & Tees, 1984; Werker & Pegg, 1992; Werker & Tees, 2002). A reorganisation of what has been learnt rather than a loss of perceptual abilities has been suggested (Werker & Pegg, 1992). It is at this age that infants begin to produce first words in a meaningful way (Bloom, 1973).

But just how do infants come to realise which sounds are important to language learning? Research has demonstrated that infants can quickly learn which sound sequences frequently co-occur with other sound sequences, especially within a familiar word such as the infant's name. Probability learning has been suggested as the general process that could facilitate language learning by aiding the recognition of familiar sound patterns. Statistical cues and probability learning will now be reviewed.

Statistical Cues

Speech is a continuous stream of sound from which infants must learn to find meaning by first establishing where the boundaries of meaningful units lie. Identification of these boundaries and the breaking down of speech is a critical step towards lexical knowledge. Implicit (unconscious) learning of the phonotactic regularities of speech is mainly dependent upon the ability to identify the co-occurring lexical strings. A sequence of sound can be split into several smaller units: short phrases, single words, syllables or phonemes. As in all developmental areas, different levels of ability lead to different levels of proficiency, in this case the learning of new words.

As James (1890) said, "Perception is of definite and probable things". Where consciousness cannot cope, unconsciousness weighs up the odds (Ellis, 2002). Implicit language learning is the unconscious calculating of probabilities, the gradual strengthening of associations between co-occurring elements.

As adult listeners, we perceive word boundaries when listening to a familiar language. However, when listening to an unfamiliar language the perception of word boundaries is more difficult if not impossible. Saffran et al. (1996) claim that infant language learners may detect word boundaries by tracking the statistical properties of the sound combinations they hear. Saffran et al.'s (1996) research utilised the head turn method to establish whether infants could detect and use the probabilities with which sounds co-occur to find word boundaries. This research exploits the novelty effect. That is, after infants have listened to a two-minute string of continuous speech consisting of four three-syllable nonsense words in random order, an unfamiliar sound sequence is played and the infants turn their attention to this new, novel sound demonstrating that they have noticed the difference.

Johnson and Jusczyk (2001) set out to replicate Saffran et al.'s (1996) findings using a complex artificial language containing words of variable length (as in natural language) as opposed to a simplified artificial language. No significant difference was found between looking times towards familiar or unfamiliar sound patterns in contrast to the findings of Saffran et al. (1996) (although there was a familiarity preference trend). Johnson and Jusczyk (2001) suggest the findings reflect the complexity of the artificial language. They suggest that the fact that Saffran et al.'s stimuli were far simpler in structure may have facilitated the infants' performance, whilst the complexity of their own stimuli rendered the task more difficult for the infants. Nevertheless, it seems unlikely that the only reason the infants failed on the task was due to difficulty in segmenting longer words as it has been demonstrated that 7.5-month-olds can segment disyllabic and trisyllabic words from fluent speech (Houston, Santelman, & Jusczyk, submitted). Furthermore, there is now ample evidence that infants are adept at statistical learning in numerous fields (Saffran, Johnson, Aslin, & Newport, 1999; Hauser, Newport, & Aslin, 2001). However, the results of Johnson and Jusczyk (2001) suggest that infants' statistical learning capabilities might be of limited use in a natural language setting, as language is much more complex than the artificial stimuli used in the laboratory.

The above research by Saffran et al. (1996) established that infants could learn and remember a pattern of sounds at the age of eight months. More recent work by Saffran (2001b) investigated whether infants could understand that new sound patterns may be words. Toddlers were exposed to fluent speech containing a series of nonwords, much as in the previous study. The researchers then attempted to teach the toddlers the names of novel objects, some of which were contained within the fluent speech. The rationale was that if infants considered the sounds they were hearing to be potential words, such as naming words, they should have more success in learning the names of the objects contained within the stimuli. It was found that infants were more adept at learning words that were considered as names, or labels. These results suggest that humans possess statistical learning mechanisms that may assist in the acquisition of this abstract component of natural language. These findings were further substantiated by more recent research by Saffran and Thiessen (2003) investigating whether infants can learn sound patterns. Infants listened to a list of nonwords that followed a CVCV pattern, for example, *gola*. After only one minute of exposure infants learnt the pattern and used it to aid word recognition in fluent speech.

The study of speech perception is a broad area, which encompasses speech segmentation, phonemic discrimination, and prosody (a preference for linguistically familiar sounds, melody and context). These processes lead to location of word boundaries through the recognition of sound patterns. Being able to learn sound patterns is a prerequisite to recognising word forms in fluent speech and in a context-free situation. The ultimate aim of speech perception must be the recognition of word forms based on stable representations formed in infants' minds.

Word Form Recognition

The purpose of speech perception is to identify words. Psychologists call this task lexical access (Frauenfelder & Tyler, 1987). It incorporates not only the study of what individuals do to comprehend speech in natural conversation, but also highly controlled laboratory conditions using synthesised speech. However, the definition of word recognition, for our purposes, is the point where an infant recognises a familiar sound pattern as being heard before, but does not necessarily know, or understand, what the sound pattern, or word, means. Word recognition differs from lexical access, as this is the point where all semantic and syntactic information about the word is known.

Much knowledge relating to language concerns knowledge regarding words. Adult lexicons range from 50,000 to 100,000 items. For each of these items we know what the word means, how the form and meaning of the word may be modulated, how often the word occurs and how often the word co-occurs with other words, how words may be combined to form phrases, clauses, sentences (Morgan, 1996).

To learn words infants must first be able to track properties, semantic, morphological, syntactic, and so on, that co-occur with particular words across a variety of instances. This is called distributional analyses (or distributional regularity – DR), and refers to assessing words in further cases, contexts or scenarios. Below is a review of word form recognition models. These models attempt to explain how we come to recognise words. Word recognition models are included here as they may highlight what underlies the implicit skill of word form recognition when learning a language.

Models of Word Recognition

The Original Cohort Model (Marslen-Wilson, 1989)

This model assumes that on the basis of the first 250ms of speech a cohort of possible words is set up. Items are eliminated from that cohort on the input of more speech. Word recognition is achieved when one item is left in the cohort. However, this model does not account for the word frequency effect, that is, why frequent words are recognised more quickly. The model accounts for the word supremacy effect in that real words can be recognised before they are finished being spoken, whilst nonwords involve eliminating all the words in the cohort before deciding that the item is not a real word. Context can be utilised to eliminate candidates from the cohort to improve recognition speed, so this model also accounts for the context effect. Regarding distortion effects, an initial distortion will be more problematic as the cohort will be set up wrongly in the first instance. It is difficult to explain how a word would ever be recognised with the wrong cohort; however, context cues could be used to aid recognition, as suggested earlier.

In light of the above problems the model was revised. Listeners are still thought to set up cohorts, but the elimination process is no longer all or nothing. Items are no longer immediately eliminated from the cohort, but are seen to slowly decay, which allows for backtracking if a word is misheard or distorted. Word frequency is accounted for by stating that frequent words become activated more quickly than infrequent words.

The TRACE Model (Elman & McClelland, 1986)

The TRACE Model is a connectionist network using the processing units of features, phonemes and words. The important features of this model are: (a) lots of simple processing units, (b) the processing units are arranged into levels, (c) the units are joined together by weighted, bi-directional connections, (d) the input units are activated by incoming information, and (e) activation spreads along the connections to other units.

This model does not account for the word frequency effect, although it could feasibly be modified in the same way as the Cohort Model. Regarding word supremacy, real words feed back to the lower levels to reinforce earlier information. Nonwords do not have this advantage so it is not clear how the model would finally decide that an item was not a real word. Context feeds down to affect the perceptual level. This model accounts for distortion effects because the individual is not so reliant on hearing everything perfectly.

The Shortlist Model (Norris, 1994)

When listening to fluent speech the impression is that of hearing discrete words. However, computational models of human speech recognition such as Shortlist and TRACE (Elman & McClelland, 1986) work on the assumption that listeners unconsciously have to consider *cat*, *a*, and *log* – and maybe *cattle* – when they hear the word *catalogue* (Norris, 1994). Listeners then interpret which one of the word forms is the correct one in any given situation. This process of deciding upon the best interpretation is described as lexical competition. Both Shortlist and TRACE are connectionist models, yet TRACE allows top-down feedback from lexical units to phonemic units, while Shortlist does not. The models also have different architecture, Shortlist operates on a full-size lexicon due to its architecture, whilst TRACE has a lexicon of approximately 200 words. Similarities between the models include the fact that they can only identify words stored in the lexicon; there is no system to learn new words. The two models function on a maximal matching heuristic. The interactive-activation framework of the models favours long words over their embedded words, for example *catalogue* versus *cat* as long words eventually receive more bottom-up inputs.

Word Recognition and Phonetic Structure Acquisition (WRAPSA. Jusczyk, 1993, 1997)

When learning to recognise words there are a few problems that need to be overcome. The first is the segmentation problem, which involves being able to identify discrete series of items from continuous speech input. The second is the representation problem, which requires being able to capture phonetic variations that are phonemically significant; and thirdly, the identification problem which entails being able to recognise segmented items as instances of particular lexical types.

Jusczyk (1993, 1997) designed a developmental model of spoken word recognition called WRAPSA (see Figure 2.1) to suggest an architecture, which would solve the three spoken word recognition problems.

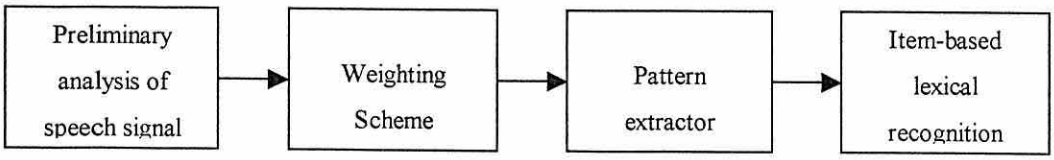

Figure 2.1. WRAPSA (Juscyck, 1993, 1997).

Jusczyk's WRAPSA model of speech perception views language acquisition as resulting from a warping of the perceptual space through foregrounding of the features, which are significant to the target language. As the infant brain matures, the child develops the ability to integrate information from different sources, so the movement is away from a general-purpose recogniser of differences (wider speech perception) towards a more sophisticated and specific recogniser of a particular language and subsequently words within that language.

WRAPSA comprises four components. The first component stores all perceptual features that the system is capable of extracting from each utterance. The second component is a weighting scheme that focuses attention on crucial language-specific features. The third component extracts patterns from the weighted output and stores these patterns in memory, where they can be said to comprise the infant lexicon. The fourth compares new patterns to old patterns to attempt a match. Feature similarities will cause old patterns (traces) to be activated. The goal is word recognition. As more tokens of each utterance are collected, more traces will be activated by new tokens, so recognition of patterns will become more efficient and ultimately lead to extraction of words.

Whilst segmenting in early spoken word recognition infants can use a variety of bottom-up cues in the speech stream to help locate word boundaries. Some of the cues are very low-level, for example co-articulation, suggesting that segmentation operates on the un-weighted signal. Infants may be able to use lexical knowledge in segmentation as soon as individual words become sufficiently familiar (see Figure 2.1).

INCremental DR Optimisation (INCDROP. Dahan and Brent, 1999)

Dahan and Brent's (1999) INCDROP model suggests that segmentation and word discovery in native language acquisition may be driven by recognition of familiar units from the start, thereby precluding the need for a bottom-up bootstrapping mechanisms. INCDROP is an extension of DR (Dahan & Brent, 1999). DR was intended to model language learners' word discovery process. INCDROP was designed to model online word segmentation and identification. New words are stored in the lexicon and frequencies of familiar words in the selected segmentation are updated.

The Cohort and the Trace models of spoken word recognition explain much of the experimental evidence concerning recognition. However, no single model appears to be able to explain all of the evidence and many speech recognition models make predictions that fail to be supported by the evidence. The role of context and the ability to segment speech from the speech stream are still problematic for many models of spoken word recognition.

There are many differences between the above reviewed models, but the most common strand appears to suggest that familiar words are easier to recognise, and this recognition can be supported through an individual's knowledge of co-occurring strings. Below is an overview of research into the recognition of word forms in infants and children.

Recognising Word Forms

By 4.5 months of age infants show a listening preference for their own names, suggesting that even at this early age infants are beginning to recognise something about word forms (Mandel et al., 1995). Madel-Emer (1999) demonstrated that infants recognise their own names in fluent speech at 6 months of age. By 7.5 months infants listen longer to passages containing pre-trained familiar words over unfamiliar words (Jusczyk & Aslin, 1995), and infants can remember the trained words two weeks later (Jusczyk & Hohne, 1997). By 10 months of age infants can successfully detect words irrespective of whether they are presented with the correct stress pattern or not. This was not possible at age 7.5 months (Jusczyk 1997). The above evidence demonstrates, therefore, an effect of familiarity, as highlighted in the above review of models of word recognition.

In Hallé and Boysson-Bardies (1994) studies, 11-month-old French infants demonstrated word recognition in the absence of any situational cues using the head turn procedure. Infants received no training on the familiar words beforehand, unlike the infants in Jusczyk and Aslin's (1995) study. The infants simply recognised words (or sound patterns) that they knew from the home environment, based on stable word representations. The current study will go one step further by using the same experimental paradigm as Hallé and Boysson-

Bardies (1994, 1996) to test infants at 10 months of age, searching for early recognisers of word forms or familiar sound patterns. Previous research has demonstrated that English native infants preferred to listen to familiar versus unfamiliar words, as indexed by attention span, at 11 months (Depaolis et al., 1998).

Houston and Jusczyk (2000) also used the head-turn preference procedure to find that infants listened longer to familiar words when spoken by a same gender person as opposed to a different gender speaker. Infants were also shown to prefer to listen to passages presented in a happy sounding voice after being familiarised with them. These findings demonstrate which factors play a role in language learning. By age 11 to 12 months infants' word recognition is no longer disrupted by variation along lexically irrelevant dimensions, such as mood, tone and context (Morgan, 1996), and infants block out, or filter, irrelevant 'noise' to extract the meaningful or familiar sound pattern leading to item-based lexical recognition. This ability to hone in on phonological patterns in word form recognition must impact on long-term memory and will therefore be related to receptive and productive vocabulary.

Werker (1999) states that by 14 to 15 months infants learn to extract words from the speech stream, to recognise words they have previously heard, to associate words with referents, and to produce first words. Mills, Coffey-Corina, and Neville (1994) demonstrated through evoked responses that infants process known and unknown words differently at 15 months, but only at 20 months do infants have full knowledge of word meaning as demonstrated by the recognition of familiar words being strongly lateralised to the left hemisphere.

Does Recognition of Word Forms Lead to Increased Word Learning?

At approximately 12 months of age infants begin producing their first words. However, by 24 months of age the same infants learn up to 9 words per day and usually have over 50 words in their productive vocabulary (Bloom, 1973). How do these infants learn so many new words so quickly? One notion is that infants might use words they know to learn new words, suggesting that each new word learnt facilitates the acquisition of further words (Ganger & Brent, 2001). If this notion is correct there are two possible ways in which infants could use familiar words to acquire new words.

First, at the phonetic level, infants could use the words and familiar sound patterns they know to parse out new acoustic combinations with distributional regularity (Dahan & Brent, 1999). During the first 12 months of life infants have demonstrated that they can segment words from fluent speech (Jusczyk & Aslin, 1995), and, furthermore, use many sources of information in word segmentation such as, allophonic cues, prosodic stress, phonotactic cues and statistical cues (Hollich, Jusczyk, & Brent, 2001). It would come as no surprise then if infants utilised existing word knowledge to segment new words from the speech stream. Second, at the conceptual level, infants could use the words they know to aid word-world mappings. Hollich et al., (2001) explored both of these possibilities.

According to the computational model INCDROP (Dahan & Brent, 1999) infants should learn the meaning of words in a familiar context faster than those surrounded by an unfamiliar one. For example, when presented with ' pretty kiosk' infants should be able to extract the familiar word 'pretty' and by doing so should infer that 'kiosk' is also a word. Hollich et al. (2001) trained twenty-four 24-month-old infants on paired familiar and unfamiliar words, and paired familiar words by using the head-turn paradigm. They found that infants looked longer towards familiar words, such as *flower* and *apple*. Individual infants did learn at least one new word, but not always in the familiar context as predicted by the model, though there was a general trend in the predicted direction.

It was concluded that infants do not use the words they know to segment the speech stream, however it may be possible that the second explanation may hold, that is, the notion of word-to-world mapping. Golinkoff, Mervis, and Hirsh-Pasek (1994) proposed a rule of novel-name-nameless category, which states that infants will select an unnamed object for an unfamiliar label or word. It implies that infants should be able to infer the name of a novel object if the novel object's name is paired with a familiar word. Hollich tested this theory and found that infants learned a word more easily if they had heard a few similar sounding words previously. Therefore familiarisation was critical in the learning of new words – this has bearing on the present study in that familiar type words may be the stepping-stone to learning other, familiar sounding words. A task such as this may be effective in investigating lexical effects predicted by the INCDROP theory, for example, any consistent preference in favour of a word presented in a familiar context. However, although infants consistently learned a word, they did not always learn the word in a familiar context as predicted by INCDROP. Results showed that infants looked significantly longer to familiar type words – suggesting the same might be true in the present study, although the children in the present study are somewhat younger.

Experiment 2 tried to minimise the contribution of other segmentation cues to encourage the use of the INCDROP strategy in segmenting words. Therefore words with initial vowels were used and the surrounding contexts of words to be learnt were elongated to full sentences. Once again the twenty-four 24-month-old infants looked longer to familiar words and did not show any significant effect of responding faster to the taught word when presented in a familiar context than to the one presented in the unfamiliar context.

Due to the above results, the authors decided to proceed to a third experiment, this time without using the individual stimuli words first in a training phase. It was decided to teach the infants the words whilst embedded within familiar and unfamiliar contexts, for example, 'faux onyx fools misers', with onyx as the target word in an unfamiliar context, and 'the opal is pretty' with opal as the target word in a familiar context. The rational of using this method was to control for any possible learning and mapping effects, which may have taken place in the initial training phase, and to properly test the INCDROP theory. Once again infants looked longer towards already familiar target words, and the mean difference in looking to the target for the newly taught words did not differ from zero, regardless of context.

It was concluded that either (a) the method used was not sensitive enough to pick up subtle INCDROP effects, or (b) INCDROP does not come online until later on in development. The upshot being that infants do not use previously learned words to learn more words at the matched phonetic level.

Hollich et al (2001) then proceeded to attempt to answer the question as to whether infants could use words already known to them to find the correct word - to-world mapping. Golinkoff, Mervis and Hirsh-Pasek (1994) proposed a principle of novel-name-nameless category (N^3C), which supports the view that if a child is faced with two objects and they know the name for one object, when given a different name to the one they know they will automatically choose the 'nameless' object – a kind of process of elimination. This should occur even if the 'familiar' word has only just been learned, as in the case of 'pylon' or 'kiosk' in Hollich et al.'s (2001) first experiment. This theory is similar to those of Markham's (1989) principle of mutual exclusivity and Clark's (1983) principle of contrast.

The infants who participated in Hollich et al's Experiment 1 were recalled a week later to test the above theory, and to establish if infants could remember words learned a week previously. The results showed that infants correctly identified the familiar words already in their vocabulary, that is, *apple* and *flower*. These findings demonstrate a robust and consistent finding that infants can identify familiar words out of context as tested in the present study and by Hallé & Boyysson Bardies (1994), and Depaolis et al. (1998). There was little evidence that the infants remembered the words learned from the previous week. Nevertheless, as stated by N^3C, the infants were able to use these words to correctly infer the meaning of novel names of objects, demonstrating that some learning of words heard previously had taken place and been remembered. This experiment therefore provides evidence that infants at 24 months of age can infer meaning on the basis of prior word knowledge. Interestingly it appears that the learning of new words is strengthened when put in a contrastive context with unfamiliar or totally novel words. This effect was shown in Hollich et al.'s (2001) study as the Known/Novel and Taught/Novel trials showed the largest mean differences, this context appears to confirm to the child whether a word is novel or not.

Hollich et al.'s study (2001) examined whether previously known words would facilitate the learning of new words, as predicted by the INCDROP model. No evidence was found to support the view that a familiar context aided segmentation of new words from fluent speech. However, at the conceptual level infants were able to assign a novel label to a novel object when the other object was presented and know by the child. This is in accordance with the N^3C (Golinkoff et al., 1994) model. Furthermore infants demonstrated conceptual stability in learning these words over a period of time.

These findings are consistent with a context dependent model of memory, suggesting that words learnt in close temporal proximity are prone to being inherently confused (perhaps this is why bilingual children take slightly longer at learning one language proficiently as they have two words for each object to disentangle).

In conclusion, these studies demonstrate that previous familiarity with words facilitates the learning of new words, though at a higher level of implementation than as suggested by INCDROP. Therefore if an infant is in a room full of toys whose referents they know, for example train, doll, car, teddy, and they are asked to fetch the 'tractor' and that child has not previously heard 'tractor' they may be able to ascertain which toy the label pertains to and procure it by process of elimination. This infers that the more words an infant knows, the more referents that child has to facilitate the learning of new words. If the child in the above scenario only knew the word 'car' and was asked to fetch the tractor from the all the toys in the room they would be more disadvantaged than the child who knew 'car', 'doll', 'teddy', 'train'.

The findings of Hollich et al. (2001) demonstrated that an infant's memory is highly context sensitive as some words taught a week previously in the laboratory were retained. Also, infants' memory for new words was found to be strengthened by combining them with novel objects. Overall, the study indicated that familiarity with words does play an important role in learning new words. This study has implications for the present study, implying that children who are adept at recognising familiar words at 10 months may have a much larger receptive and productive vocabulary in later life than those infants who were slower to recognise familiar words.

Summary

It has been shown by previous research that infants can, by the time they reach 9 or 10 months of age, demonstrate knowledge of their native language. By 9 months, infants have learned a lot about their native language: Infants prefer to listen to speech in their native language rather than an unknown one, can recognise whether pauses are prosodically appropriate in both clauses and phrases in their native language and prefer common rather than rarer phoneme sequences. It appears that, when learning a first language, infants attend more to familiar sound patterns as demonstrated by the studies by Hallé and Boysson-Bardies, (1994, 1996) and Depaolis et al., 1998). This knowledge is accumulated through experience, beginning in the womb. The findings of Hollich et al. (2001) indicated that familiarity with words plays an important role in learning new words. The implication is that children who are adept at recognising familiar words at 10 months may, at a later stage, have a larger receptive and productive vocabulary than those infants who were slower at recognising familiar words.

At 10 to 12 months, the failure to discriminate between foreign phonemic contrasts is not a sudden change, but rather the culmination of experience of sorting out relevant and salient native language properties. The age at which infants begin to lose or ignore their discriminatory abilities in favour of focusing more on their native language has to be the most significant step in becoming a comprehender and producer of a particular language.

Few studies to date have investigated the relationship between speech perception in the context of word form recognition and emerging word learning. There appears to be, from the evidence above, an indication that word learning appears at age 10 months, when infants begin to focus less on non-native sounds and more on native sounds and co-occurring sound patterns.

Jusczyk (1997) suggests that infant speech perception abilities develop in order to facilitate the segmentation of individual words from the speech stream. Word form recognition is the final process in speech perception. In the context of spoken word recognition the important question is whether lexical information feeds back down to influence earlier stages of phonological analysis. That is, upon hearing a word, does information from existing vocabulary feed back down the system to affect the way sounds are processed in the word? Although this is intuitively appealing, and embraced by some (Hollich et al., 2001), lexical feedback has been dismissed by other researchers (Norris, McQueen and Cutler, 2000; Golinkoff et al., 1994) who claim that lexical knowledge does not feed back to influence earlier stages of speech analysis as lexical feedback cannot facilitate word or phoneme recognition. However, Jusczyk's WRAPSA model (1993, 1997) actually infers that infants may be able to use lexical knowledge in segmentation as soon as individual words become sufficiently familiar, therefore implying a two-way interaction.

This thesis will attempt to discover whether word form recognition could predict, through forward feeding, speech production, receptive vocabulary and phonological short-term memory, rather than language acquisition being influenced by phonological short-term memory.

Chapter 1, main points, and their implications for the present study:

1. **Main point:** Infants prefer all things linguistically familiar (except when reaching saturation point as exploited in the novelty effect), that is, tone, voice, sound patterns, language and words (even if pre-trained on 'familiar' words).

   Implications: Infants should listen longer to the words they recognise as familiar.

2. **Main point:** Word knowledge begets more word learning, that is, lexical knowledge can facilitate the learning of new words, impacting on receptive and productive vocabulary.

   Implications: The more linguistically able infants at 10 months should retain their ability and be more linguistically adept throughout the longitudinal study in comparison with the less able infants.

3. **Main point:** Recognition of familiar words is easier when in a contrastive context with unfamiliar words.

   Implications: The unfamiliar versus familiar list in the present study should facilitate the recognition of the familiar words for a child who has those mental representations.

4. **Main point:** Ten months appears to be the age in which linguistic reorganization occurs and when more linguistically able infants begin to produce their first words. Eleven-month-olds have been found to have mental representations of familiar words out of context, but 9 month-olds have not.

   Implications: Ten months is the ideal age to study individual differences in linguistic ability.

Chapter 2

Speech Production and Comprehension

This chapter will look at how individuals understand and produce words. Speech production does not simply mean producing words. Speaking is our most complex cognitive-motor skill. Vast networks of brain structures contribute to the high-speed generation of utterances in different communicative settings.

Speech conveys two messages: information about 'what' one is saying and 'how' one feels about it. The use of prosodic features such as variation in pitch and rhythm make this possible. The 'what' follows grammatical rules, whilst the 'how' is a 'linguistic code' (Pickett, 1999), which expresses mood or emotion. Prosodic patterns usually extend over several successive phoneme segments. They are referred to as suprasegmental. Stress and intonation are the most important prosodic features that convey linguistic information. By means of stress, we differentiate similar forms that have different meanings. Compare the two phrases, 'That's just insight' and 'That's just in sight' (Pickett, 1999). The stress is on *in* in the first phrases but on *sight* in the second phrase, thus conveying a totally different meaning. Stress is, therefore, an important feature in English for identifying the meaning between same sounding phrases or words.

Vocal Production

Speech perception has a profound effect on speech production. At 2 months of age infants can successfully imitate the pitch of infant-directed speech (Vihman, 1996). In hearing children, canonical babbling occurs between 6 and 10 months. However, deaf children do not enter the canonical babbling stage until later (Oller & Eilers, 1988). Furthermore it has been found that whilst consonant variety increases in hearing children, the opposite is true of deaf children (Stoel-Gammon & Otomo, 1986). This evidence suggests that the early transitional period involving canonical babbling relies heavily on speech perception and auditory input. Those children who cannot perceive speech, not surprisingly, do not follow the usual developmental route. Hearing children appear to understand the social nature of speech even before they can produce meaningful utterances. Between 10 and 12 months infants may participate in 'conversational babble', which consists of strings of sounds and syllables with a variety of stress and intonational patterns. Conversational babble sounds as though it could be real language and is accompanied by gestures and intonations. It is clear that the utterances contain meaning for the child, for example the rejection of food or toys, or a request for help or attention (Menn, 1976).

Vihman (1993) states that early babbling shows little differentiation among languages. For instance /h/ does not occur in French, but it is frequently produced in French infants' early syllables, as much as in English infants' outputs. However, as French infants begin to learn the sound patterns of their native language they gradually decrease the production of /h/ and follow and produce the more frequent sound patterns of word forms, implying that sound pattern recognition (leading to word form recognition) influences production. We would therefore expect to see a link in the present study between word form recognition and speech production that represents adult word patterns.

Canonical babbling begins at 6 to 8 months of age and by 9 to 10 months infant vocalisations already reflect some of the properties of the native language (de Boysson-Bardies, Hallé, Sagart & Durand, 1989; de Boysson-Bardies & Vihman, 1991). Thus, we see that in babbling the emerging language-specificity we observed in speech perception occurs at the same age, that is, at 10 months.

The fact that infants make many mistakes with their first word productions, for example [gog] instead of *dog*, [dʌk] instead of *truck*, suggests that when learning first words infants may not represent all of the information or detail found in adult speech (Gerken, 1994). There are parallels between production and comprehension. Stager and Werker (1997) showed that 14-month-olds confuse similar-sounding words in a word-object association task, suggesting that infants do not represent all of the phonetic detail, or that they do not use it. Hence, in the increasing specificity of babbling at 10 months and in the inconsistency of phonetic detail in early word production, we see parallels to the functional reorganisations involved in speech perception and word comprehension.

Different models account for these changes such as, the motor theory (Liberman & Mattingly, 1985), the perceptual magnet approach (Kuhl, 1991), phonological bootstrapping and probabilistic accounts (Saffran et al., 1996). Not entirely happy with the above models, Werker (1999) suggests an alternative explanation labelled the probabilistic epigenetic model. This model accounts for sensitivities in newborn infants by suggesting an interaction between genetics and human speech. Greenough (1986) identified the interaction as involving 'experience expectant' brain development, maintaining that genes are not deterministic, but are influenced by environmental factors. Werker (1999) argues that these experience-expectant, interactive changes account for the speech-specific biases shown by infants and that general experience-dependent information storage capabilities of infants are used to identify, remember, and use both frequency and probabilistic information to learn about the phonetic, rhythmical and syntactic properties of the native language (Werker, 1999).

Children differ in that some will only attempt sound patterns they are sure of articulating accurately and others will casually adapt any adult word to fit their output repertoire (Ferguson & Farewell, 1975). This presumably points to individual differences in production, but what do these differences indicate? Do they point to different levels of linguistic ability? Alternatively, are they just different coping or problem-solving strategies for language learning?

Thal, Bates, Zappia, and Oroz (1996) present two case studies of linguistically precocious talkers. SW (single word utterances) was 21 months old and MW (multi-word utterances) was 17 months old. The vocabularies of the two children were comparable to 'normal' children aged 30 months. SW had a vast vocabulary yet usually produced words singly. Therefore, SW demonstrates dissociation between vocabulary size and mean length of utterance.

The apparent difference between SW and MW (whose outputs had been known to contain strings of six words on occasion, for instance, "Too much carrots on the dish") is one of memory. Thal et al. (1996) conclude that memory determines the size of unit we can hold and manipulate and MW seems to be able to manipulate longer strings than SW. Yet the fact that SW has a larger vocabulary than other children of the same age suggests that she too has superior verbal memory. Indeed, remembering how newly encountered words sound is a prerequisite to learning what those words mean (Hoff-Ginsberg, 1997, p. 99). It is doubtful whether memory is the main difference between SW and MW. The difference is probably more one of learning style.

Most children during the transition to language develop proto-words that are stable sound patterns, which hold certain meaning for the child, enabling them to express themselves (Ferguson & Farewell, 1975; Vihman & Miller, 1988). 'Talkative' babblers at this time begin to produce recognisable and appropriate word forms, though the words are usually context-bound (Vihman & McCune, 1994). During the second year referential or symbolic word use is attained, when infants discover the relationship between sounds and meaning (McShane, 1979; Vihman & McCune, 1994; McCune & Vihman, 2001).

At 9 months of age most infants are only just beginning to comprehend a few words and build a receptive lexicon (Jusczyk, 1997; Jusczyk & Aslin, 1995). However, at this same age some infants begin to produce their first words in which the repeated use of an initial consonant has been frequently observed (Vihman, 1996; Dowker & Pinto, 1993). A good example of individual differences in babbling and later word production is discussed in the paper by Ferguson and Farewell (1975), where early stages of linguistic development of two girls, T and K are studied. T hardly ever babbled and after 13 weeks of weekly observations had 51 words. K, on the other hand, was a voluble babbler and at the end of her 13 weeks of weekly observations had 72 words. K was 'less fussy' about perfect articulation in comparison to T, who appeared more concerned with details. It is impossible, at present, to establish which linguistic ability (sensitivity to word forms or phonological memory) is more important in the acquisition of language. Phonological memory and vocabulary acquisition have previously been studied with regard to production abilities.

Infants' ability to produce words dramatically increases between 13 and 20 months (Fenson et al. 1993). During this time, vocabulary size increases slowly at first and then more rapidly (for example, Goldfield & Reznick, 1990). A child may take many months to produce the first 50 words but then may acquire several new words per day (see Barrett, 1995, for a review); this is known as the vocabulary burst. Prior to the vocabulary burst, words tend to be context bound, while after the vocabulary burst words are used in a more referential manner and in a variety of contexts (Bates, Bretherton & Snyder, 1991).

Lexical Phrases

Ellis (1996) argues that the automaticity of auditory word recognition is the result of learning sequential regularities in a language. Frequently co-occurring phonemes and syllables will be chunked together and will be processed as single perceptual units. This leads to speedier perceptual processing. An example would be a child repeatedly uttering a word string learnt as a single chunk, such as *gimme* or *puppy-puppet-show*. Children seem to almost chant these segments of speech and find it difficult to separate the phrases into smaller chunks. The easier an infant finds it to learn phonological sequences, the more low frequency word regularities can be learnt. Therefore, these individuals will have more exemplars within their long-term memory to compare new or novel words to. Lexical phrases produced by language learners demonstrate a learning of routinised sound patterns. These lexical phrases are not redundant however, as they can ensure a steady growth in language development by allowing for the expansion of previously acquired knowledge as learners become more proficient. For instance, the phrase pattern *I'm sorry* could be expanded upon as learners become more proficient by adding extra words such as *I'm very (awfully, terribly) sorry* (Porto, 1998). This functional feature of lexical phrases allows the possibility of expressing the same function in increasingly difficult ways by expanding the initial formula. Therefore, far from being redundant, lexical phrases can act as a springboard for language development (Porto, 1998). Furthermore, fixed lexical phrases are easily accessible with minimal effort. The statement, "Human beings aim at the most efficient information processing possible" (Sperber & Wilson, 1986, p.49) implies that fixed phrases are a shortcut to minimise effort, yet their contribution is significant.

The above literature suggests that those infants who are easily able to learn fixed lexical phrases, which are sometimes assumed to be redundant, actually demonstrate the availability of an effective building block on which to expand. It follows that those children who acquire and use high frequency context-bound lexical phrases may also find it easy to learn less frequent sound patterns. Those infants will develop a broader productive vocabulary than children who struggle to learn phonological sequences. In other words, the ability to acquire the phonological regularities of a language should be predictive of the rate at which an individual learns first and second language vocabulary. Phonological short-term memory and phonological sequence learning could both be predictors of language learning, implying that word form recognition should have a strong link with vocabulary; both productive and receptive.

The continuity theory proposes that early language production is rooted in pre-linguistic vocal productions, or babbling (Vihman, Macken, Miller, Simmons & Miller, 1985). Continuity theory claims that infants' phonological patterns in early meaningful speech are directly linked to the patterns they use in babbling. The patterns are those that the infant has managed to bring under voluntary control. The continuity theory therefore strongly suggests that sensitivity to phonological patterns is of paramount importance in speech production. Infants babble, perceive their own babbling and later build on those sounds that are most salient to them. A child's first words' phonological structure is induced from sound patterns relating to word forms in their own and others' speech output (Vihman & Velleman, 2000).

The Articulatory Filter Hypothesis

Vihman (1993) claims that an articulatory filter leads the infant to seize upon sound patterns in adult speech that are similar to their own output. At 6 to 8 months infants begin producing CVCV sounds (canonical babbling), for example, [baba], [dada]. Over a period of time infants begin to selectively pay attention to sound patterns produced by others that are similar to their own output. For instance, if an infant heard "Daddy will be home soon. Where's Daddy. Can you see Daddy yet?" and the infant can already produce [dada], then *Daddy* will be highly salient for that individual. This is the crux of the articulatory filter. The infant may recognise a similar word in the adult speech stream as 'Daddy' if it has a similar sound pattern or accentual characteristics; for example, 'Danny' may be enough to trigger a response of 'dada' in the infant. This is due to the global representation of 'Daddy' by the infant. Juscyzk (1986) proposes a global impression or "sketch" of some salient aspects of the word pattern, which need not be fully specified phonologically for word recognition to take place. Infants' early productions are also holistic in nature, that is, "errors are based on whole-word patterns due to distortions in sequencing to accommodate the child's emerging system of production plans" (Vihman, 1993, p.75).

Infants first produce adult forms that match an existing vocal motor scheme (Vihman, 1991). First words usually have a high proportion of /b/ and /d/

sounds. In relation to this theory it could be said this is because /b/ and /d/ are easily produced by infants, which heightens their attention to /b/ and /d/ sounds in the language environment. Elbers (1989) considers that auditory feedback from a child's output is more strongly represented than adult input as it is both produced and perceived, engaging more effortful processing.

Factors other than individual differences in linguistic ability may influence language acquisition. Genetic and environmental influences will be briefly reviewed.

Genetic Influences

Infants can discriminate between many speech sounds, but linguistic categories may be built due to experience with speech and language throughout childhood and possibly adulthood. Speech perception presumably reflects continuing interaction between genetic endowment and the environment (Hawkins, 1999). Sex differences are also apparent, though small. Fenson, Dale, Reznick, Bates, Thal, & Pethick (1994) found that girls are more advanced in vocabulary development than boys. But this could be because mothers talk more to female infants than male infants (Cherry & Lewis, 1978), which suggests language input makes a small difference. However, Huttenlocher, Haight, Bryk, Seltzer and Lyons (1991) found a sex difference in the rate of vocabulary growth that could not be accounted for by differing inputs.

Bishop (2001) found that genes are good indicators of nonword repetition and phonological short-term memory, therefore implying that memory span is heritable. That is, if a child is born into a family where the parents are good language learners, and perhaps have more than one language, then the child will possibly inherit the ability for language learning. Alternatively, Bishop argues that although inherited traits such as specific language impairment (SLI) could put a child at risk from having a language impairment, the severity could also depend on environmental factors. Therefore, genes are not the only factors that affect linguistic ability. Even monozygotic twins differ in their language capabilities.

In 2002, Bishop found that two types of deficits could cause SLI. Bishop demonstrated that nonword repetition and an auditory processing task (Tallal, Sainberg & Jernigan, 1991) actually measured separate things, therefore SLI could be caused by an additive effect of more than one deficit that is, impairments in auditory processing and phonological short-term memory. Bishop found that deficits in auditory processing showed no evidence of genetic influence, whereas the nonword repetition deficit was highly heritable. Since phonological short-term memory has been demonstrated to index later vocabulary acquisition, we could expect infants with parents who are good at languages to have possibly inherited this talent.

Environmental Influences

Individual differences in linguistic ability play an important role in language acquisition; they explain how it is that young children, who have the same language input and mature at the same time, have different language abilities and vocabulary sizes, such as twins (Bishop, 1997). Environmental factors include such things as parental influences, noise in the home, middle ear infection and exposure to music.

Vihman, Kay, Boysson-Bardies, Durand and Sundberg (1994) demonstrate infants' individual differences in vocal production. It was found that whereas mothers' speech showed few differences in phonological patterns, there was enormous variability in the children's speech patterns. Even though it has been found that input (Huttenlocher et al. 1991), sex (Fenson et al. 1994), birth order (Fenson et al. 1994; Pine, 1995) and socioeconomic status (Fenson et al. 1994; Hoff-Ginsberg, 1993) affect language development to some extent, these elements alone are not sufficient enough to explain individual differences in linguistic abilities.

Do environmental influences have a major impact on language learning? Gathercole and Baddeley (1990) demonstrated that environmental differences such as auditory exposure to novel words could be ruled out. They tested two groups of young children with controlled exposure to toys with unfamiliar names, for example *Piemas*. Both groups were matched on nonverbal intelligence and were physiologically mature enough to be able to pronounce the unfamiliar words, yet some children were much better able at retaining and learning the unfamiliar words than others. This suggests that cognitive abilities such as memory span are more influential in learning language than external influences.

From the above section on environmental influences it can be noted that, although external influences can be important, the main factor which influences language acquisition is individual differences in innate linguistic abilities.

There has been much debate regarding the most accurate means to measure receptive and productive vocabulary. Below is a review of observational and parental report methods.

Observational Versus CDI Measurements

The Oxford CDI was developed by Hamilton et al. (2000), as a comparable British version of the MacArthur CDI. The CDI can plot the exact course of vocabulary development for individuals and groups of infants and contains 416 words in a checklist (though there is space for parents to write extra words known or known and produced by their child). Considerable variation between individual infants has been described in both the MacArthur and the Oxford CDIs. Bates et al. (1991) used parental reports and found them better predictors of later behaviour than the short-term observations made by herself and her colleagues.

Fenson et al. (1994) looked at differences in infant vocabulary production, using the CDI on approximately 80 to100 children. Parental reports can be useful in the early stages of language acquisition. In this case "the interviews were validated repeatedly against concurrent behavioural data" (p.270). In addition, the interviews (where the CDIs were completed) were found to be better predictors of later behaviour than the short-term observations.

Hallé and Boysson-Bardies (1996) state that observations in naturalistic settings may underestimate the productive lexicon yet overestimate the receptive lexicon, a criticism also levelled at parental measures such as the CDI. In order to combat this problem the researchers applied an experimental approach using the head turn preference procedure. Findings showed that 11- to 12-month-old native French infants listened longer to familiar words; this is interpreted as recognition of familiar words without specific training (Hallé & Boysson-Bardies, 1994). Word recognition, revealing the formation of an early receptive lexicon, appeared to be firmly established at 12 months, while it appeared to be emerging at 11 months of age. Hallé and Boyyson-Bardies (1996) used the same procedure with Japanese infants to find that 12-month-olds looked longer towards familiar words, whereas 10-month-olds showed no such looking preference.

Various contextual cues such as intonation, situation, behavioural routines, and so on probably leads to a tendency to overestimate infants' comprehension abilities. Observational studies (Harris, Yeeles, Chasin, & Oakley, 1995) suggest that word comprehension begins by 9 to 10 months. A study based on parental reports found that 8-month-olds were claimed to understand some 36 words on average (Bates, Dale, & Thal, 1995).

Parental interpretations of word comprehension may be optimistic as word comprehension may be based on the word's sound pattern plus the situation, rather than word representations being based purely on a linguistic code or sound pattern (Hallé & Boysson-Bardies, 1996). For instance, communicative exchanges between parents and infants accompany activities such as bathing, playing and feeding. During these activities parents often comment on the infants' actions and often repeat and exaggerate their vocalisations (Fernald & Mazzie, 1991). Some laboratory-based experiments found that infants did not reach the onset of word comprehension until 12 to 13 months (Oviatt, 1980; Thomas, Campos, Shucard, Ramsay, & Thomas, 1981). However, there is disparity between these findings and those of ERP studies with 14-month-olds, which demonstrate that early comprehenders can demonstrate differential processing of familiar and unfamiliar words (Mills et al.,1994). It appears then, that there is controversy over when exactly word form recognition and comprehension occurs; methodological issues of measurement fuel this controversy.

Separability of Comprehension and Production

Hamilton et al. (2000) possess child developmental inventories for over 650 British infants less than 25 months of age. The general trend mirrors that of earlier studies (for example, Fenson et al., 1994), showing that there is a vocabulary spurt in production whilst comprehension develops in a more linear fashion. This provides evidence that comprehension and production involve two separate systems. Mills et al. (1994) tested the validity and reliability of parental reports (the MacArthur CDI) in the United States by studying ERPs in 20-month-olds and 13- to 17-month-olds to auditorily presented words. They found that children's ERPs were reliably different according to whether the stimuli were known or unknown words, as rated by their parents. High comprehenders displayed ERPs that were earlier and more focally distributed than were those of low comprehenders. ERPs were recorded as children listened to a series of words whose meanings were understood by the child, words whose meanings the child did not understand, and backwards words. Large individual differences were found.

Studies have been carried out to establish whether the vocabulary spurt is due to underlying changes in comprehension (Schafer & Plunkett, 1998; Bates et al., 1991). The findings were that infants between 13 to 18 months acquired new receptive labels with minimal exposure. The results suggest that the ability to acquire new word meanings occurs well before the naming explosion, and, therefore, points to comprehension and production being differently activated systems. Changes in productive abilities may be linked to changes in memory, whereas increases in comprehension abilities are more likely to be the results of conceptual changes.

Bates et al. (1991) conducted a longitudinal study of 27 babies at ages 10, 13, 20 and 28 months. They found that comprehension at 10 months related to comprehension at 13 months and early production related to later production, again suggesting a separability of comprehension and production. Although the 10-month-olds' comprehension did not predict later production, it did correlate highly with 13-month-olds' language, reflecting 'analysed production', especially referential style and flexible object naming.

Bates et al. (1991) investigated individual differences in language development in 27 children at 4 age levels, 10, 13, 20 and 28 months of age, that is, from the learning of first words to grammar. The goal of this work was to identify associations, dissociations, and packages of abilities that 'hang together' (p. 7). Bates and colleagues assume that "individual differences in the content of early language development occur through differential strength and/or differential timing of two or more underlying mechanisms responsible for language acquisition and language processing" (Bates et al., 1991, p.7).

At each age level data were collected in two sessions, the first in the home and the second in the laboratory within seven days of the first session. A mixture of parental interviews and observations of free speech and play were used, supplemented by more standardised experimental tasks pertaining to particular linguistic or symbolic behaviours.

The study of most interest here is Bates et al's first study (Study 1) of comprehension and production at 10 and 13 months of age. Dissociation was found between these language learning mechanisms. At 10 months data was collected by parental report of words comprehended and words produced. At 13 months a parental report on language development was again administered with a further measure of videotaped and transcribed structured play sessions in the laboratory. The observational measures were kept simple: a total count of all the different recognisable words produced by the children. These were further divided into spontaneous and imitative productions. Imitations are defined as any word produced which had occurred in the immediate preceding adult utterance. These measures are both word types rather than tokens since each word counted only once despite the fact that the child may have repeated the same word several times.

Only one observational measure was used for comprehension, that being a multiple choice test whereby the children were asked to choose one of three objects which corresponded to the word given.

The main findings of Study 1 were:

- At 13 months no correlation was found between comprehension and production tasks. The authors state that this is not surprising, as at this age infants typically understand more than they can say.
- Nouns were the most common type of word both comprehended and produced. The more nouns a child knew were indicative of more precocious development.
- Due to the above findings it can be seen that a relationship existed between comprehension and production (at least as far as nouns were concerned).

In the interview production totals averaged 12 words whilst comprehension averaged 48.25 words. Some investigators have argued that a receptive vocabulary of fifty words marks a 'vocabulary burst' similar to that which occurs in productive vocabulary at fifty words typically observed in the second half of the second year (for example, Benedict, 1979). Bates et al (1991) found that half of their sample had reached a receptive vocabulary of fifty words or more, with one child almost reaching fifty words on productive vocabulary.

Lower levels of language production were found in the observation, as expected. An average of 1.69 spontaneous word types was observed, with imitative words averaging .69. Eleven children produced no recognisable speech at all. To control for the possibility that parents overestimated their child's productive abilities Bates et al investigated (1) whether the *pattern* of results in the observational data was consistent with the pattern obtained by maternal report and (2) examined correlations between observational and interview data. It was found that the same pattern of dissociation between comprehension and production totals existed in both the interview and the observational data. In particular, although the imitation and spontaneous production measures were significantly correlated, neither was related to the multiple-choice test of comprehension.

Furthermore, the respective comprehension and production totals in the interview and the observations cross-validate each other: interview and laboratory comprehension scores correlate with each other, but not with observed production; interview production levels correlate with observed productions in both spontaneous and imitative productions, but not with comprehension testing. However, the laboratory based multiple-choice comprehension test did correlate with number of nouns produced. In general it can be stated from these findings that there is a high degree of dissociability between receptive and productive vocabularies at 13 months.

But what of the relationship between comprehension and production at 10 and 13 months of age? At 10 months the only measures taken were parental report on language development. It would be impossible therefore to validate these findings against observational data (although in the present study receptive vocabulary can be validated by the word recognition task to some extent, that is, although the infant may not fully understand what the word means they may understand it enough to recognise that they have heard it before).

In this particular study the children had made significant linguistic advances by 10 months of age. The average number of comprehended words was 17.9, according to parental reports (although some comprehension only took place within certain contexts). Words produced by the 10 months olds were on average 5.7 again, many were within a well-known context such as "hi", 'bye". Words produced also included 'wordlike' sounds such as "mmmmm". Nevertheless it appears that infants begin to produce first words 2 months earlier than usually reported.

In contrast to the findings at 13 months a relationship between comprehension and production was found to be significant at 10 months of age. It was also found that later word comprehension (at 13 months) could be predicted by earlier word comprehension (at 10 months). A further interesting finding is that even though comprehension did not predict later word production *totals*, it appeared to reflect "analysed production" such as referential style and flexible object naming, although this was not a significant finding.

In Bates et al.'s Study 1 and later studies (1991) such patterns of association and dissociation are used to make inferences about underlying language acquisition mechanisms.

At this stage Bates et al's findings suggests that speech comprehension and production are separable. However, comprehension and production are typically related as both increase as a lexicon expands, although at a different rate. It is also possible that these two strands of language depend on different underlying abilities.

Bates et al. (1991) therefore suggested two partially dissociable 'strands' in language development, based on two kinds of acquisition mechanisms:

1. A mechanism responsible for comprehension and for productive, analysed use of the same forms in speech (mainly nouns); and
2. A mechanism responsible for picking up new forms in the sound stream for immediate use in language production, before extensive analysis has taken place.

These two partly dissociable strands sound similar to word form recognition, receptive and productive vocabulary and phonological short-term memory. The first strand appears to have its roots in phonological patterns and word form recognition, suggesting a link with receptive and productive vocabulary. The second strand could refer to word form recognition and its influence in word production and phonological memory performance.

In the first step in investigating these underlying mechanisms it was concluded that "comprehension predicts comprehension and production predicts production, with very little overlap between the two modalities" (Bates et al., 1991, p. 81). The second strand was examined by investigating spontaneous and imitative speech productions at 13 months. During this study (1) Bates et al. failed to assess the contribution of imitation to the 'second strand' in language development. However in their second study, using observations and interviews, it was found that the content of MLU at 20 months is continuous with a 'pure' production strand originating at 10 months, but not with early comprehension. Furthermore it appeared that variation in 20 month MLU was continuous with rote, unanalysed aspects of production from very early language acquisition. Therefore, Bates at al. (1991) concluded that MLU and morphology are continuous with rote aspects of production at the early stages, and that they come under the second strand.

The semantic-conceptual-dialogue was regarded as being continuous with the first, analytical strand, on a continuum with early comprehension and flexible object naming, thereby demonstrating a double dissociation between the strands of development at 13 and 20 months of age. Furthermore, in Bates et al's (1991) subsequent studies it was found that the children who were understanding and producing high proportions of nouns from the earliest stages continue to accrue content words at a higher rate in later stages, these findings were "typical of the more advanced children" (p.111).

In conclusion, it appears that the first strand involves comprehension, as well as those aspects of production that have been analysed and understood by the child. The second strand begins in early production reflecting variance in speech output that is unrelated to comprehension or to productive naming.

The test for multiword comprehension consisted of presentation of a paired series of linguistic commands including both a familiar and unfamiliar command, for example "Kiss the baby" versus "Kiss the ball". Single word comprehension testing used the same multiple-choice test as for Study 1. An interesting finding regarding these comprehension studies is that there was no correlation between the test at 13 and 20 months. Furthermore, the single-word comprehension results only correlated with 2 (interview semantic-conceptual cluster, and interview verb density) out of 22 variables (MLU, 7 clusters, and 14 lexical measures) at 20 months, although these findings were in the predicted direction. Bates et al. (1991) regarded this as enough evidence to place comprehension within the first strand. Multiword comprehension was found to bear no obvious relationship with early language measures, but a relationship was apparent between multiword comprehension and multiword production. This relationship could possibly be due to a developmental increase in either the size or the efficiency of working memory (Shore, 1981). If this is the case, the relationship between single and multiword comprehension found by Bates et al. (1991) could be based on an age-specific shift in the number of units a child can manipulate in working memory.

The findings of the studies performed by Bates et al., which may have a bearing on the present study will now be summarised; it was found in Study 1 that certain types of production align with comprehension, notably the flexible use of object names in a variety of contexts. Those children who have reached this ability at 10 months have supposedly reached the insight that everything has a name. All children eventually reach this stage, but those who reach it at 10 months are ahead of schedule. There was a correlation between words spoken and understood at 10 months, and comprehension at 10 months predicted comprehension at 13 months, production at 10 months predicted production at 13 months. However, by 13 months of age there was no correlation between comprehension and production, possibly due to infants at this age knowing more than they can actually produce. The fact that a dissociation was found at this very young age suggests that dissociations in language functioning begin in the early stages of lexical development and seem to involve rote production versus comprehension and analysis of words and their meanings.

Later studies demonstrate that the ability to comprehend and produce multiword utterances is reliant upon changes in cognitive ability at 20 months. In Study 5 it was found that rote processes were linked to imitation of a novel word when it is first presented, that is, prior to understanding (as in PSTM), therefore imitation belongs to the second strand in this instance. It was further found that the strands of variation that appear in the longitudinal study were not artifacts of 'general intelligence', as discovered by administering and then partialling out, the Peabody Picture Vocabulary Test at 28 months. A sharp dissociation between comprehension and production within the domain of grammar at 28 months, mapping directly onto a corresponding comprehension-production split in the lexicon.

In light of the findings in Study 11 it was proposed that there were actually three, not two dissociable language acquisition mechanisms, which are emphasised at different developmental stages. These are comprehension, rote production and analysed production. The two-strand theory fitted the findings at

13 and 28 months, but at the other age levels findings were unclear. One continuous pathway of comprehension appeared to run through all findings at all ages, flanked by two smaller pathways, from 13 to 20 months the two rote production factors were linked, but this disappeared by 28 months. A new and separate pathway linking the two comprehension factors emerged at 20 months and linked to 28 months.

In the above studies it was found that parental reports were extremely useful in the early stages of lexical development, and the 13- and 20-month interviews were repeatedly validated against concurrent behavioural data. These interviews were generally found to be better predictors of later behaviour than the short-term observations.

Bates et al. (1991), as in the present study, tried to understand language development within a more general framework of cognition, perception, and learning. Bates et al. remain convinced that patterns of variation shown by individual children contain rich information about the universal mechanisms of language learning.

The increase in receptive vocabulary occurs at a somewhat earlier age than does the spurt in productive vocabulary. A typical 12-month-old understands approximately 50 words, but this number may double or triple in just 2 to 3 months (for example, Barrett, 1995; Fenson et al., 1994). At 18 months, the average lexicon size is 110 words. An average toddler at 24 months has a productive vocabulary of slightly over 300 words, 546 at 30 months (Fenson, et al., 1994), and at 36 months this figure leaps to 1000 words (Wehrabian, 1970). Stoel-Gammon (1987) found that a typical 24-month-old is capable of producing a variety of word and syllable shapes and articulating consonantal sounds with a range of place and manner features, which means that infants should be capable of undertaking the nonword repetition task in the present study.

Expressive language is minimal, below 10 words before 12 months of age, increasing to an average of 40 words at 16 months (Fenson, et al., 1994; McCarthy, 1954). Fenson et al. (1994) found that after the age of 12 months individual differences in language production became more apparent. The bottom 10% of the sample produced no speech, whilst the top 10% were producing 26 words or more. A correlation between age and production showed that age accounts for only 22% of variance, leaving age-independent individual differences among children as a major source of variability in word production. At 16 months, children in the top 10% of Fenson et al.'s (1994) sample were producing nearly 180 words, whilst those children in the bottom 10% were producing fewer than 10 words (and, in some cases, no words at all). The expressive vocabulary burst usually occurs between 17 and 20 months. Why the sudden burst? Infants' ability to produce words dramatically increases between

13 and 20 months (Fenson et al. 1993). Prior to this, words tend to be context bound. The most opportune time to study the production by early talkers or infants sensitive to phonological patterns would, therefore be between 14 and 18 months of age.

Gleitman (1994) summarises vocabulary acquisition into three problems that need to be overcome:

1. Children have to achieve knowledge of the concepts that words express
2. Children have to extract recurrent phonological patterns from incoming speech (sensitivity to word patterns leading to word form recognition?).
3. They have to solve what has been termed "the mapping problem", lining up each concept with one of these phonological patterns (solving the mapping problem is a prerequisite to receptive vocabulary. Receptive vocabulary is needed in order to embark on the building of a meaningful productive vocabulary).

This suggests that speech perception leads to being able to recognise familiar sound patterns such as word forms, which, in turn, links to both receptive vocabulary and productive vocabulary. Deficits in vocabulary could reflect difficulty with any of the above processes. Similarly, the same processes should be responsible for more proficient vocabulary acquisition.

Language Disorders

Evidence has been found to strengthen the link between speech perception and production. Grooenen, Maassen, Crul and Thoonen (1996) studied apraxia – a disorder of phonological and articulatory output processes and the assumption that perceptual deficits may contribute to the disorder. Tests of identification and discrimination of synthesised monosyllabic words differing in place of articulation of the initial voiced stop consonants were administered. Analyses of the discrimination performance and articulation data demonstrated a specific relationship between the degree to which auditory process is affected and the frequency of place of articulation substitutions in production. From this it can be inferred that there is an interdependence of word form recognition, as this is reliant on early perceptual abilities, and production.

Phonological development depends on many factors including a child's developmental readiness, as well as facilitative psychosocial factors in the communicative environment. Congruent with this viewpoint is a theory of phonological disorders as an interruption to normal phonological acquisition. Gibbon and Grunwell (1990) proposed five possible reasons why phonological learning may be delayed: The child may be overwhelmed by the phonetic complexity of the sound patterns they are exposed to and find it difficult to abstract new information from the speech environment. Persisting output constraints may be caused by maturational delay. The child's phonological organisation may be habituated and cognitive flexibility inhibited, therefore suppressing the ability to form new linguistic hypotheses or rules. A lack of interpersonal feedback and awareness may compound these problems. The organisation of phonological knowledge may cause difficulty for some children if they cannot cope with variability.

It has been demonstrated that in children with SLI there is a relationship between speech perception deficits and poor speech production (Bishop, 1997). If this is so, then it should follow that there is a relationship between exceptional speech perception and exceptional speech production. Furthermore, Bishop (1997, p.83) states, "In many children with SLI, word learning appears to be affected by problems in phonological memory".

The above review of language disorders suggests that there is a relationship between speech perception deficits such as word recognition, and poor speech production (Bishop, 1997). Furthermore, Bishop (1997) states that word learning can be affected by problems in phonological memory, implying a link between word form recognition and phonological short-term memory.

The above account of the association and dissociation between speech comprehension and production and the tools used to measure progress, that is, the CDI and observational studies, implies that prolific babblers reach the transition to speech at an earlier age than less prolific babblers; this could be accounted for by an individual's sensitivity to word forms, phonological memory or both. However, the most viable concept is that sensitivity to sound patterns at an early age would lead firstly to stable mental representations of sounds and words being formed and these representations would lead to earlier speech production.

Together, the findings reviewed in this chapter show a remarkable preparedness for speech perception, word recognition and productive and receptive vocabulary in human infants. Around a child's first birthday the knowledge of acceptable sound patterns in the native language is present.

Summary

Precocious babblers have been found to develop language more comprehensively and at a younger age than those who are slow to produce vocal motor schemes (McCune & Vihman, 2001). The articulatory filter hypothesis (Vihman, 1993, 2002) demonstrates a link between word form recognition and production of speech in infants. Furthermore it is implied that if an infant's babbling contains a wide variety of sounds similar to those used in adult speech then they will be able to more rapidly produce adult word forms earlier than a child who has a more restricted babbling vocabulary. In relation to the present study this implies that infants who are more voluble more will reach speech production earlier than their less vocal counterparts.

It was also suggested that changes in productive abilities might be linked to changes in memory, whereas increases in comprehension abilities are more likely to be the results of conceptual changes as a result of perception. This implies that word production may be linked to phonological short-term memory in the present study and receptive vocabulary may be linked to word form recognition.

ERP and CDI studies suggested that speech comprehension and speech production are separable. Further evidence comes from Bates et al. (1991), who initially suggested two partially dissociable 'strands' in language development, based on a mechanism for the comprehension and production of known words and new words. However, due to their very nature within vocabulary acquisition productive and receptive vocabulary may be related at the early stages, but will diverge when infants understand more than they can say. The two strands will realign in later years as production catches up with comprehension.

Bishop (1997) in her SLI research demonstrated a relationship between speech perception deficits in recognising phonological patterns and poor speech production, implying a positive relationship exists between word form recognition and speech production. Therefore, if an individual is good at, or sensitive to, picking out phonological sound sequences this should, by implication, be reflected in their speech production.

The CDI has received mixed reviews. Some researchers claimed it was more reliable than observational studies, whilst other researchers implied that parents underestimate their child's production and overestimate receptive vocabulary. Hallé and Boysson-Bardies (1996) proposed the head turn procedure as the most effective method of measuring a child's sensitivity to phonological patterns. This suggests that a study using all three methods of measurement, such as the current study proposes to, would give a clearer overview of linguistic knowledge.

It seems reasonable, in light of the above evidence, that children's phonological knowledge is reflected in their perception and word form recognition, and that their early productions are an artefact of word form recognition as this takes place before word production begins. Therefore, perception is more advanced than production suggests.

To conclude, this chapter has reviewed evidence suggesting comprehension and production to be separable, and that sensitivity to phonological patterns may be linked to receptive and productive vocabulary, and word production may be linked to phonological short-term memory. This leaves the question of whether sensitivity to word forms is associated with phonological memory, can it be directly linked, or are comprehension and production the mediators?

Chapter 2, main points, and implications for the present study:

1. **Main point:** Comprehension and production are initially correlated, but then diverge as a child learns more than they can say. Later these strands realign. Comprehension levels predict later levels, and production levels predict later levels.

   Implications: We would expect the CDI measures of receptive and productive vocabulary to be related early on then dissociated. Early levels of comprehension and production will predict later levels.

2. **Main point:** There has been some controversy over the effectiveness of certain measures of receptive and productive vocabulary.

   Implications: Using three methods, namely the head-turn procedure, parental measures (CDI), and an observational measure would be beneficial in cross-validating these measures.

3. **Main point:** An infant's ability to produce words dramatically increases between the ages of 13 and 20 months.

   Implications: Two ages within this range would be the ideal age at which to study individual differences in language production.

4. **Main point:** Precocious babblers reach word production earlier than their less voluble counterparts. A relationship has been found between speech perception deficits and poor speech production.

   Implications: There may be a link between word form recognition and production. Exceptional word form recognition may lead to exceptional language production.

Chapter 3

Phonological Short-Term Memory

Phonological short-term memory has been proposed as a predictor of vocabulary acquisition (Gathercole and Baddeley, 1989a). Phonological memory is a cognitive skill that can account for some differences in language learning. Gathercole and Baddeley (1989a) found that children with better phonological memory skills had more advanced vocabularies at five years as predicted by their memory skills a year previously.

Memory is thought to play an important part in recognition of speech sounds. Phonetic categories are at least partly language and accent specific, so they must be learned and stored in long-term memory.

The repetition of nonwords, or unfamiliar phonological sequences, is a more effective measure of memory span than digit span or real word repetition (Gathercole and Baddeley, 1989b), as the phonological memory system has to encode and maintain the unfamiliar nonword in order to aid its articulatory output. The phonological store temporarily maintains information whilst more phonological long-term representations are constructed. The larger a nonword an individual can repeat, the larger their phonological memory.

Phonological memory is capable of enhancing word production and nonword repetition through access to stored memories of past exposure to co-occurring lexical strings. This implies that word form recognition could be a prerequisite for phonological short-term memory.

The Working Memory Model (Baddeley & Hitch, 1974, 1986)

The multi-component model of working memory was developed from an earlier concept of short-term memory, which was assumed to comprise only a unitary temporary store (Atkinson & Shiffron, 1968). However, this earlier model could not account for defective short-term memory in some individuals with normal long-term memory. The working memory model (introduced by Baddeley and Hitch in 1974 and refined by Baddeley in 1986) consists of three components; an attentional control system, the central executive, aided by two subsidiary slave systems, the phonological loop and the visuospatial sketchpad. This model has been successful in accounting for developmental changes in verbal short-term memory throughout childhood. The subsystem of working memory known as the phonological loop is specialised for the maintenance of linguistic material. The loop consists of a phonological store and an active rehearsal process involving subvocal articulation to maintain decaying phonological representations (see Figure 3.1).

Verbal material is stored in the phonological store, in a phonological code, and this decays over time. The rehearsal process recodes nonphonological inputs, such as printed words, so that they can be held in the phonological store, while verbal speech can gain access to the phonological store directly, without the articulatory process.

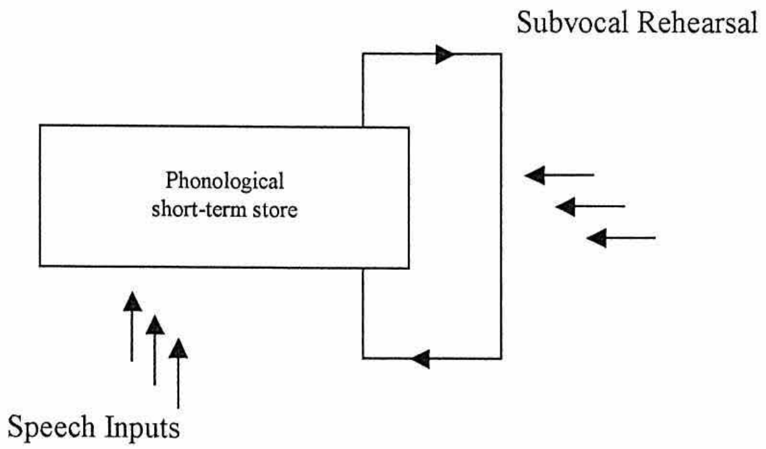

Figure 3.1. The phonological loop model, based on Baddeley (1986)

Much experimental evidence led to this particular phonological loop model being devised, supported by studies of neuropsychological patients with deficits that appear to correspond to the subcomponents of the loop. A brief summary follows.

Articulatory Suppression

Articulatory suppression involves individuals repeatedly saying irrelevant material, such as 'the, the' the'. It has been demonstrated that memory for printed lists of words is greatly depressed during articulatory suppression (Peterson & Johnson, 1971). The working memory model assumes that the disruptive effect of articulatory suppression is caused by the decreased ability to be able to rehearse. Phonological coding is therefore disrupted and subvocal rehearsal prevented. This results in the inability to refresh the contents of the phonological store, so items will immediately decay, and not enter into longer-term memory. Therefore, memory traces in the phonological store fade unless refreshed by rehearsing the trace within the articulatory control process, which then feeds it back into the store.

Baddeley, Gathercole and Papagno (1998) purport that the function of the phonological loop is to aid the learning of new words, not to remember familiar words as such. The repetition of familiar words or digits within phonological short-term memory could be enhanced by lexical knowledge held within long-term memory (Hulme, Maughan & Brown, 1991), as they may possess similar phonological properties or meaning. The repetition of nonwords, as unfamiliar phonological sequences, has been found to be a more effective measure of memory span (Gathercole & Baddeley, 1989b), as the phonological system has to encode and maintain the unfamiliar nonword in order to aid its articulatory output. The phonological store temporarily stores information whilst more phonological long-term representations are constructed. The larger a nonword an individual can repeat, then the larger their phonological short-term memory.

Neuropsychological studies of brain-damaged, and non brain-damaged, patients have led to theories suggesting the involvement of phonological short-term memory as a major contributor to vocabulary acquisition in the learning of new words (for example, Gathercole & Baddeley, 1989a; Gathercole et al., 1991a). Furthermore, longitudinal studies have suggested that phonological memory span can predict vocabulary or subsequent language acquisition in children (Gathercole & Baddeley, 1989a). However, phonological memory skills are not so influential in later vocabulary acquisition as other skills may come into play such as semantic and conceptual skills (Gathercole et al., 1991a) in the learning of abstract words and new concepts. One such skill that influences later vocabulary is reading, therefore, from about eight years of age phonological memory span becomes less of a major contributor to language learning as reading skills begin to enhance vocabulary acquisition (Gathercole et al., 1991a)

This section will now cover language disordered adults and children in an attempt to discover whether their disability is due to a deficit in phonological short-term memory or a deficit in some other cognitive ability such as segmentation and subsequent word form recognition.

Neurological evidence for a defective phonological store

The study of PV, performed by Baddeley, Papagno and Vallar (1988) found normal phonological output skills, yet PV was unable to learn new nonwords or foreign words via auditory presentation, and could only repeat nonwords of one or two syllables. The study of PV provides evidence for a damaged phonological store which was unable to hold phonological information long enough to be encoded within long-term memory. The evidence suggests that phonological short-term memory plays a major role in the learning of unfamiliar phonological sounds and subsequent incorporation of the new material into our vocabulary. However, there is another case that represents a paradox to the hypothesis that phonological short-term memory is of major importance in the acquisition of new words. SR had a low nonword repetition and digit span, but still managed to acquire a 'normal' vocabulary range and function at a high level across a range of intellectual tasks (Trojana & Grossi, 1995). PV's phonological deficit had occurred after she had acquired the majority of her natural vocabulary, but SR's deficit appeared to be due to a developmental disorder beginning in childhood. The question arises as to how SR acquired such a large vocabulary. Baddeley et al. (1998) suggest that SR's vocabulary was acquired due to his "general intelligence and motivation", and his "cognitive and educational advantages" (p.7). One such 'cognitive advantage' could be segmentation and word form recognition abilities, as discussed previously.

Deficits of phonological short-term memory in language disordered children

Gathercole and Baddeley (1990a) attempted to find evidence to support the hypothesis that a deficient phonological working memory could be a contributory factor in language impairments, such as poor vocabulary development and poor reading ability. Gathercole and Baddeley selected children with vocabulary, comprehension and reading problems, but who had normal nonverbal intelligence. The children were matched to two groups, with the first group being matched on age and nonverbal intelligence scores. The children in the second group were approximately two years younger and were matched on vocabulary and reading ability. Gathercole and Baddeley tested the children on their ability to repeat nonwords and found that the language-disordered children were poorer at repeating three and four syllable nonwords than the two control groups.

The results were taken to provide direct support for the hypothesis that phonological memory deficits are of major importance in the language development problems experienced by language disordered children, and that differences between the groups were due to the contributions of phonological working memory. However, other possibilities are plausible, for instance other, nonmemory, deficits such as impairments in temporal sequencing, perception and segmentation (Tallal & Piercy, 1975; Tallal et al., 1996) could account for poor nonword repetition and vocabulary growth.

Tallal et al. (1996) studied language-learning impairments in aphasic children who had normal short-term memories. They found that the children's difficulties in understanding fast-changing speech components could be improved by improving their segmentation abilities. Tallal et al. (1996) exposed the children to 'stretched' speech via a computer that slowed down the speech enough to enable segmentation and word form recognition to take place. With practice, and continually decreasing the time between sounds, the children could eventually understand normal speech. The findings suggest that slow, clear, prosodically exaggerated speech is easier to segment and can be an important factor in giving a child a head start in acquiring new words (such as Motherese, the type of speech directed towards infants). In addition, the findings cast doubt on Gathercole's work by suggesting that phonological short-term memory and repetition are not the major contributors and predictors of vocabulary acquisition and new word learning and may, themselves, be reliant upon a third factor, such as segmentation through exposure and sequence analysis perhaps?

The ability to learn and recognise sequences such as familiar words, and to segment sounds, may indeed be the key to vocabulary acquisition. After all, one has to correctly perceive and analyse a new word by segmenting it into phonological sequences prior to storage in phonological short-term memory. It may be that sequence learning and subsequent segmentation may be the source dictating the performance in nonword repetition (Snowling, 1981; Snowling et al., 1986). It therefore follows that if an individual has a strong ability to learn and recognise sequences such as familiar words, these words could be a stepping stone to learning, or at least repeating, less familiar words with a similar sounding word structure, such as English-like nonwords.

Papagno, Valtentine and Baddeley (1991) suggest that increased phonological short-term memory use is apparent in adult word learning. Using articulatory suppression to disturb retention by preventing rehearsal in phonological short-term memory it was found that there was a greater impairment in the recall of foreign words than of familiar words. The findings therefore suggest that the phonological loop is involved more directly in learning unfamiliar words than words that have phonologically familiar material of which individuals have previously stored knowledge. However, there is a point here worth querying. Papagno et al. (1991) stated their was a 'greater impairment' in recall of words, yet learning was not impossible even though the phonological loop was 'busy' with other tasks. The fact that some learning went on despite articulatory suppression suggests acquisition was established via other methods. So, can we learn words without rehearsal in the phonological loop?

Papagno et al's (1991) study and Ellis & Sinclair (1996) have suggested that phonological short-term memory contributes to vocabulary acquisition through repetition and rehearsal of novel words promoting long-term consolidation. If the novel word cannot be rehearsed due to articulatory suppression then no learning should occur. However, other evidence suggests that articulation and repetition are not needed in the process of receptive vocabulary acquisition. Exposure to a word may be enough, for example babies can learn to understand language and segment sequences even before they have the ability to repeat words. Saffran et al. (1996) demonstrated that eight-month-old babies learn to recognise phonological segments of unfamiliar speech after only two minutes exposure, lending support for the argument that repetition is inconsequential for the functioning of the phonological loop.

Furthermore, just one exposure to a novel word is enough for acquisition to take place according to Carey and Bartlett (1978). Under experimental conditions children were asked to fetch the 'chromium' plate, a word they had never heard before. One week later fifty percent of the children remembered the word. Carey and Bartlett put forward the idea of 'fast mapping' whereby a child maps a word after one exposure but that word can still be open to alteration and updating in long-term memory if needed.

To summarise so far, there have been theories postulating that:

(a) Vocabulary knowledge of children during early school years is linked to phonological memory ability and children with low ability have been found to be slow at learning novel names in experimental tasks. Phonological short-term memory is also a strong predictor of second language acquisition.

(b) Studies of language disordered children and neurological studies have revealed a deficit of phonological working memory.

(c) Studies of adults and children learning unfamiliar (either foreign or non) words have shown that ease of learning is influenced by articulatory suppression, phonological similarity and word length, which are all factors believed to influence the phonological loop.

Other studies, however, have put forward opposing views, suggesting that vocabulary acquisition, or at least part of vocabulary acquisition, can be attributed to other abilities, such as segmentation and recognition of sequences within the linguistic environment via exposure to streams of speech. Phonological short-term memory and segmentation abilities differ in that segmentation appears to be based on pattern recognition (such as the pattern of certain words) and the learning of statistical regularities on a long-term basis. Recognition of a meaningful lexical unit can be facilitated if it has been heard before (such as familiar words used often in the home for infants), therefore reaction times will be quicker, or looking time longer, due to previous exposure (priming). Phonological short-term memory, on the other hand, is more concerned with the learning of new words via a short-term store that enhances repetition (repetition can also enhance the trace in the store) and subsequent long-term construction.

There are also similarities between the two abilities: Both are influenced by individual differences and both are probably needed for the acquisition of vocabulary through their different functions. The differences and similarities between phonological short-term memory and word form recognition, will be discussed in more detail after the data collection and analyses have been completed for the current study, hopefully making the distinction clearer.

In 1994 Gathercole et al. expressed doubts as to whether experimental techniques could be developed to distinguish segmentation and subsequent word form recognition from phonological memory processes. The present study is an attempt to tease apart these processes, even though the representations in the phonological loop are the direct products of the segmentation process. It appears that Gathercole and associates acknowledge that perception and segmentation contributes to vocabulary acquisition but have trouble visualising a method to test these abilities which will enable the phonological processes of vocabulary acquisition to be further deconstructed, just as 'memory' has been in the past.

A fourth component called the episodic buffer has recently been added (Baddeley & Wilson, 2002). The episodic buffer was added to the revised model of working memory to explain the pattern of individuals with good immediate but poor delayed prose recall. The episodic buffer is assumed to be a limited capacity system that is episodic in the sense that it can integrate information from many sources into a single episode. The phonological loop could not explain the articulatory suppression effect. According to the model suppression by continually uttering an irrelevant word such as 'the' should prevent the subsequent rehearsal and retrieval of words to be memorised. Suppression does have a significant effect, though not a totally devastating one. In a typical study, auditory memory span might drop from seven to five digits. Furthermore, individuals with grossly impaired phonological short-term memory, resulting in an auditory memory span of one digit, can typically recall about four digits with visual presentation. Baddeley and Wilson (2002) wished to know how such digits are stored. They questioned how information from different sources is integrated, and where the chunks are stored: in the phonological loop, in long-term memory, or in a third back-up store. Baddeley named this third store as the episodic buffer. The episodic buffer differs from long-term memory. Long-term memory holds long-term representations, whereas the episodic buffer is capable of manipulating representations in a novel and creative way. Baddeley and Wilson (2002) give the example creating a totally novel image, such as, "An elephant singing an aria from Madame Butterfly, while accompanying herself on the ukulele", a process that goes beyond the simple activation of existing representations. This would be useful in the language acquisition stages where sentences and words are put together in orders never before produced by the individual.

Findings from a range of studies converge on the view that both components of the phonological loop (the store and rehearsal process) are in place by the time a child reaches 4 years of age (for example, Baddeley, Thompson & Buchanon, 1975). Due to the suggestion that phonological memory capacities are too underdeveloped to be tested in children below four there has been relatively little investigation into the phonological working memory skills of very young children. Gathercole and Adams (1993) have, however, tested 2- to 3-year-olds with some success using the conventional memory procedures of digit span, word repetition and nonword repetition, suggesting that the phonological loop comes into play at a much earlier age, although it is the general opinion that the rehearsal process is not needed at this very young age (see the review of the phonological loop model, this Chapter).

The relationship between phonological short-term memory and speech production

Bronwell (1988) investigated the relationship between memory span and spontaneous language production in children at the early stages of language acquisition. The aim was to examine any existing parallels between children's ability to produce integrated sequences of discrete behaviours in the second year. Between 12 and 30 months children become more adept at combining sequences such as the transition from one to two word utterances (for example Fenson & Ramsay, 1980), an increase in the combinatorial complexity of motor imitation (for example Bronwell, 1982), an increase in problem-solving skills (DeLoache, Sugarman, & Brown, 1985), interactions with peers (Bronwell, 1982), and so on. Therefore it is fair to say that an increase in combinatorial skills emerges at this age. Few studies have examined age-related convergences between the different combinatorial domains, although Shore, O'Connell and Bates (1984) found a relationship between limited language and gesture at 20 months of age. Bronwell decided to study the relationships between peer interaction, language, pretense play, and manipulative play with objects, social play with an adult and motor play. Bronwell chose these domains, as they had not been previously examined together, although separately each domain had been shown to increase in complexity within the second year.

Thirty-three day care children of two age groups participated. Sixteen children were in the 18- to 22-month-old group, and 17 were in the group aged 24 to 30 months of age. Each child participated in three 15-20 minute sessions over a period of two weeks. During the first two sessions the researcher modeled certain play activities, which the child was encouraged to imitate. These included object play, pretense play, social play and motor play, such as stirring in a cup, stirring in a bowl. Some behaviours were labeled as familiar (on the basis of pilot testing) and some unfamiliar. A total of 28 imitation items over the four domains were included for each child. The third session was unstructured free play with a same-sex, same-age peer – a standard set of toys was provided at this stage. All sessions were videotaped and coded by independent observers for imitation of combinations or parts of combinations, for number of discrete social behaviours in each peer-directed social interaction, and for number of words in individual utterances.

Three main questions were asked:

1. Whether there were age differences in combinatorial skills within each of the domains observed.
2. Whether there were correspondences across these domains in combinatorial skills.

3. Whether the hypothesised task demands manipulated in the imitation sessions affected performance, and if so, if those effects interacted with age.

Findings showed that in all cases the older children produced more combinations than the younger children. Relations emerged in the expected direction. Relations amongst all four domains in the imitation sessions were strong, that is, children who demonstrated combinations of two or three components in one behavioural domain also did so in the other domains. There was also a relationship between the number of components children combined during imitation, the number of words they combined in their spontaneous language utterances, and the number of behaviours they combined into peer-directed social interactions.

The findings indicate that a young child's thoughts grow in complexity in that the child has increased ability to "conceptualise, remember and produce specific relations among multiple, independent entities in the world" (p. 681). It is interesting to note that there appears to be a general developmental constraint on certain behaviours before age two, such as language and complex imitative play, likewise after this age an increased level of all combinatorial complexity behaviour occurs.

Two views have emerged to explain the above findings. One follows in Piaget's footsteps – the child makes a transition to symbolic thought at about 18 months which permits the child to encode, store and retrieve associations between two entities to guide their own behaviour. The second train of thought suggests that an increase in memory or information processing capacity occurs in the second year which enables the child to remember and to plan future sequences more adeptly (for example, Shore et al., 1984).

It was also found in this research that children found it easier to reproduce familiar combinations as opposed to unfamiliar, and shorter rather than longer combinations. In conclusion this research has found that there may be a general growth in combinatorial ability as a child grows, suggesting that the same skill contributes to the planning and coordination of behaviours in the production of sequences in the domains of language and behaviour imitation. The implication is that early social interactions may be influenced by general, age-related cognitive constraints.

Blake, Austin, Cannon, Lisus and Vaughan (1994) extended these findings regarding the relationship between word span and language imitation in 2 to 5 year olds. The basic question was whether individual differences in memory span would predict both spontaneous and imitative language productions. It was found by Blake et al (1994) that word span predicts the complexity of sentence imitation in infants in the early stages of language acquisition regardless of age. This experiment therefore highlights individual differences in speech production and the relationship between memory span and speech production (Blake et al., 1994). It was concluded that although phonological skills are important in vocabulary acquisition, it was doubtful whether preschool children used rehearsal (Kail, 1990). This is in line with the phonological loop model based on Baddeley (1986). Since infants are sensitive to, and do, imitate sound patterns in their surroundings from very early on it is reasonable to assume that the phonological loop is in place and in working order from as soon as a child is able to babble, or at least from the production of first words.

The question that Blake et al. (1994) address is whether memory constrains complex sentence production and whether span limitation lessens with age. Children know more than they can produce, is this simply because their memories cannot hold the traces long enough at this age to facilitate speech production?

The relationship between memory and language is supported by findings that language-delayed children have a more limited memory span than non-delayed children. Menyuk and Looney (1976) found that only language-disordered children had difficulty in repeating sentences of three or more words. Kushnir (1986) found that preschool children with language delay had significantly lower memory spans on both auditory memory tasks and a name-the-missing-object task compared with typically developing children matched on age, sex and nonverbal general intelligence. As Blake et al. (1994) state, " Direct tests of the proposal that language complexity is constrained by memory span in typical children is rare" (p.92), although vocabulary knowledge and phonological short-term memory have been tested (see Gathercole's work). However, Bronwell (1988) found a relationship in pre-schoolers between an action memory task and the number of words in their spontaneous utterances. Daneman and Case (1981) found that production and comprehension of nonwords (nonwords were paired with a corresponding action) were predicted more by memory span than by age in 2- to 6-year-old children. A more detailed review of Blake's work follows.

Thirty-one children between the ages of 32 to 59 months participated in Blake et al.'s (1994) study. For statistical analyses the children were divided into two groups, those aged over 3.5 years and those aged below 3.5 years of age. An initial speech sample of each child was obtained and recorded while the experimenter conversed with each child individually whilst the child played with a small set of toys. A mean length of utterance (MLU) was obtained for each child. Two tasks were undertaken, a word span task and a sentence imitation task. The word span task involved the children repeating the names of 19 common animals with either one or two syllables, two to six animals at a time in a list. The sentence imitation task consisted of two lists of 22 sentences that varied in length, semantic complexity and syntactic complexity. Two vocabularies were used, a circus and a farm vocabulary. A Snoopy puppet, who said the sentences twice before the child was asked to repeat it, presented the sentences.

The results showed that MLU differed between the two age groups, as did both language measures. The over 3.5-year-olds scored significantly higher. For the whole group (both the younger and older children together) sentence imitation was significantly related to both MLU and word span, however, MLU and word span were not significantly correlated. However, for the younger group MLU and word span were significantly correlated. In fact, for the older group MLU was not significantly correlated with any of the other variables, including age.

The interpretation of these findings was that the relationship between memory span and sentence imitation could not simply be attributable to age, but that "both word span and age are significant predictors and account for unique variance in sentence imitation scores" (p.99). Age, therefore cannot be the only factor in the relationship between memory span and sentence imitation as the reverse could also be true, that is, that much of the age effect could be attributable to memory span. The authors view this theory as more appealing as memory span is a more specific variable than the global factor of age.

Since the sample was small in the young age group the authors embarked on a second experiment with 23 children in order to confirm the relationship between memory span and MLU at the early stages of syntax. In addition, this second experiment was to examine the possibility that the relationship found between memory span and MLU might be entirely due to an underlying mental ability variable, or g-factor, therefore a measure of intelligence was also administered.

The language and memory tasks were as in Blake et al.'s first experiment, with a slight variation in presentation of the animal names. The Merill-Palmer Scale of Mental Tests (Stutsman, 1948) was used as an intelligence measure. This measure included both verbal and nonverbal measures and gave a mental age score to be used in the statistical analyses. It was found that MLU and word span were correlated with chronological age, word span more so than MLU. MLU and word span also correlated with each other, as did chronological and mental age. Regression analyses were then conducted to find which were the best predictors of MLU. Word span was found to be the most powerful predictor, mental age accounted for a small amount of additional variance, with chronological age adding nothing of any value.

These results replicate Blake et al.'s original findings and were actually stronger in demonstrating that memory span is a better predictor of spontaneous language complexity than age. Furthermore, the relationship between memory span and MLU was not due to mental age (as measured by the general intelligence task). Only memory span was a significant predictor of MLU. The sample sizes used were small, but since Experiment 2 replicates Experiment 1 the findings appear more reliable. The authors interpret the findings as support for the notion of a programming constraint on productive language complexity and that such a constraint is general in that it applies to both imitative and spontaneous measures of language. However, in Experiment 1 no relationship between word span predicting spontaneous language complexity in the older children was found. This appears to imply an age limit on the operation of a memory constraint in respect to MLU at least. Spontaneous productive complexity appears to be limited by memory span at the early ages of syntax when more effortful attentional processing of morphemes is required. It could, however, be argued that the opposite is true, that is, that higher MLUs and better articulatory skills enhance memory span due to the correlational nature of this work. But, if this were true, then it could be expected that this relationship would be present in older children, that is, that more complex spontaneous language would lead to higher MLUs. This was not found in Experiment 1 with the older children. MLU and memory span were not related in older children and the older age group did not have larger memory spans than the younger group.

The findings appear to support Baddeley's working memory model (1986) in that productive articulatory abilities were related to memory. Baddeley opines that all developmental increase in memory span can be explained in terms of the articulatory loop, thereby implying that speech rate increases with age, leading to faster rehearsal and improved memory. However, Blake et al. prefer a more general capacity model, not tied to the articulatory loop, as they doubt that preschool children use rehearsal. They prefer the notion that phonological skills are reliant upon phonological representation and probably, therefore, phonological storage. However, Blake et al.'s findings cannot go beyond those of language production. As Blake et al. are aware, support for a general capacity model like *M*-power (Pascual-Leone, 1987) would require prediction of their language measures from a nonverbal measure of memory. They state that, " a purely speech-based model, which stresses articulatory rate, misses what we believe to be the essential abstract nature of the constraint on linguistic rules and structure, i.e. on underlying phonological, syntactic, and semantic representation" (p. 105).

In conclusion, Blake et al. (1994) view their work as supporting a model of capacity constraints on language production. Further research is needed to strengthen the case for a causal interpretation that it is processing capacity that underlies early language acquisition.

The Pascual-Leone (1970, 1987) model of working memory is an alternative model of working memory that originates from an entirely different starting point to Baddeley and Hitch's (1974) model. The Pascual-Leone model originated from the neo-Piagetian perspective, which accounts for cognitive development in terms of information processing within a limited capacity working memory. Baddeley and Hitch's model was developed originally to explain short-term phenomena in adults, although it has now been applied to the development of short-term memory in children (for example, Hitch, Halliday, Dodd, & Littler, 1989). The following model is therefore concerned with explaining and predicting the development of working memory in children.

The Pascual-Leone (1970, 1987) Model of Working Memory

The model was proposed to account for the development of attentional capacity (Pascual-Leone, 1970; Pascual-Leone & Morra, 1991: Pascual-Leone & Baillargeon, 1994), with two levels of psychological constructs; schemes and hardware operators. Schemes refer to the basic units of cognition and as such carry information and situation specific constructs. They can be figurative or operative and differ in content and modality. Executive schemes are a subdivision of the operative schemes and are responsible for the control of performance. In contrast hardware operators do not carry information. They are 'content-free processing resources' (Kemp, De Rammelaere, & Desmet 2000, p.90). These resources represent functions such as mental attention and structural learning. The following operators have been proposed; a content-learning operator, an effects operator, which minimises the complexity of performance, an interrupt (I) operator which inhibits task-irrelevant schemes, and a mental energy (M) operator which boosts the activation of task-relevant schemes. In the Pascual-Leone model cognitive performance is proposed to be due to the interaction of schemes and hardware operators. When an input is given a number of schemes are activated constituting the 'field of mental attention' or working memory. The selection and activation of these schemes depends on three mechanisms: the M-operator, the I-operator, and the executive schemes.

The M-operator, M-capacity or M-power refers to the maximum number of discrete chunks of information or independent schemes that can be activated within a single mental operation. The size of the M-operator is limited, yet increases in correspondence with the developmental Piagetian stages as a function of chronological age. It has been demonstrated that M-capacity increases by one unit every second year, from 1 unit at age 3 years to the adult capacity of 7 units at age 15 years (Johnson, Fabian, & Pascual-Leone, 1989;Morra, Moizo, & Scopesi, 1988). Maturational growth in M-capacity can account for developmental changes in cognitive performance such as language (Johnson et al., 1989).

Comparison of the Two Models

At first glance it appears that the two models are contradictory. Studies based on Baddeley and Hitch's model failed to initially formulate any developmental predictions as work was carried out mainly with adults, whereas Pasual-Leone's Model was developed purely for investigating the age-related increase in working memory capacity. Furthermore, Baddeley regards working memory as a system with its own specific processes, whereas Pacsual-Leone considers working memory to be an activated subset of long-term memory. The central attentional component of working memory (the M-operator) has received most of the attention by Pascual-Leone's perspective, whilst it is the peripheral phonological and visuo-spatial components of Baddeley and Hitch's model that have received the most attention.

However, rather than being contradictory the two models actually complement each other. Both models assume working memory to be a nonunitary system. Both models can account for an age-related increase in the size of working memory (Baddeley, 1986; Pascual-Leone, 1970). Pascual-Leone accounts for cognitive development by the increase in M-capacity every other year, whilst Baddeley accounts for the development of verbal span in terms of an increase in articulatory speed.

In 1994 Ribaupierre and Bailleux conducted a longitudinal study to examine the development of attentional capacity in line with Pascual-Leone's model. During the study it was realised that the findings could also be interpreted in light of Baddeley and Hitch's (1974) working memory model. Ribaupierre and Bailleux (1994) examined the attentional capacity of four groups of children aged 5, 6, 8, and 10 years with a short-term spatial memory task adapted from Case (1985), Mr. Peanut. This task involved presenting the child with a clown figure with coloured dots placed on different parts of its body. The figure was then removed and replaced with a blank clown figure. The child had to recreate the original figure and place coloured dots where they were on the original. Two versions were used: a unicoloured task (Peanut-P), in which participants had to recall the positions of the dots, and a multicoloured task (Peanut-C), in which participants had to recall both the positions and the colour of the dots.

The data was compatible with both models of working memory, with each model being stronger for different sets of findings. For instance, performance on Peanut-P increased steadily with complexity, while performance on Peanut-C tended to stabilise beyond a certain level of complexity – this could be interpreted within Pascual-Leone's model. Alternatively, the drop in performance in the fourth year could be accounted for by Baddeley's model due to the computerization of the task. Responding with a computer mouse relies on the same sub-system as the Mr. Peanut task, that is, the visuo-spatial sketchpad, leaving fewer resources for recall. Due to its assumption of independent subsystems for verbal and visuo-spatial material, Baddeley's model was also more apt to interpret the finding that using the mouse interfered more with the recall of positions than colours. Therefore the authors concluded that the two models were complementary rather than contradictory.

Kemp et al., (2000) further explored the complementarity of the two models by extending the work of Ribaupierre and Bailleux (1994) to establish whether the complementarity of the models holds both ways, that is, does the Pascual-Leone model also complement Baddeley and Hitch's model?

The development of working memory was assessed in 60 Belgian children in four groups of ages 5, 6, 8, and 9 years using the Mr. Peanut task (as above) and the visuo-spatial Corsi block task (Milner, 1971). This task consisted of a set of nine black blocks arrayed in a quasi-random pattern, the researcher tapped a sequence of blocks and the participant was required to tap out the same pattern immediately afterwards. It was hypothesized that both tasks would show an age-related increase in performance – in line with Pascual-Leone's model, and that performance on both tasks would diminish when administered with concurrent verbal suppression – in line with Baddeley's perspective that at a young age visuo-spatial coding is complemented by phonological coding.

Both hypotheses were confirmed, that is, both tasks yielded a developmental trend in performance, and verbal suppression caused a substantial impairment in the performance of the older children on the Mr. Peanut task, but did not interfere with recall in the younger group. This difference between the age groups was not expected according to Pascual-Leone's theory. However, it can be explained with regard to Baddeley's account of working memory. The effect of articulatory suppression in the older group is documented as a developmental trend for verbal recoding of visually presented information (Halliday, Hitch, Lennon, & Pettipher, 1990; Hitch, Halliday, Schaafstal, & Schraagen, 1988). Younger children are thought to retain pictorial material in visual form, therefore articulatory suppression has no effect with visually presented stimuli. However, older children, who have access to the articulatory loop, recode visual information into a verbal form for the purpose of short-term retention, therefore articulatory suppression had an effect on visually presented stimuli. In other words, to aid memory of where the coloured dots were on the clown the older children probably remembered the name of body parts, whereas the younger children just remembered where the dots were in spatial terms. The 6-year-old group was just beginning to demonstrate the effect of subvocal rehearsal, suggesting this is the age whereby children begin to facilitate spatial processing with verbal encoding.

Articulatory suppression had no effect whatsoever on the Corsi block task. This can be explained by the dissociation between verbal and visuo-spatial processing. This result can also be explained in terms of Pascual-Leone's model by referring to the distinction between activated schemes according to modality and mode. The available M-capacity is allocated to linguistic schemes (articulatory suppression) and to spatiotemporal schemes, which support the spatial encoding of the Corsi blocks.

Both models converge with respect to the idea that there is an age-related growth in working memory capacity, but the models differ in their underlying assumptions. As stated earlier Pascual-Leone's M-capacity increases according to Piaget's qualitative stages of cognitive development, whereas Baddeley attributes the development of verbal working memory to an age-related increase in articulation. As far as language is concerned research has shown (for example, Vaquero, Rojas, and Niaz, 1996) that performance in language courses could be better explained by Baddeley's model which postulates simultaneous storage and processing of information, yet performance in science courses could be best explained by a model that posits the processing of a large number of bits of information at the same time, that is, Pascual-Leone's model in this instance.

In light of the above research it is probable that the current research will have more in common with Baddeley's model of working memory than with Pasual-Leone's as this study is language based. However, performance on the longitudinal tasks such as the Oxford CDI will steadily increase with age, which could be accounted for by both models.

Phonological short-term memory and receptive vocabulary

There is increasing evidence of a link between children's phonological short-term memory abilities and vocabulary acquisition and the development of both reading and language comprehension abilities (for example, Gathercole, Willis, Baddeley, & Emslie, 1994). The children tested by Gathercole and Adams (1993) showed high correlations between word and nonword repetition tasks and later receptive vocabulary knowledge. Several differing interpretations of the findings were proposed including the suggestion that memory test performance was directly influenced by the children's knowledge of the stimuli to be repeated. In plain terms, it was suggested that linguistic knowledge, held within long-term memory, supplements and enhances phonological working memory (Hulme, Maughan, & Brown, 1991). If long-term representations possess similar phonological properties, or meaning, as the word to be repeated, then production may be enhanced. This implies that the recognition of words and sound sequences could enhance performance on phonological short-term memory tasks.

In a longitudinal study of 4- to 8- year-olds Gathercole, Willis and Baddeley (1991) found a positive relationship between vocabulary and nonword repetition ability. For the first three years of the study the correlations between scores on the nonword repetition tests and receptive vocabulary tests were highly significant. These correlations were less significant by age eight due to reading skills aiding vocabulary learning. Furthermore, the relationships between nonword repetition and vocabulary scores remained significant even after controlling for possible confounding factors such as age and nonverbal intelligence. The correlational relationship between nonword repetition and vocabulary acquisition appears to be consistent with the hypothesis that short-term phonological memory contributes to the long-term phonological learning of new words. However, correlations do not establish causality, let alone the direction of causality. The results could just as easily be viewed as being consistent with Snowling, Chiat and Hulme's (1991) opposing view that children use existing word pattern knowledge to enhance repetition of nonwords, especially if the nonwords have a similar phonological structure to real words, that is, a high word-likeness. Snowling et al. (1991) suggest that nonword repetition ability may be dependent on other language skills such as vocabulary development rather than contributing to them; again implicating speech perception in the context of word form recognition as a possible factor.

Knowledge of phonological regularities (from long-term memory of lexical knowledge) has been shown to influence phonological short-term memory (Bailey & Hahn, 2001). For example, English-like nonwords are easier to repeat than nonwords or foreign language words that do not resemble native language words (Ellis & Beaton, 1993; Gathercole, 1995a, 1995b).

To establish directional causality and dispel Snowling et al.'s (1991) theory, Gathercole et al. (1991) carried out cross-lagged correlations. They found that the causal link between phonological memory and vocabulary knowledge changed during the course of the longitudinal study. Between ages 4 and 5 years, early nonword repetition scores were more closely associated with later vocabulary knowledge than early vocabulary was with later repetition scores. The results of the cross-lagged correlation lend support to the hypothesis that phonological memory plays a causal role in word learning between ages 4 and 5 years. However, with correlational studies there is always the possibility that a third unidentified factor is influencing both phonological memory skills and vocabulary knowledge, especially in early vocabulary acquisition, such as a rich linguistic environment or sensitivity to phonological sequences.

Gathercole and Baddeley (1990) tried to rule out environmental differences such as increased exposure to novel words in a rich linguistic environment by testing children on toys, which were assigned unfamiliar names such as *Piemas*. All children had the same controlled exposure to the new word, yet the group of children with previously high nonword repetition scores were better at learning the novel name than the group with low nonword repetition scores. Both groups were matched on nonverbal intelligence so the results could not have been due to the children with better phonological memory being generally more advanced. The results suggest that phonological memory contributes to the long-term learning of new words. Even though exposure was the same for both groups, the higher scoring phonological group showed more rapid learning and better delayed retention of the toy labels.

However, there is a possibility that sensitivity to phonological patterns could be a better predictor of language learning. Since phonological sensitivity was not tested for it cannot be ruled out as a possible contributing factor. In fact, Brady (1991) interprets the correlation between verbal short-term memory and ease of articulation as an indication that verbal short-term memory is dependent on the quality of the phonological system and the phonological representations in the mental lexicon and, furthermore, Gathercole and Baddeley (1989b) actually suggest that learning new words initially depends on the ability to represent unfamiliar phonological forms. Differences in individuals' phonological memory skills may result from different degrees of 'richness and redundancy of phonological representations' (p.254). This implies that word learning is reliant on sensitivity to phonological sequences and the ability to maintain those phonological representations.

Knowledge is acquired about which phonemes or syllables commonly co-occur in a language. Words containing frequent sequences of co-occurring phonemes and syllables are processed with greater ease, suggesting that short-term retention of novel word forms not only depends on the capacity of the short-term store but also on knowledge of the frequency with which strings of phones occur in a language. First, however, a language learner must build knowledge of the regularities of a language. This ability may be an important individual difference, which moderates the limits of short-term store capacity in vocabulary learning, implying that sensitivity to word forms has some relation to phonological short-term memory.

Adult Second Language learning and the Implications for Infant Native Language learning

Speciale, Ellis and Bywater (2004) studied the working memory model and the unconscious learning of phonological sequences (Saffran et al., 1996; Saffran, Newport, Aslin, & Tunick, 1997). The unconscious learning of phonological sequences has been implicated as a source of individual differences in adult second language vocabulary development. It is plausible, therefore, that phonological sequence learning will also be a factor in infant first language acquisition, as discussed earlier. The study by Speciale et al. (2004) is included here as it has many parallels with the present study in that both include a measure of word form identification or recognition and a phonological short-term memory measure. Since Speciale et al.'s work is concerned with second language learning it is feasible that similar results in native language learning by infants can be expected.

As noted earlier, in Chapter 2, Ellis (1996) argues that the automaticity of auditory word recognition is the result of learning sequential regularities in a language. The easier an infant finds it to learn phonological sequences the more low frequency word regularities can be learnt and therefore these individuals will have more exemplars within their long-term memory to compare new or novel words to. They will end up with a broader vocabulary than someone who struggles to learn phonological sequences. In other words, the ability to acquire the phonological regularities of a language should be predictive of the rate at which an individual learns both first and second language vocabulary. Phonological short-term memory and phonological sequence learning could both be predictors of language learning. Knowledge of phonological regularities (from long-term memory of lexical knowledge) has been shown to influence phonological short-term memory (Bailey & Hahn, 2001). English-like nonwords are easier to repeat than nonwords or foreign language words that do not resemble native language words (Ellis & Beaton, 1993; Gathercole, 1995a, 1995b). This is known as the wordlikeness effect. Furthermore, there are lexicality effects. Short-term memory span for words is better than for nonwords. This effect relates to words' phonological rather than semantic properties (Hulme, Roodenrys, Brown, & Mercer, 1995).

Both the capacity of the phonological store and the ability to learn phonological sequences of language may limit language learning. Are these abilities dissociated or entwined through experience?

Speciale et al. (2004) demonstrated in their first of two experiments that word form recognition and phonological short-term memory are separate indicators of later language development. Forty adult participants had to (a) learn a second language (German) from computerised presentation; (b) undergo a lexical decision task to tap into language lexical knowledge; (c) undergo a phonological sequencing index task (PSI) – used to determine individual differences in the ability to learn phonological sequences and (d) repeat nonwords up to eight syllables in length.

Participants who rapidly acquired the phonological sequences of the target items were able to discriminate between new and 'heard before' items earlier on in the learning sequence. This has many parallels with the present study whereby infants who learn the phonological sequences of familiar type words earlier on in life may have a distinct language learning advantage. Surprisingly no relationship was found between the phonological sequencing index and the nonword repetition task, or between the PSI and the lexical decision making task. However, the German productive and receptive learning tasks were significantly related to PSI. Measures of nonword repetition performance were significantly related to performance in the German productive task but not to performance in the German receptive task. Nonword repetition was also significantly correlated to the English lexical decision task.

In Speciale et al. (2004) PSI was not related to native language vocabulary knowledge as indexed by the English lexical decision performance. What reasons could there be for PSI being influential in learning a foreign language but not knowledge of low frequency native language acquisition? Two possibilities were put forward.

(a) The undergraduate participants may not have experienced the rare words. In addition, if they had they may have done so through print rather than in conversation. Anderson, Wilson and Fielding (1988) found that people who read more have a broader vocabulary. Thus, print exposure and the amount the participants had read might be a predictor of knowledge of these words. The correlation between nonword repetition and English lexical decision performance is consistent with this reasoning in that the phonological store is involved in the reading aloud of nonwords and low frequency words (Goswami & Bryant, 1990). (b) The second explanation concerns the roles of phonological short-term memory in vocabulary acquisition at differing levels of proficiency. There are now other studies that suggest that for learners with substantial familiarity with a language, new vocabulary acquisition is mediated largely by existing lexical knowledge representations, and that it is the earlier stages of learning words in a new language where phonological short-term memory plays a much more predominant role in acquiring new phonological structures (Gathercole, et al, 1991; Masoura & Gathercole, 1999). Saying this, it will be important for the infants in this thesis, as they do not have the amount of stored lexical knowledge that undergraduate students will have.

Speciale et al. (2004) demonstrated that, in second language learning, phonological sequence learning and phonological store capacity are separable cognitive components. Phonological sequence learning was found to be a significant predictor of receptive vocabulary learning. Phonological sequence learning and phonological store capacity were proposed to make independent additive contributions to productive vocabulary learning.

Speciale et al's (2004) follow on study (Experiment 2) involved learning Spanish as a second language. The results showed that PSI was most related to tasks that tap auditory word recognition skills – much like the task in the current study whereby infants are to recognise familiar words – but not those that tap visual recognition skills, that is, reading comprehension. It was found that phonological sequence learning is related to aural receptive language abilities (as measured by exam performance) and that student phonological sequence learning ability measured at the beginning of the course is predictive of the amount of receptive learning during the course and their eventual attainment, implying that in the present thesis perceptual abilities may correlate with receptive vocabulary learning as indexed by parental reports.

Another interesting finding was that particularly the better learners of Spanish repeated Spanish nonwords more proficiently than nonword-like nonwords. If this holds true for the present thesis, it can be expected that the better learners of the English native language will be better repeaters of the English word-like nonwords.

As in Experiment 1 PSI and nonword repetition were not significantly related at time 1 (two to three weeks after the start of the course), yet at time 2 (seven weeks later) there was a significant prediction of nonword repetition by PSI. This may hold for the present thesis again – perhaps at a very early age there will not be a relationship between perception and phonological short-term memory, but, at a later date when the infants have learnt more about their native language there may be a correlation between these two abilities.

By using nonword-like items in the PSI task an adequately pure measure of learners' phonological sequence learning was attained. At the very beginning of learning a language it appears that phonological store capacity and sequence learning ability are more readily separable, suggesting dissociation between these abilities. However, as exposure to the language increases, be it the native language as an infant learner or a second language as an adult learner, long-term lexical knowledge could influence sequence learning. That is, the greater the learning rate the greater the resultant receptive vocabulary, and thus the greater the possibility for this long-term memory contribution to short-term repetition of wordlike second language stimuli (Spanish in Experiment 2). As in Experiment 1, PSI was independently correlated with receptive learning.

In conclusion, the results of the two experiments by Speciale et al. (2004) confirm the association between phonological short-term memory ability and second language vocabulary acquisition in adults. The research suggests that perception of speech and phonological short-term memory are not actually measuring the same thing. Perception can be seen as the learning and recognition of phonological sequences, whilst phonological short-term memory aids the production of novel words. Although a correlation was not found between perception and phonological short-term memory in these second language learning studies, it is possible that when learning language for the first time, perception and phonological short-term memory have a closer, more integrative relationship, as was the expected (but not found) result in Experiment 1.

In child phonology it is common to see an infant's productions as a reflection of their internal grammar. However there are problems with this approach, namely variability, the nature of perception and preverbal acquisition. Infants' productions show much variability, both between individuals and within individuals. This variability is difficult to account for in terms of grammatical competence only (Hale & Reiss, 1998). Research into speech perception demonstrates two points. First, that native language influences speech perception, that is, non-native sound patterns are assimilated to native patterns (Hallé, Segui, Frauenfelder & Meunier, 1998). Second, native words are mapped onto abstract underlying representations in the mental lexicon (Lahiri & Marslen-Wilson, 1991). These data are problematic for current models of phonological acquisition, which rely on faithful perception in order to bootstrap to linguistic competence.

Gathercole, Frankish, Pickering and Peaker (1999) argue that vocabulary competence is not only a function of the short-term phonological store but also a function of the ability to exploit the regularities of the language. This suggests that individuals of high lexical competence should be better able to exploit the regularities in word-like items than individuals of lesser lexical competence. That is, the difference between repetitions of nonwords, both high and low in word-likeness, should be greater for those who are good vocabulary learners than for those who are poor vocabulary learners. Gathercole et al. (1999) compared 16 children of high and low vocabulary knowledge on nonword repetitions for nonwords high, low and very low in word-likeness. For the low vocabulary group recall improved as a function of increasing word-likeness of stimuli, whereas for the high vocabulary group it increased more markedly. This shows that efficient language learners outperform less efficient language learners on nonword repetition tasks under the same conditions.

Summary

The repetition of nonwords, or unfamiliar phonological sequences, was found to be the most effective measure of memory span (Gathercole and Baddeley, 1989b); the larger a nonword an individual can repeat, the larger their phonological memory. Furthermore, longitudinal studies implied that phonological short-term memory span could predict vocabulary or subsequent language acquisition in children (Gathercole and Baddeley, 1989a).

It was suggested that infants who are easily able to learn fixed lexical phrases, which are sometimes assumed to be redundant, actually demonstrate the availability of an effective building block on which to expand. It follows that those children who acquire and use high frequency context-bound lexical phrases may find it easy to also learn less frequent sound patterns. If an individual is efficient at learning co-occurring strings and can chunk and memorise these strings together as a single unit, it is reasonable to propose that these individuals will be able to retain more information within their phonological short-term memory and long-term memory than someone who is less efficient at learning and retaining phonological patterns.

Word learning was implied to depend on sensitivity to phonological sequences and the ability to maintain those phonological representations (Gathercole & Baddeley, 1989b). Accepting the interpretation that long-term lexical knowledge influences phonological memory, it should follow that children who possess an early ability to learn or recognise words may perform at a more advanced level on repetition tasks at an early age than children whose linguistic development proceeds more slowly. Evidence to substantiate a connection between performance on infant word form recognition tests and individual linguistic development would mean that later vocabulary acquisition and reading abilities could be predicted at a much younger age than is now possible.

Longitudinal empirical research on individual differences in infant speech perception, production and phonological memory is needed to integrate these areas more fully. The present study is an attempt to do so.

The area of interest in the present study is the relationship between sensitivity to familiar words or sound patterns and phonological short-term memory. It has been proposed that individuals who have a good memory for sound patterns, and therefore for learning new words, should be good language learners of a second language (as demonstrated by Speciale et al., 2004) and native language. The sensitivity to sound patterns provides the individual with a solid base for learning sound-meaning symbolic relationships that underlie word learning.

The research reviewed in this section has implied that word form recognition and phonological short-term memory are separable components in acquiring a second language, leaving open the question of the relationship between word form recognition and phonological short-term memory when learning a first language. Following Speciale et al.'s (2004) study of second language learning word form recognition and phonological short-term memory could be expected to correlate significantly with word production in the current study, but word form recognition scores may not correlate with phonological short-term memory scores (although a relationship is expected). It was further implied that receptive vocabulary scores should correlate with word form recognition scores. Word form recognition and phonological memory were found to measure different processes and to make independent additive contributions to productive vocabulary learning.

It was implied that children below the age of 4 years of age do not have a functional phonological loop, but manage to absorb phonological sounds straight into the phonological store to facilitate the repetition of nonwords. In any case Gathercole and Adams (1993) successfully tested 2- to 3-year-olds on nonword repetition tasks, suggesting young children do have a functionable phonological loop and that phonological memory span is measurable at 2 years of age.

Chapter 3, main points and implications for the current study

1. **Main point:** Recognition of a meaningful lexical unit can be facilitated if it has been heard before.

   Implications: The familiar words in the word form recognition task will be more readily identified as familiar to those children who have mental representation of those words.

2. **Main point:** Children who have a poor phonological memory are poor at learning languages, and those children who have an excellent phonological memory will excel in languages. Both productive and

receptive vocabulary have been linked to phonological short-term memory spans.

Implications: Those children who have a high repetition score in the phonological short-term memory task should also be high scoring on all other tasks.

3. **Main point:** Few studies have successfully tested pre-schoolers on nonword repetition tasks.

   Implication: The fact that it is possible for children not only to understand the task, but to also participate, indicates that it is not impossible for the 24-month-olds in the current study to generate useable data.

4. **Main point:** Word form recognition and phonological memory are separable.

   Implications: Word form recognition and phonological memory may be correlated with different abilities throughout the longitudinal study, and, in light of Speciale et al.'s (2004) findings, may not be related to each other at all.

Hypotheses

On the basis of existing literature it can be inferred that a sensitivity to sound patterns is a prerequisite for language learning. This sensitivity is the basis for the formation of stable mental lexical representations in an infant's long-term memory; this denotes the beginnings of receptive vocabulary. Those representations can then be expanded and built upon through babbling and speech production. Infants who are efficient phonological pattern learners may make an earlier start on word production. Sensitivity to word patterns and their storage in long-term memory should underlie phonological short-term memory, which is a known predictor of later vocabulary.

The links in the following hypotheses can therefore be expected:

1. Word form recognition at 10 months of age, that is, the sensitivity to phonological sequences such as word forms, as indexed by the head-turn preference procedure, will be positively related to phonological short-term memory, as indexed by the repetition of English-like nonwords, at 24 months. The rationale is based on the assumption that sensitivity to word patterns underlies phonological short-term memory.
2. The same sensitivity to phonological sequences and word patterns that underlie word form recognition and phonological short-term memory will be a contributing factor to word production, as indexed by the CDI and observational studies, and the development of stable lexical representations. Performance on the

word form recognition and phonological short-term memory tasks will, therefore, be positively related to an infant's productive vocabulary.

3. Receptive vocabulary as indexed by the CDI, should mediate the relationship of sensitivity to form. Therefore, receptive vocabulary will be positively related to word form recognition performance, productive vocabulary and phonological short-term memory span.

An Overview of the Present Study

The implications of the preceding literature review suggest that individual differences at the word recognition level carry over into later vocabulary acquisition. That is, individuals who form mental word representations early on, who attend longer to familiar sounds and are highly vocal, have a more efficient phonological memory, which may make them more capable of learning language, acquiring a large vocabulary, and acquiring a second language more easily. If the ability to pick out and recognise recurring strings of sound patterns with or without meaning is, as this thesis proposes, a precursor of phonological memory, then an inability to identify sounds as recognisable words early on may delay the onset of speech production. This may lead to a low vocabulary pool in later life, difficulties in reading and an inability to learn a second language efficiently.

The perceptual analysis of fluent speech by segmenting it into phonological sequences such as words is necessary prior to storage in phonological and long-term memory if that word is to be produced correctly in the future. Perception and sequence learning may be the factors underlying performance in nonword repetition rather than phonological memory being the prerequisite for sequence learning (Snowling, Goulandris, Bowlby, and Howell, 1986).

Hallé and Boysson-Bardies (1994) found that French infants of 11 months and Japanese infants of 12 months of age (1996) listened longer to familiar words versus unfamiliar words. A replication of this study in Bangor with English infants of 9 and 11 months of age resulted in similar findings, that is, that 11-month-olds looked longer towards familiar words and the 9-month-olds showed no significant preference for either list (Depaolis et al., 1998).

An independent group of 11-month-olds will be tested in the present study in an attempt to replicate the previous findings, using a newly devised set of stimuli. A group of 10-month-olds will then be tested. The rationale for the second test is that if infants, as a group, have mental representations of familiar words at 11 months of age, but not at 9 months of age, then at 10 months some infants may demonstrate greater attention to familiar words, and some may not. Those who are more linguistically developed may show recognition patterns (as measured by looking time to the lists) similar to children of 11 months of age, and those infants who do not demonstrate a difference in looking time between the familiar versus unfamiliar word lists may show a pattern similar to 9-month-olds. These individual differences will be examined in relation to the subsequent measures of receptive and productive vocabulary and phonological short-term memory.

The question this thesis attempts to address is whether phonological short-term memory at 24 months is related to an infant's implicit ability at 10 months to form mental representations of words in the absence of any referential cues. If one assumes the language learning process to be an integrated system, it follows that a child may be efficient at all aspects of language processing, that is, perception, comprehension, production, and memory. If this is the case then an individual's later vocabulary and language proficiency could be predicted earlier than five years, perhaps through word form recognition abilities at 10 months.

During the time interval period between the word form recognition study and the phonological memory study an observational production study will be carried out. This production study entails video-recording infants in free play with a parent for 30 minutes at 14 and 18 months of age to establish which infants are more vocal and which infants have a better 'grasp' of language learning at the specified ages. The ages of 14 and 18 months were chosen as this is within the range of 13 and 20 months of age whereby Fenson (1993) states that language production really takes off. Fourteen and 18-months of age will, therefore, be the optimum point at which to gauge individual differences in speech production. The production study is included in order to present a fuller developmental picture of the language learning process in relation to word form recognition, comprehension and phonological short-term memory and to assess the validity of observational studies versus CDI studies.

The CDI (measuring both receptive and productive vocabulary) will be completed by the parents of the participants at all stages of the longitudinal study. The CDI is easily administered and collated, and is used to establish whether links existed between receptive and productive vocabulary at ages 10, 14, 18 and 24 months of age, and whether any relationships between receptive and productive vocabulary and word form recognition and phonological short-term memory exist.

Infants are to be recruited for these studies through word of mouth, by advertising in local newspapers, local doctor's surgeries and nurseries (with ethics approval by the North Wales Health Authority Research Ethics Committee (West)) and through flyers positioned at tills in specialist children's shops.

The main aims of this thesis are; to examine the relationship between performance on the word form recognition task and the phonological short-term memory task; and then to investigate the relationships between all variables, that is, sensitivity to word forms, phonological memory, receptive and productive vocabulary. Subsidiary hypotheses are to be specified within each experimental chapter, that is, Chapters 4, 5, 6, and 7.

Table 3.1 summarises the study, the measurements, and the number of participants and Table 3.2 highlights the 11-month-old replication study.

Table 3.1. The Longitudinal Study

	10 months	**14 months**	**18 months**	**24 months**
Studies	Word form recognition	Observed Production	Observed Production	PSTM
	CDI	CDI	CDI	CDI
				McCarthy
				STAP
Participants	24	21	21	21

Table 3.2. Replication Study

	11 months
Studies	Word form recognition
	CDI
Participants	12 – replication of 1998 study

Chapter 4

Word Form Recognition Study

If the ability to pick out and recognise recurring strings of sound, with or without meaning, is a precursor of phonological memory, then an inability to perceive sounds as recognisable strings may delay the onset of speech. This may lead to a low vocabulary pool in later life, difficulties in reading and an inability to learn a second language efficiently.

Molfese and Narter (1997) suggested a link between word form recognition, memory and word processing, stating "When words are heard by the infant, one might expect the auditory and cortical systems to first detect and process this acoustic information, then perhaps to compare it to remembered information, before extracting and understanding the meaning of the utterance" (p.326).

The goal of Hallé and Boysson-Bardies' (1994) French study with 11-month-olds was to establish at what age infants forge mental representations of words frequently heard within the home, in the absence of any referential cues, that is, recognising a string of co-occurring sound patterns as a word form. A replication of the Hallé and Boysson-Bardies study was carried out with English infants in 1998 (Depaolis et al.), using the same head turn procedure with modifications. Similar results to those of the French study were obtained, that is, 11-month-olds, as a group, looked longer towards familiar words. The replication study also tested 9-month-olds, but these infants did not demonstrate any group preference.

The first experiment to be reported here is Experiment 1a, a replication of Depaolis et al. (1998) with a different group of 11-month-olds, using newly devised stimuli. The aim was to establish whether the original findings could be replicated with new stimuli on an independent group of 11-month-olds to validate the previous finding that this age group has the capacity to form mental representations of words that are familiar to them in the absence of any referential cues.

Fenson (1994) reported that infants of 10 months understand, or recognize, a number of words, though it is not clear whether infants could recognise words out of context. Infants of this age group have not as yet been tested on this paradigm. Therefore, Experiment 1b will use the same stimuli as Experiment 1a with 10-month-olds, to establish whether greater attention is paid towards the familiar words.

The ultimate aim of Experiment 1b is to establish whether there is a link between early word form recognition abilities at 10 months of age and phonological short-term memory span at 24 months of age. Memory span has been shown to predict later vocabulary acquisition. If a significant relationship is found between these two measures it could mean that later vocabulary acquisition could be predicted earlier by testing word form recognition abilities. According to the present hypothesis, infants who fail to show greater attention to familiar words at 10 months should later perform less well on phonological short-term memory tasks than infants who showed greater attention.

Experiment 1a

The rationale of this experiment is to replicate earlier findings using alternative stimuli. The 11-month-old English infants should attend longer to familiar words versus unfamiliar words.

Method

Participants

Babies were recruited by various means, including leaflet distribution, posters, newspaper advertisements, and word of mouth. Twelve 11-month-old English infants, 6 males and 6 females participated. The children were all healthy with no history of hearing impairment.

Parents were asked how often they used the words in the familiar word list with their child. Children received an Infant Scientist Certificate Degree in exchange for their participation and parents received £5 to cover travel expenses.

Apparatus

A three-sided booth similar to that used by Hallé and Boysson-Bardies (1994, 1996) was used (see Figure 4.1). The windows of the laboratory were blacked out to limit visual distractions. The booth was dimly lit by a background lamp. Throughout the experiment the infant sat on the parent's knee.

Stimuli

A new set of phonotactically similar familiar and unfamiliar words (see Table 4.1) were devised for this study to ensure that the paradigm was not restricted to a single word list. A female native English speaker recorded the word lists using a Shure 515SD microphone and TASCAM DAT tape recorder. The stimuli were then digitised into computer files.

All words were disyllabic. The list of 12 disyllabic words in the familiar list was compiled using words most likely to be produced as first items by an infant, based on earlier studies (Hart, 1991; Vihman & McCune, 1994). The list consisted of seven trochees and five iambs to reflect the proportion found in a child's early lexicon (Vihman, DePaolis, & Davis, 1998). Frequency tables were used to compile a list of phonetically similar yet unfamiliar words list following Mines, Hanson and Shoup (1978). Items selected were of low frequency within the English language.

Table 4.1. New set of perception stimuli

Familiar trochees	**Transcription**	**Structure**	**Unfamiliar trochees**	**Transcription**	**Structure**
bye-bye	baɪbaɪ	CVCV	balmy	bɑmi	CVCV
biscuit	bɪskɪt	CVCCVC	booklet	bʊklɪt	CVCCVC
dinner	dɪnə	CVCV	banner	bænə	CVCV
tickle	tɪkəl	CVCVC	knuckle	nʌkəl	CVCVC
tummy	tʌmi	CVCV	timer	taɪmə	CVCV
cuddle	kʌdəl	CVCVC	muddle	mʌdəl	CVCVC
all gone	ɔlgɒn	VCCVC	algid	ælʒɪd	VCCVC
Familiar iambs	**Transcription**	**Structure**	**Unfamiliar iambs**	**Transcription**	**Structure**
hello	hɛləʊ	CVCV	belie	bilaɪ	CVCV
a drink	ədrɪnk	VCCVCC	admix	ædmɪks	VCCVCC
settee	sɛti	CVCV	tattoo	tætu	CVCV
some more	sʌmɔr	CVCVC	negate	nəgeɪt	CVCVC
again	əgɛn	VCVC	abut	əbʌt	VCVC

All items in each word list were phonetically transcribed and their phonotactic structures and phoneme frequencies analysed (see Appendix 1, Table 4.2). The word lists were analysed acoustically to ensure no differences in amplitude or duration existed between the familiar and unfamiliar word lists. Boxplots were performed and outliers discarded. When a set of twelve words were matched in each list a *t*-test was performed to ensure that the lists were not significantly different in terms of length.

The familiar and unfamiliar words were then pseudo-randomised into a set of 10 lists, 4 for the training phase and 6 for the test phase in each experiment. The pseudo-randomised lists ensured that each word appeared as either the first or the second item in one of the test phase lists. This procedure ensured that each word would be played at least once during the test phase.

Procedure

The stimuli were presented to the infant via speakers on each side of the booth, above which blue lights were positioned (see Figure 4.1). The central red light, illuminated manually, oriented the infant to centre before each trial. When the list had been fully presented, or when the infant looked away for more than two seconds, the trial ended, and the infant was again oriented to centre by the red light.

Both researcher and parent wore headphones and earplugs to avoid any inadvertent cuing. Through the headphones a 'stimulus mix' was played. This consisted of all items on the stimuli lists being superimposed several times following Pinto, Fernald and McRoberts (1999). Pinto et al. (1999) found that even if the researcher stated that they were unaware of which items were being played, when asked to guess they were 75% correct. A masking tape with mixed stimuli sounds was found to be more effective at masking stimuli than any other combination of sounds.

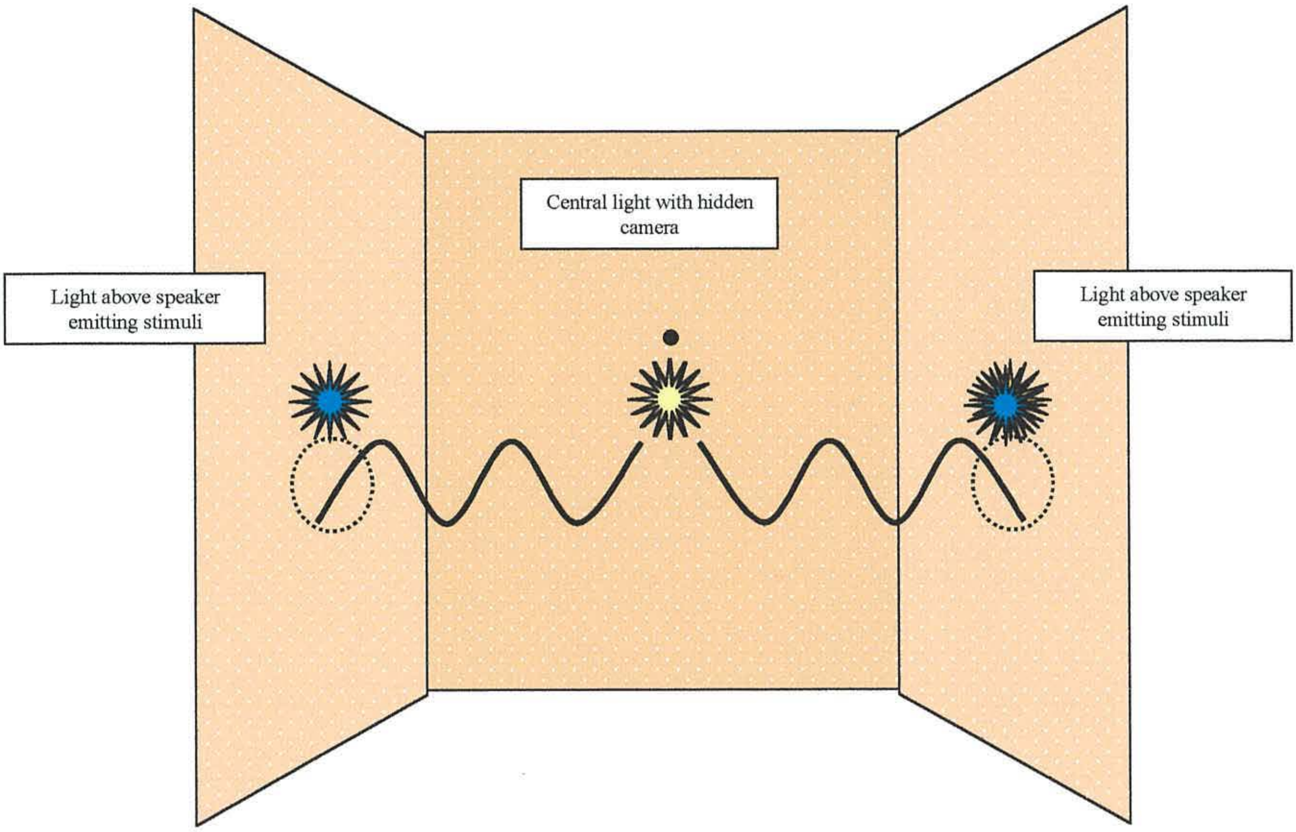

Figure 4.1. The three-sided booth

Experimental sessions consisted of two phases: a training phase and a test phase.

Training Phase

Two lists of each type were presented to enable the infant to become familiar with the procedure and set up. Infants were alerted to stimuli presentation by the blue light flashing above the corresponding speaker.

The sidelight was extinguished during the training trials as soon as the infant oriented to the speaker. This modification was implemented as the previous procedure of keeping the side light on during training appeared to lead to shorter lengths of orientation overall on the test trials to follow (Kemler Nelson, Jusczyk, Mandel, Myers, Turk and Gerken, 1995). If the infant continued looking towards the stimuli source the list ran until the end. If the infant looked away for more than two seconds the list was automatically terminated.

Test Phase

Each word list was presented six times, making twelve trials. Again, if the infant looked away for more than two seconds the list was terminated. If the infant's attention was held, the list ran to the end. In the test phase the blue light above the speaker presenting the current list blinked four times and then remained on until the list was terminated. A half-second delay occurred before each list was presented.

The researcher sat in front of a monitor linked to the hidden video camera so that the infant was in full view. The researcher, by means of a response box, controlled the onset of each list and the flashing red central light. The response box incorporated two buttons corresponding to the right and left speaker. The researcher held down the corresponding button for as long as the infant oriented to the speaker presenting the stimuli, as judged by a head turn of 30 degrees or by obvious eye movement. The control box was linked to the computer, which calculated looking times on each trial. Video-recordings were made and were scored by a second rater for reliability.

Results

A P (reference) ratio was calculated from infant looking time to familiar words over total looking time; analysis in these terms allows some factoring out of individual differences in attention span. A P ratio over .5 reflects longer looking time to familiar words, less than .5 indicates longer looking time to unfamiliar words (see Table 4.3 and Figure 4.2).

Table 4.3. Total looking time towards familiar and unfamiliar words (measured in seconds) and the corresponding P ratio for 11-month-olds.

Participant	Familiar	Unfamiliar	P.Ratio
1	25.3	31.35	0.447
2	28.59	11.78	0.708
3	38.11	17.30	0.688
4	58.81	41.24	0.588
5	59.08	45.19	0.567
6	13.95	12.76	0.522
7	48.97	43.03	0.532
8	62.38	17.73	0.779
9	57.46	38.59	0.6
10	42.59	34.76	0.551
11	28.49	6.16	0.822
12	45.62	43.08	0.514

Table 4.4. Descriptive statistics for the 11-month-old group's total looking time, $N = 12$.

	M	*SD*
Familiar	42.45	15.76
Unfamiliar	28.58	14.4
P.Ratio	.61	.12

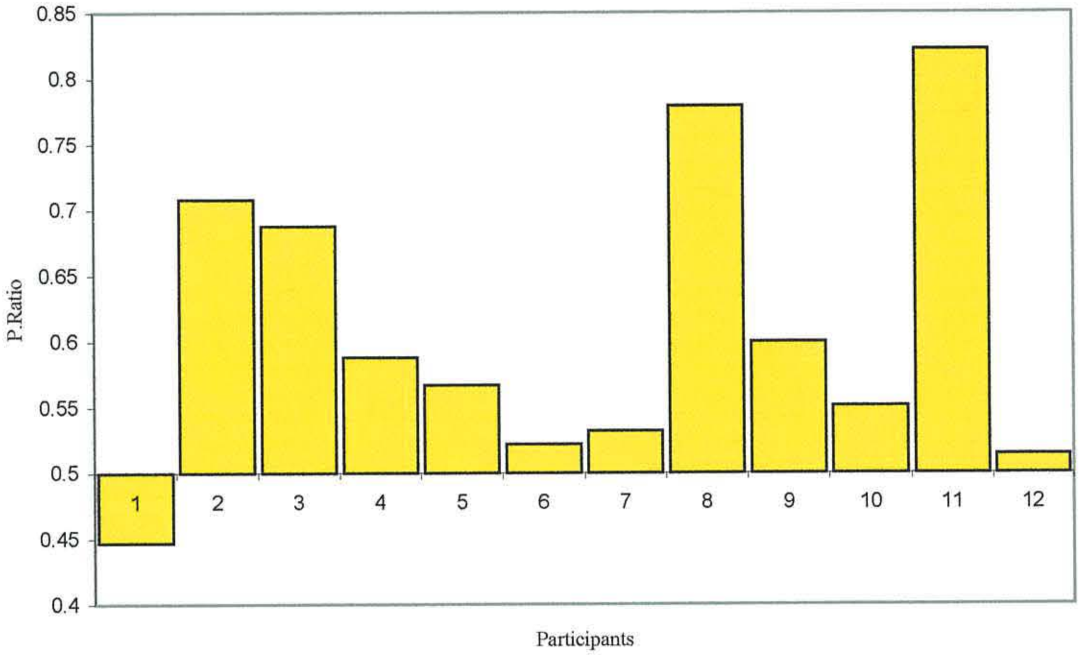

Figure 4.2. P. Ratios for 11-month-olds

As can be seen by Figure 4.2 eleven out of the twelve participants much preferred the sound of the familiar words versus the unfamiliar words. This finding was significant. At 11 months the English infants showed significantly longer looking times to familiar words, t (11) = 3.66, p = .004 (2-tailed paired t-test).

There were twelve tapes, one for each infant. A second rater scored a random sample of 3 out of the 12 (25%) video-recordings offline, that is, after the session. However, as Pinto, Fernald, McRoberts and Cole (1999) point out there is a slight concern regarding inter-rater reliability with the head-turn procedure, that is, a disagreement between the two observers can have no effect on the course of the experiment as the second rater is coding after the event. The online observer can occasionally make a mistake and terminate a certain trial too early or too late, thereby influencing the course of events. Therefore, the online and offline observers' judgments cannot be truly independent. However, the researcher in the present study was very familiar and experienced with the procedure, which minimised any possibility of error. Furthermore, to counter the inter-rater reliability issue, real time offline coding was performed using the same data-recording apparatus as online (in accordance with Kemler & Neslon, 1995). The second rater viewed the videotapes and coded looking time to the left and right speakers by the infant, without sound (see Appendix 9, Table 4.5). Therefore the second rater was totally blind to the side of stimuli presentation. Trial by trial data can then be compared and any discrepancies between on and offline records can then be noted.

Looking time between raters was analysed by performing regression analyses. Ninety-two percent of the variance in the scores from the first rater can be accounted for in the scores from the second rater, demonstrating a high inter-rater reliability, $R^2 = .922$, $F(1,4) = 47.3$, $p = .002$ (see Appendix 9, Tables 4.5, 4.10, & 4.11).

Discussion

As indicated by the significant *t*-test and Figure 4.2, there was a strong familiarity effect. The word lists were matched for complexity, so it could not be that infants preferred the familiar words for this reason. The results indicate that the infants had formed mental representations of the familiar words in the absence of any situational cues. The infants had recognised the words by phonological form alone. It could be argued that previous findings have indicated word recognition as early as 7.5 months (for example, Jusczyk et al., 1994). However the infants had received previous training on the 'familiar' stimuli. In the current study the infants had received no specific training. The words used were those that were expected to be of relevance to the infants. The current findings successfully replicate earlier findings (Hallé & Boysson Bardies, 1994; Depaolis et al, 1998) in demonstrating that 11-month-olds can recognise word shapes. The infants may not totally understand the word forms at this age, that is, they may not have mapped the word form schema onto the actual object as yet. But, shortly, these words will become available for production.

Experiment 1b

This experiment differs from Experiment 1a by participant age and number of participants. The participants are 10 months of age. The rationale is to identify the age group whereby the onset of word form recognition begins. Since previous studies have shown that 11-month-olds are capable of maintaining word representations whilst 9-month-olds are not, it seems plausible to expect variability in word form recognition scores in a group of 10-month-olds. That is, some infants will look longer towards familiar words, some towards unfamiliar words and some will show no preference.

Method

Participants

Twenty-four 10-month-old English infants, 15 males and 9 females were tested. The children were healthy and had no history of hearing impairment. Data from an additional 5 participants were not included because of fussiness (n = 2) and equipment failure (n = 3).

Procedure, Apparatus and Stimuli

As in Experiment 1a

Results

Unexpectedly, at 10 months, there was a significant difference in looking times towards the word lists. Infants looked significantly longer towards the familiar word-list, t (23) = 2.86, p = .009 (for a 2-tailed paired t-test). Sixteen out of the 24 infants (66.7%) looked longer towards familiar words, as shown on Figure 4.3. Two infants were around the P ratio mark of .5 (signifying no preference), but six infants actually preferred unfamiliar words (25%).

Table 4.6. Total looking time towards familiar and unfamiliar words (measured in seconds) and the corresponding P (reference) ratio for 10-month-olds.

Participant	**Familiar**	**Unfamiliar**	**P.Ratio**
1	20.43	14.11	0.592
2	50.97	42.70	0.544
3	37.46	12.81	0.745
4	30.49	16.16	0.654
5	31.14	23.73	0.568
6	28.76	33.89	0.459
7	36.7	41.03	0.472
8	36.16	35.73	0.503
9	32.81	11.03	0.748
10	50.00	19.89	0.715
11	26.59	21.41	0.554
12	47.51	28.92	0.622
13	49.62	38.11	0.566
14	40.00	38.00	0.513
15	25.68	29.03	0.469
16	32.49	25.35	0.562
17	66.11	44.16	0.600
18	24.59	21.03	0.520
19	56.16	24.54	0.696
20	26.27	10.97	0.705
21	30.27	12.86	0.702
22	30.11	39.51	0.433
23	15.51	33.46	0.317
24	24.05	41.78	0.365

Table 4.7. Descriptive statistics for the 10-month-old group total looking time, $N = 24$

	M	SD
Familiar	35.41	12.31
Unfamiliar	27.51	11.15
P.Ratio	.57	.12

A second rater scored a random sample of 3 of the 24 the video-recordings (12.5%, see Appendix 9, Tables 4.9, 4.10, & 4.11).

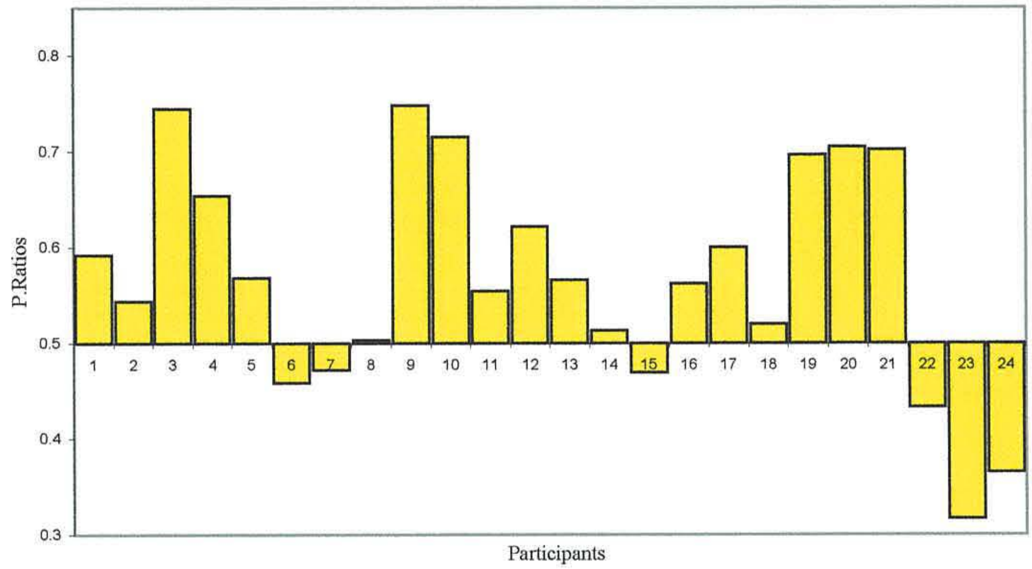

Figure 4.3. 10-month-olds P ratios, > .5 = familiar preference, < .5 = unfamiliar preference

The same procedure was used in Experiment 1a. A regression analysis was conducted to measure inter-rater reliability indicating that 91% of the variance in the scores from the first rater can be accounted for by variance in the scores from the second rater, $R^2 = .912$, $F\,(1,4) = 41.31$, $p = .003$.

Discussion

The results suggest that a mental representation of the familiar words had been formed by 10 months. The 10-month-old group as a whole had recognised the words by phonological form, as did the 11-month-old group. It was not expected that such a strong preference for familiar words would be apparent at this very young age. Previous studies had demonstrated that an 11-month preference occurs, but a 9-month-old preference does not. It was therefore expected that the 10-month-olds would be more of a 'mixed bag'.

Sixteen out of 24 infants preferred familiar words (66.7%), with six (25%) preferring unfamiliar words, as indicated in Figure 4.3. The unfamiliar preference could mean one of two things. Firstly, it could be possible that the infants were so linguistically advanced that the unfamiliar words were novel to them – thereby producing a 'novelty effect'. This suggestion is unlikely considering that these infants are just 10-months-old. Or, secondly, it could be that the 'unfamiliar' words were actually familiar to them, more so than the 'familiar' stimuli. However, this second suggestion can be discounted as the parents initially completed a questionnaire to rate the familiarity of the familiar and unfamiliar stimuli. It was found that the unfamiliar words were very rarely used in the home, if at all. More work is needed in future studies to address the unfamiliar preference effect; there is no scope within this thesis to address this issue at present.

Phonological sequence learning has been proposed as a source of individual differences (Speciale et al., 2004) in second language adult learners. If sequence learning is an important issue in second language then it follows that it is an important factor in first language infant learners, as in this study with 10-month-olds. The sequences may be implicitly learnt simply by hearing certain words over and over again in context, for example, a mother may say 'Yum, dinner?' every time she gives her infant food. In the present research two infants actually began waving when they heard the word 'bye-bye' in the context-free environment of the perceptual task, thus demonstrating a mental representation of a learnt sequence linked with meaning, albeit heard out of context. However, the understanding of word meaning was not an issue in the word form recognition task, the mere recognition of the sequences as familiar denoted by looking response was all that was required.

Perhaps the findings are not as surprising as at first thought. Ten-month-old infants had not been previously tested on this paradigm. Werker and Pegg (1992) suggested a reorganisation of infant discrimination between 10 to 12 months of age, whereby there is rapid change in infants' sensitivity to phonological and phonetic structure. Ten months is also the age when vocally precocious infants begin to produce their first identifiable words (Vihman, 1996). It is therefore not so surprising that more than half of the 10-month olds have started on their path of full language acquisition.

Chapter 5

Observational Production Study

Production has been studied previously in relation to both speech perception and phonological memory. It has been demonstrated that in children with SLI there is a relationship between speech perception deficits and poor speech production (Bishop, 1997). Furthermore, Bishop (1997, p.83) states, "In many children with SLI, word learning appears to be affected by problems in phonological memory".

Individual differences in linguistic ability play an important role in language acquisition, as do auditory exposure and physiological maturation. Fenson et al. (1994) looked at differences in the rate of infant vocabulary production, using the CDI on approximately 80-100 children. Expressive language is minimal, below 10 words before 12 months of age, increasing to an average of 40 words at 16 months (Fenson et al., 1994; McCarthy, 1954). Fenson et al. (1994) found that by the age of 12 months individual differences in language production became more apparent. The bottom 10% of the sample produced no speech, whilst the top 10% were producing 26 words or more. A correlation between age and production showed that age accounts for only 22% of variance, leaving age-independent individual differences among children as a major source of variability in word production.

Bates et al. (1991) found that half of their sample, that is thirteen 13-month-olds, had a receptive vocabulary of fifty words, whilst one child had almost fifty words in their productive vocabulary, as measured by parental report. Much lower levels were found in the laboratory-based observations of spontaneous word types with an average of 1.69 word types being observed. Eleven children produced no recognizable speech at all. However, correlations were found to exist between observational and parental reports.

Initial word pronunciation may be facilitated or hindered by perceptual, cognitive, and articulatory abilities, and also the word's semantic complexity, its social or emotional significance for the child, and the number of times the word is heard. The acquisition of a new word requires learning not only the link between sound and meaning but also a set of unfamiliar articulatory movements.

There has been some controversy over methods for measuring vocal production (and comprehension). Some researchers advocate observational studies (for example, Harris et al., 1995) as being the more reliable measure, whilst others prefer the use of the CDI (Fenson et al., 1994; Bates et al., 1994) or the head turn procedure (Hallé & Boysson-Bardies 1996). Hallé and Boysson-Bardies (1996) are of the opinion that observational studies in naturalistic settings, may underestimate the productive lexicon yet overestimate the receptive lexicon. Experiment 2 uses an observational measure, but CDI studies are also carried out at ages 10, 14, 18 and 24 months (Chapter 6, Experiment 3) as a comparison (Chapter 8).

The initial aim of Experiment 2 is to establish the production abilities of infants at 14 and 18 months of age. The ages of fourteen and eighteen months have been chosen due to Fenson et al.'s (1993) observation that an infant's ability to produce words dramatically increases between 13 and 20 months and that prior to this, words tend to be context bound (Vihman & McCune, 1994).

The ultimate aim of Experiment 2 is to establish whether existing links can be determined between word form recognition, word production and phonological short-term memory. For instance, phonological memory may be related to productive vocabulary and word form recognition to receptive vocabulary. This is addressed in the General Results Chapter (Chapter 8).

Experiment 2

The rationale of this study is to establish whether there is a relationship between the production abilities at 14 and 18 months of age, measured by observational studies. The results from this study can then be compared with the CDI scores from Chapter 6 to establish which measure more accurately reflects an infant's productive vocabulary.

Method

Participants

The participants were 21 infants who participated in the word form recognition study at 10 months of age; they were observed at 14 and 18 months of age. Out of the initial 24 children, 3 did not participate as they had moved from the area. Participants received £5 for each visit, plus a copy of the videotapes.

Procedure

The children were video-recorded in their homes, or in the infant laboratory if more convenient for the parent, during 30 minutes free-play mother-child interactions. The mothers were encouraged to play as they normally would with their child for the 30-minute session. No specific instructions were given. The observer sat quietly, watching and occasionally checking the recording equipment. The child's attempts at involving the observer in play were averted.

Coding

Only vocalizations that bore a phonetic resemblance to an adult word, in a plausible context were considered as words. Following Vihman and McCune (1994) an utterance was considered a word if:

1. the word occurred more than once in the given, or similar context if ambiguous.
2. the utterance was familiar from previous recordings of the child.

3. the mother responded to the vocalization as if it were a word.

The infants' word productions were transcribed and notes were taken as to whether words were spontaneous or imitative. Onomatopoeias, for example, 'meow', 'grrr', 'vroom', 'choo-choo', were included as words. Word types and word tokens were totaled for the 30-minute session to give some indication of how many words the infant produces on a daily basis. Word tokens are defined here as vocal productions that can be classed as words. Therefore, the same word may be produced many times during the 30-minute observation and each production of that word would be included in the word token total. Word types are defined as how many categories of words were produced, that is, no matter how many times a single word was produced it would only be counted once in the total of word types. Spontaneous word types only are counted, that is, the infant's utterance is not present in the immediately preceding adult utterance. Vihman and Miller (1988) found that the number of observational word types produced in a half hour period could be doubled to approximate an infant's total productive vocabulary.

Apparatus

A Sony video-recorder and tripod were used. A standard set of toys was taken to supplement the child's own toys, to prompt productive responses from the child.

Results

Linear regression and correlational analyses are the main statistical analyses used to establish links and possible predictors in this and subsequent chapters. Neither multiple regression nor causal path analyses could be performed due to the relatively small number of participants in relation to the number of variables measured. The low number in the sample and low degrees of freedom would lead to the analyses lacking statistical power. Furthermore some effects may be missed as a result. These studies would have benefited from a larger sample to ensure that a causal pathway analysis could have been performed to yield more meaningful results, however, this was beyond the scope of this thesis with the time restrictions imposed. Future research should therefore be undertaken to validate the findings.

Linear regression analyses will be carried out. Regression analyses predict a response variable, in this case, speech production, receptive vocabulary and phonological memory, based on contributions from a number of other explanatory factors. It is primarily used as a tool to evaluate the significance and magnitude of selected factors in the presence of other correlated factors, possibly also significant.

Table 5.1. Observed word production at 14 and 18 months

Participants	14 months word tokens	14 months word types	18 months word tokens	18 months word types
1	61	4	65	24
2	29	4	62	22
3	19	9	34	12
4	54	10	139	47
5	41	8	93	39
6	11	5	1	0
7	39	10	56	8
8	3	3	81	20
9	54	12	272	25
10	25	5	30	16
11	53	11	83	33
12	14	3	16	9
13	51	15	181	62
14	105	34	136	51
15	7	4	24	4
16	27	9	14	8
17	34	9	160	52
18	16	10	102	51
19	80	37	134	63
20	19	5	22	9
21	11	8	16	10

Note. 'Word tokens' denotes the amount of vocalisations classed as words. 'Word types denotes the total of different words produced spontaneously at least once.

Table 5.2. Descriptive statistics for word types and tokens at 14 and 18 months of age, $N = 21$.

	M	*SD*
14 months word tokens	35.86	25.27
14 months word types	10.24	8.8
18 months word tokens	81.95	67.12
18 months word types	26.91	18.5

As predicted a significant linear regression between word type observed at 14 and 18 months was found, whereby word types observed at 14 months predicted 42.5% of variance of scores at 18 months (see Figure 5.1 below, Table

5.3, and Table 8.9, Appendix 8 for correlational information), $R^2 = .425$, $F(1,19) = 14.07$, $p = .001$.

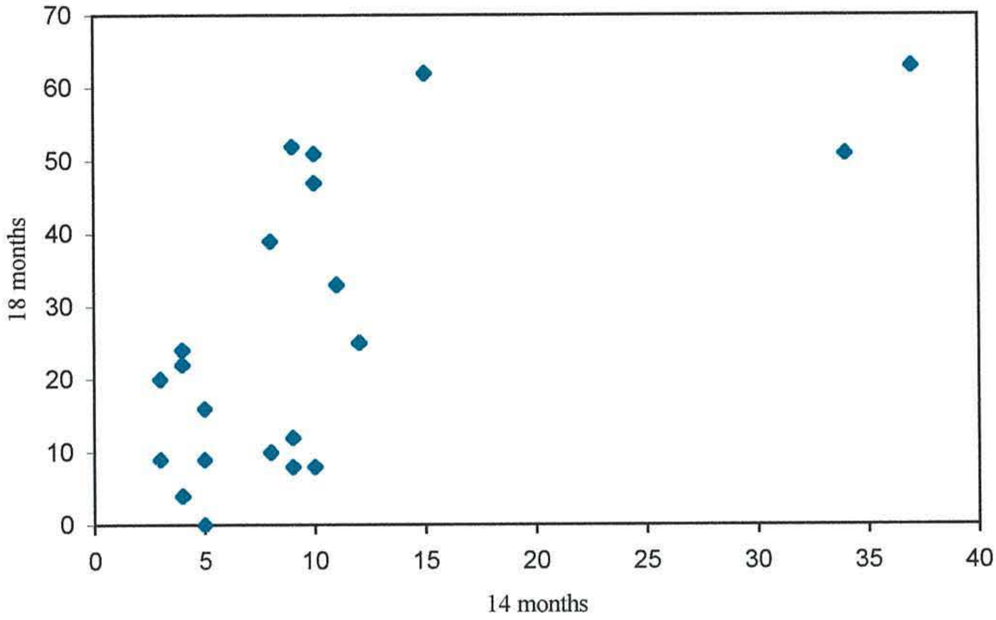

Figure 5.1. A scattergram illustrating the relationships between the observational productive studies at 14 and 18 months of age for word types.

A significant relationship was also found between word tokens observed at 14 and 18 months, whereby word tokens observed at 14 months predicted 34.6% of variance of scores at 18 months (see Figure 5.2 and Table 5.3), $R^2 = .346$, $F(1,19) = 10.06$, $p = .005$.

Table 5.3. Summary of regression analyses for the prediction of word type and word tokens, $N = 21$.

Variables	Predict 18 mos word types			
	B	SE B	β	R^2
14 mos word types	1.47	.39	.65***	.43
	Predict 18 mos word tokens			
	B	SE B	β	R^2
10 mos word tokens	1.56	.49	.59 **	.35

Note: $^{**}p < .01$, $^{***}p < .001$

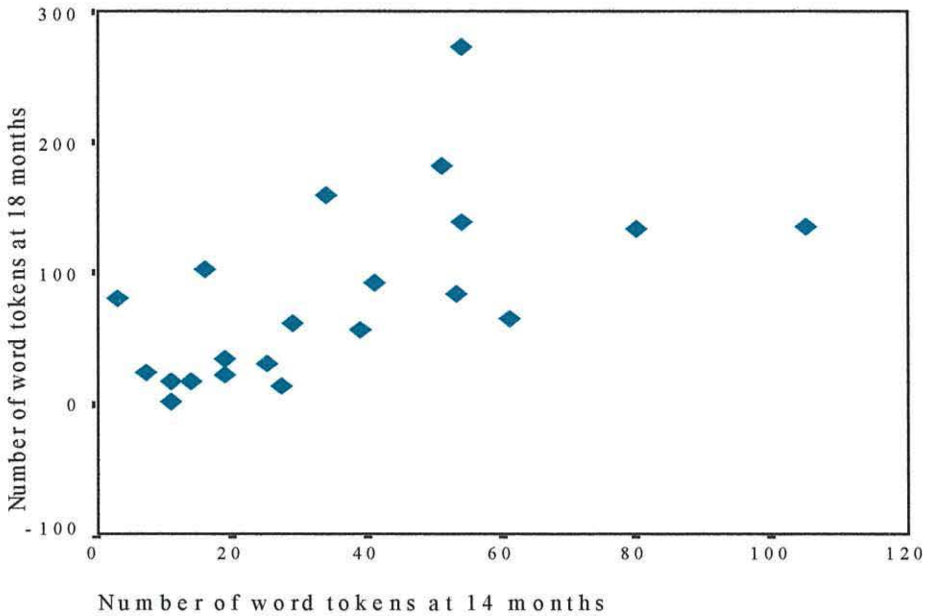

Figure 5.2. A scattergram illustrating the relationships between the observational productive studies at 14 and 18 months of age for word tokens.

At 14 months the mean average spontaneous word type productions were 10.24 (see Table 5.2), with five children producing an above average number of word types, sixteen children below (see Table 5.1). The most vocal child was participant number 19 with 37 word types at 14 months. The lowest number of word types produced was by participants 8 and 12, who produced 3 word types within the 30-minute observation.

From Table 5.1 it can be seen that eight infants were producing above the mean average of 26.91 (Table 5.2) spontaneous word types at age 18 months. The most vocal of infants, participants 13 and 19 were producing 62 and 63 word types respectively. Thirteen children were producing lower than the mean average, with one child producing only one word token (which was an imitation, so therefore was not included in the word type data), but no word types at all during the observational session. However, at age 14 months this same child produced 11 word tokens and 5 word types, suggesting that this child may have just been having an 'off day' at the time of testing at 18 months. This reasoning is further supported by the fact that this particular infant is the only child who actually decreased in volubility over both word tokens and word types at the second stage of observations. As can be seen by Table 5.1 the majority of children increased in both word tokens and word types over the four-month period, with the exception of participant 7 who produced 10 word types at 14 months but only 8 at 18 months, and participant 15 whose number of word types remained at 4. However, both of these children did increase in their number of word tokens.

Correlational analyses between word tokens and types yielded a strong existing relationship at 14 months ($r = .804$, $N = 21$, $p < .001$), and 18 months of age ($r = .721$, $N = 21$, $p < .001$) (See Figures 5.3 & 5.4). This suggests that those infants who are more voluble actually produce more word types than their quieter counterparts.

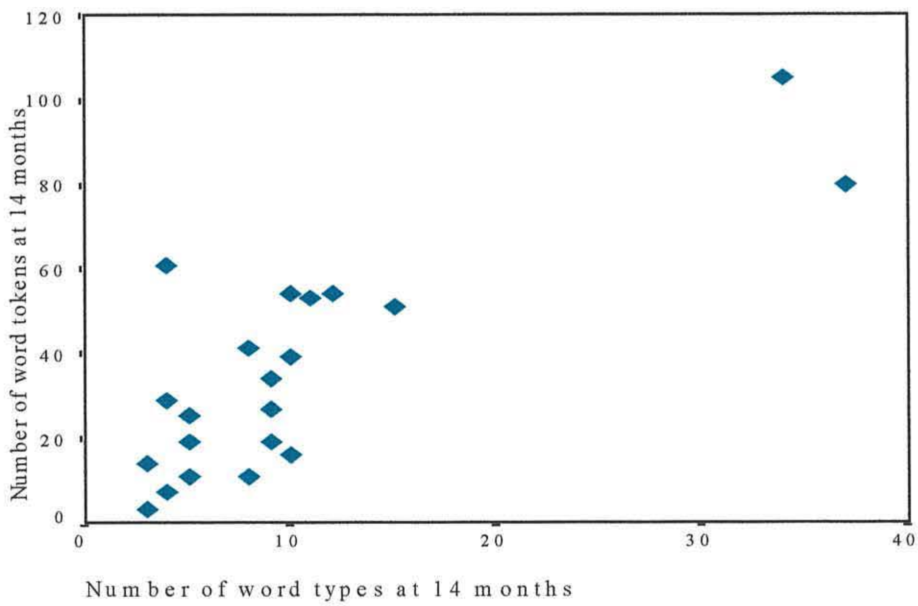

Figure 5.3. A scattergram illustrating the relationships between the observational productive studies at 14 months of age between word types and word tokens.

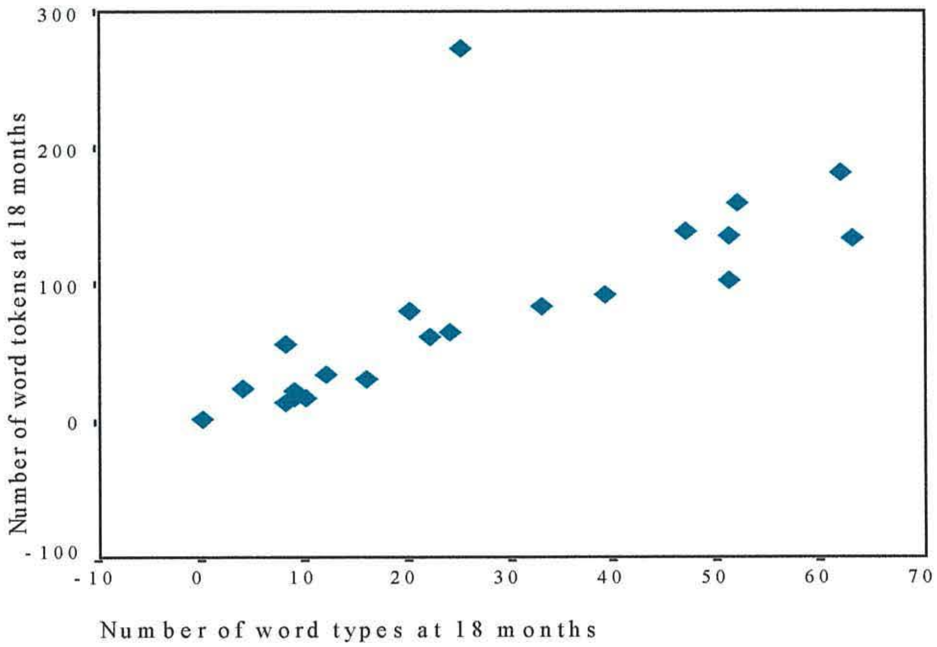

Figure 5.4. A scattergram illustrating the relationships between the observational productive studies at 18 months of age between word types and word tokens.

A second rater transcribed a random sample of 3 out of the 21 video-recordings (14.3%). The second rater viewed the 30-minute videotapes, one for each infant, and recorded the number of word types and tokens. A regression analysis was conducted to measure inter-rater reliability between the total of word types and tokens recorded by both raters (see Appendix 9, Tables 5.3, 4.10, 4.11). It was found that 95.6% of the variance in the scores from the first rater could be accounted for by variance in the scores from the second rater for 14-month-olds, $R^2 = .956$, F (1,4) = 87.01, $p = .001$, and that 91% of the variance in the scores from the first rater could be accounted for by variance in the scores from the second rater for 18-month-olds, $R^2 = .91$, $F\,(1,4) = 40.34$, $p = .003$ (Appendix 9, Tables 5.4, 4.10, 4.11).

Discussion

The findings suggest that the observational studies are reliable in that the number of spontaneous vocal productions (measured as word types) at 14 months predict a high proportion of word types at 18 months, as expected (see Figure 5.1). Furthermore, the fact that a strong relationship exists between word tokens and word types at both ages suggests that the most linguistically advanced children are the most voluble as they produce far more word tokens than their less advanced counterparts. The fact that word tokens at 14 months predicts performance at 18 months also demonstrates that the more vocal children remain so over a 4 month period and continue to increase in their word knowledge at a faster pace than the less vocal children.

In comparison to Bates et al.'s (1991) observational findings of productive abilities in 13-month-olds the children in the current study produced many more words. In Bates et al.'s study the 13-month-olds produced on average 1.69 spontaneous word types compared to the 14-month-olds in the current study producing an average of 10.24. Why this large difference? Some differences would have occurred due to the one-month age difference. Another possibility is that in the current study, to maximize word productions, the majority of observations (19 out of 21 in both age groups) were carried out in the child's familiar home environment by the researcher who saw them previously (in contrast to Bates et al.'s study where observations were carried out in the laboratory), with an extra set of toys to elicit and maintain interest for the 30-minute observational period. The fact that the infants were in their home environment, surrounded by their familiar toys, may have elicited more word productions.

Unfortunately, although Bates et al. (1991) performed observational analyses at 20 months they did not report the actual number of word types produced at this age (they were concerned with MLU), so no comparisons can be drawn with their 20-month-olds and the current 18-month-olds. However, if the total number of word types is doubled for the 14-month-olds, which gives an average of approximately 20.5 known words in total (in line with Vihman & McCune, 1994 to gain an approximation of total words within a child's productive vocabulary), then it appears that the children in the current study are comparable to the children in Fenson et al.'s (1994) parental report study, whereby 12-month-olds were found to produce an average of 10 words, and 16-month-olds an average of 40 words. If the total number of word types is doubled for the 18-month-olds, which gives an average of approximately 54 known words (in line with Vihman & McCune, 1994), then it appears that the children in the current study are not comparable to the children in Fenson et al.'s (1994) parental report study, whereby 18-month-olds were found to produce an average of 110 words.

Parental reports, in Bates et al.'s study, showed that one child had a productive vocabulary of nearly 50 words at 13 months, whilst 11 children appeared to have no recognizable speech at all (all children in the current study produced 3 or more word types at 14 months). It was found however that a correlational relationship did exist between the observational and parental reports in Bates et al.'s (1991) study. Comparing the current observational findings with the CDI productive findings from Chapter 6 will further validate the high variability in productive vocabulary. This will be carried out in Chapter 8, the General Results Chapter.

Chapter 6

The Communicative Development Inventory Study

An increase in receptive vocabulary occurs at an earlier age than an increase in productive vocabulary. A typical 12-month-old understands approximately 50 words, but this number may double or triple in just 2 to 3 months (for example, Barrett, 1995; Fenson et al., 1994). At 16 months, children in the top 10% of Fenson et al.'s (1994) sample were producing nearly 180 words, whilst those children in the bottom 10% were producing fewer than ten words. By 18 months, the average lexicon size was 110 words. An average toddler at 24 months has a productive vocabulary of slightly over 300 words, 546 at 30 months (Fenson, et al., 1994), and at 36 months this figure jumps to 1000 words (Wehrabian, 1970).

Hamilton et al. (2000) have collected child developmental inventory data for over 650 British infants below 27 months of age. The general trend mirrors that of the earlier Fenson et al. (1994) studies, showing there is a sudden increase in productive vocabulary compared to receptive vocabulary, which develops in a more linear fashion. Furthermore, Mills et al. (1994) tested the validity and reliability of CDI parental reports in the United States by studying ERPs to auditorily presented words. They found that 14-month-old infants' ERP readings were reliably different according to whether the stimuli were known or unknown words, as rated by their parents, suggesting that CDIs are a valid and reliable measure of vocabulary. Bates et al. (1991) found strong relationships between observed production and parental measures using regression and correlational procedures.

The ability to acquire new word meanings well before the sudden increase in productive vocabulary implies that comprehension and production are differently activated systems (Bates et al., 1991). Bates et al. (1991) conducted a longitudinal study of 27 babies at ages 10, 13, 20 and 28 months. They found that comprehension at 10 months related to production at 10 months and to comprehension at 13 months. Early production levels was found to be related to later production levels, and early comprehension levels were found to be related to later comprehension levels, yet no relationship was found between comprehension and production in the older age groups, except for comprehension and noun production. This therefore suggests a dissociation of comprehension and production. Although the 10-month-olds' comprehension did not predict later production totals, it did correlate highly with 13-month-olds' language reflecting 'analysed production' especially referential style and flexible object naming. Bates et al. concluded there were two (or possibly three) types of language acquisition mechanisms, one for production, one for comprehension, and a third mechanism which relates comprehension to noun, or rote, production.

The Oxford CDI (Hamilton et al., 2000) has been successfully implemented with infants up to age 27 months of age in the Oxford Baby Laboratory at the University of Oxford. But, there has been some dispute over which method of measurement of productive and receptive vocabulary is most reliable (see Chapter 5), that is, the CDI or observational measures. Therefore, this chapter will attempt to establish which method, the CDI or observational studies, are most indicative of an infant's vocabulary. Vihman and McCune (1994) discovered that if the number of words an infant produced in a 30-minute observation were doubled, this approximated the total number of words in that child's productive vocabulary. This theory will be put to the test with the data from this study's observational and CDI data.

In this case, it is possible to assess language development by carrying out regression analyses with the CDI results and results from the word form recognition experiment at 10 months of age (Experiment 1b) and the phonological short-term memory studies at 24 months of age (Experiment 4). Hallé and Boysson Bardies were of the opinion that the head-turn preference procedure is a very effective measure of receptive vocabulary. These analyses are reported in the General Results Chapter (Chapter 8). Correlational analyses on the productive observational studies at 14 and 18 months of age (from Experiment 2) and CDI results are carried out here. A correlation would indicate that both measures are related in some way or are measuring the same thing, such as productive vocabulary in this case.

Experiment 3

The hypotheses for this study are:

Hypothesis 1: There will be a positive relationship between receptive measures on the CDI at 10, 14, 18, and 24 months of age.

Hypothesis 2: There will be a positive relationship between productive measures on the CDI at 10, 14, 18, and 24 months of age.

Hypothesis 3: Although receptive and productive vocabularies have been shown to be separable, there will be a positive relationship between receptive and productive vocabulary as measured by the CDI.

Hypothesis 4: There will be a positive relationship between the CDI productive measures and observed word type production at 14 and 18 months.

Method

Participants

The 21 infants who participated in the observational production study and word form recognition study also participated in this study at 10, 14, 18, and 24 months of age.

Apparatus

The Oxford CDI (Hamilton et al., 2000. See Appendix 2) was used; it was designed as a British version of the original American MacArthur CDI see Hamilton et al., 2000 for a review on the development of the Oxford CDI). A possible 427 words could be attained for both categories of words 'understood' and words 'understood and spoken'. Within the CDI words are split into the following categories; animal sounds, animals, vehicles, toys, food and drink, body parts, clothes, furniture and rooms, outside, household items, people, games and routines, action words, descriptive words, question words, pronouns, prepositions, quantifiers and extra words.

Procedure

Parents were asked to complete the CDI for their infant at ages 10, 14, 18 and 24 months.

Results

Table 6.1 shows the raw scores of the completed CDI.

Table 6.1. Total words understood and total words understood and spoken by infants at 10, 14, 18 and 24 months of age, as measured by the CDI.

Participant	CDI	10 months	14 months	18 months	24 months
1	U	56	125	156	61
	US	1	6	55	348
2	U	17	68	123	0
	US	0	9	51	411
3	U	89	186	240	50
	US	10	33	49	353
4	U	21	97	91	0
	US	2	17	151	385
5	U	60	262	175	0
	US	7	26	187	412
6	U	20	110	220	295
	US	2	3	12	82
7	U	16	33	124	64
	US	2	6	12	189
8	U	19	31	62	76
	US	0	3	19	106
9	U	11	101	142	66
	US	4	31	53	304
10	U	0	26	137	27
	US	0	0	37	312
11	U	24	117	145	54
	US	2	12	76	317
12	U	37	58	101	201
	US	1	0	13	116
13	U	16	50	172	8
	US	0	32	45	397
14	U	55	102	150	12
	US	3	23	57	356
15	U	8	23	41	119
	US	0	3	15	108
16	U	19	31	75	104
	US	3	6	12	154
17	U	87	244	106	3
	US	0	83	230	365
18	U	88	126	65	0
	US	7	47	248	386
19	U	37	95	84	20
	US	25	78	170	385
20	U	28	56	147	137
	US	4	9	40	158
21	U	28	62	153	123
	US	4	7	46	133

Note: U = understood, US = understood and spoken. A zero score in 'U' category at 24 months indicates that the child can can produce all words that they understand – see the 'US' figure.

Table 6.2. Descriptive statistics for the CDI on receptive and productive vocabulary across all ages, $N = 21$.

	M	*SD*
10 months receptive	10.05	27.05
10 months productive	3.67	5.59
14 months receptive	95.38	66.99
14 months productive	20.67	23.74
18 months receptive	129	50.6
18 months productive	75.14	74.38
24 months receptive	67.62	75.83
24 months productive	275.1	121.16

Note. Receptive data here refers to words 'understood' but not spoken.
Productive data here refers to words 'understood and spoken'.

However, to reach the final total of number of words understood the figures from both the understood category and understood and spoken category have to be totaled (see Table 6.3) as words from the understood and spoken category include words already within the receptive vocabulary. It will appear that receptive vocabulary diminishes over time as productive vocabulary increases if this calculation is not made.

Table 6.3. Total number of words in infants' receptive vocabulary as measured by adding the totals in the understood, and understood and spoken category of the CDI at ages 10, 14, 18, and 24 months of age.

Participant	10 months	14 months	18 months	24 months
1	57	131	211	409
2	17	77	174	411
3	99	219	289	403
4	23	114	242	385
5	67	288	362	412
6	22	113	232	377
7	18	39	136	253
8	19	34	81	182
9	15	132	195	370
10	0	26	174	339
11	26	129	221	371
12	38	58	114	317
13	16	82	217	405
14	58	125	207	368
15	8	26	56	227
16	22	37	87	258
17	87	327	336	368
18	95	173	313	386
19	62	173	254	405
20	32	65	187	295
21	32	69	199	256

Table 6.4. Descriptive statistics for the CDI on the overall receptive vocabulary across all ages, $N = 21$.

	M	SD
10 months receptive	38.71	28.5
14 months receptive	116.05	81.04
18 months receptive	204.14	81.36
24 months receptive	342.71	69.94

Note. Receptive vocabulary means are based on the overall receptive data from Table 6.3, that is, whereby words 'understood' and words 'understood and spoken' are totaled to represent total receptive vocabulary.

Receptive Vocabulary Results

Using linear regression analyses receptive vocabulary at 10 months of age was found to be positively related to receptive vocabulary at 14, 18 and 24 months of age (see Table 6.5 and also the correlation matrix, Table 6.6, Appendix 3). Scores on the CDI at 10 months predicted; 62.4% of scores on the CDI at 14 months, $R^2 = .624$, $F\ (1,19) = 34.22$, $p = .001$; 50.1% of scores on the CDI at 18 months $R^2 = .501$, $F\ (1,19) = 21.07$, $p = .001$; and 15.9% of scores on the CDI at 24 months of age $R^2 = .159$, $F\ (1,19) = 4.79$, $p = .041$.

Table 6.5. Summary of regression analyses for the prediction of receptive vocabulary at 14, 18 and 24 months of age, $N = 21$.

Variables		Predict 14 mos receptive		
	B	SE B	β	R^2
10 mos receptive	2.28	.39	.8 ***	.62
		Predict 18 mos receptive		
	B	SE B	β	R^2
10 mos receptive	2.02	.44	.73 ***	.5
14 mos receptive	.87	.1	.89 ***	.79
		Predict 24 mos receptive		
	B	SE B	β	R^2
10 mos receptive	1.08	.49	.45 *	.16
14 mos receptive	.52	.15	.62 **	.35
18 mos receptive	.65	.13	.76 ***	.55

Note. $*p < .05$, $**p < .01$, $***p < .001$.

Receptive vocabulary at age 14 months was related to receptive vocabulary at 18 and 24 months, predicting 78.5% of scores on the CDI at 18 months $R^2 = .785$, F $(1,19) = 74.05$, $p = .001$, and 35.3% of scores on the CDI at 24 months $R^2 = .353$, $F(1,19) = 11.89$, $p = .003$.

Receptive vocabulary at age 18 months was related to receptive vocabulary at 24, predicting 54.7% of scores on the CDI at 24 months, $R^2 = .547$, $F(1,19) = 25.19$, $p = .001$.

Discussion of Receptive Results

The above findings appear to indicate that the CDI is a reliable measure of vocabulary acquisition as scores increase in a linear fashion as expected. In addition it is interesting to note that while each age group has successfully predicted future vocabulary in the later age groups, it appears that the strongest predictions are for the subsequent age group. For instance, at 10 months the strongest prediction and correlation was for receptive vocabulary at 14 months (62.4%), diminishing to a prediction of just 15.9% of scores on receptive vocabulary at 24 months of age. A similar pattern was found with 14 months of age, with the strongest predictions being for the 18 month old age group. This auto-regressive effect suggests there is high test-retest reliability within the parental reports (see Haslam & McGarty, 2003, for a review on reliability and validity).

The findings mirror the findings from Bates et al.'s (1991) study, which showed a strong correlation between receptive vocabulary at 10 and 13 months of age. Fenson et al. (1994) and Barrett (1995) stated that on average a 12-month-old understands approximately 50 words. This figure may double or triple by 14 or 15 months. The current results reflect these findings as at 10 months the mean average receptive vocabulary for this sample was 38.71, leaping to 116 by 14 months of age.

Productive Vocabulary Results

Using linear regression analyses, productive vocabulary at 10 months of age was positively related only to productive vocabulary at 14 months of age (see Table 6.7 and the correlation matrix, Table 6.6, Appendix 3). Scores on the CDI at 10 months predicted 34.4% of scores on the CDI at 14 months $R^2 = .344$, F $(1,19) = 9.97$, $p = .005$.

Productive vocabulary at 14 months of age was positively related to productive vocabulary at 18 and 24 months of age. Scores on the CDI at 14 months predicted 60.6% of scores on the CDI at 18 months $R^2 = .606$, F $(1,19) = 29.26$, $p = .001$, and 33.3% of scores on the CDI at 24 months $R^2 = .333$, F $(1,19) = 9.48$, $p = .006$.

Productive vocabulary at 18 months of age was positively related to productive vocabulary at 24 months of age, predicting 41.6% of scores on the CDI at 24 months $R^2 = .416$, $F\,(1{,}19) = 13.51$, $p = .002$.

Table 6.7. Summary of regression analyses for the prediction of productive vocabulary at across all ages, $N = 21$.

Variables	Predict 14 mos productive			
	B	SE B	β	R^2
10 mos productive	.14	.04	.59**	.34
	Predict 18 mos productive			
	B	SE B	β	R^2
10 mos productive	3.01	.02	.4	.16
14 mos productive	2.44	.45	.78 ***	.61
	Predict 24 mos productive			
	B	SE B	β	R^2
10 mos productive	1.32	.01	.29	.08
14 mos productive	2.95	.96	.58 **	.33
18 mos productive	1.05	.29	.65 **	.42

Note. $*p < .05$, $**p < .01$, $***p < .001$.

Discussion of Productive Results

It is surprising that the productive section of the CDI at age 10 months does not predict productive vocabulary on the CDI at 18 and 24 months of age. But the results still appear to reflect the receptive vocabulary results in that the subsequent age range on the CDI is predicted most strongly by the preceding age group's vocabulary. For instance at 14 months productive vocabulary predicted 60.6% of data at 18 months, but only 33.3% at 24 months. These findings suggest that productive CDI measures are an accurate measure of vocabulary due to the strong relationships between data at each age level. Furthermore, the infants results here are comparable to earlier parental measure studies (for example, Fenson et al., 1994), which found that at 16 months the top 10% of the sample produced 180 words and the bottom 10% produced less than 10 words on average. Fenson et al. (1994) found that 18-month-olds produced 110 words on average, and by 24 months this figure had risen to 300. Looking at Table 6.2 it is shown that 24-month-olds produced on average 275.1 words. The 18-month-olds in this sample were not as comparable with Fenson et al. as the current sample produced just 75.14 words on average, although it must be noted that the range was between 12 and 248, with 5 participants producing more than 110 words. However, by 24 months 12 infants from the current sample exceeded Fenson et al's 300-word production average. Both studies demonstrate a steady increase in productive vocabulary growth until between 18 and 24 months when there appears to be a sudden increase (vocabulary spurt).

Receptive and Productive Vocabulary Results

Using linear regression analyses, receptive vocabulary at 10 months of age was positively related to productive vocabulary at 10 months of age (as in Bates et al., 1991), 14 months, 18 months and 24 months (see Table 6.8, and the correlation matrix, Table 6.6, Appendix 3). Scores on the receptive CDI at 10 months predicted 17.6% of scores on the productive CDI at 10 months $R^2 = .176$, $F(1,19) = 5.28$, $p = .033$, 40.5% of scores on the productive CDI at 14 months $R^2 = .405$, $F(1,19) = 14.6$, $p = .001$, 42.1% of scores on the productive CDI at 18 months $R^2 = .421$, $F(1,19) = 15.55$, $p = .001$, and 16.1% of scores on the productive CDI at 24 months of age $R^2 = .161$, $F(1,19) = 4.835$, $p = .04$.

Table 6.8. Summary of regression analyses for the prediction of productive vocabulary at across all ages, $N = 21$.

Variables		Predict 10 mos productive		
	B	SE B	β	R^2
10 mos receptive	8.93	.04	.47*	.18
		Predict 14 mos productive		
	B	SE B	β	R^2
10 mos receptive	.54	.14	.66 ***	.41
14 mos receptive	.22	.04	.75 ***	.55
		Predict 18 mos productive		
	B	SE B	β	R^2
10 mos receptive	1.71	.43	.67 ***	.42
14 mos receptive	.69	.13	.76 ***	.58
18 mos receptive	.73	.13	.79 ***	.61
		Predict 24 mos productive		
	B	SE B	β	R^2
10 mos receptive	1.87	.85	.45 *	.16
14 mos receptive	.874	.27	.6 **	.33
18 mos receptive	1.03	.25	.69 ***	.45
24 mos receptive	.53	.08	.85 ***	.82

Note. $*p < .05$, $**p < .01$, $***p < .001$.

At 14 months of age receptive vocabulary was positively related to productive vocabulary at 14, 18 and 24 months of age. At 14 months data on the receptive CDI measure predicted 54.5% of the variance of productive data at 14 months $R^2 = .545$, $F\ (1,19) = 24.99$, $p = .001$, 58% of variance at 18 months $R^2 = .58$, $F\ (1,19) = 28.59$, $p = .001$, and 32.5% of variance at 24 months $R^2 = .325$, $F\ (1,19) = 10.63$, $p = .004$.

At 18 months of age receptive vocabulary was positively related to productive vocabulary at 18 and 24 months of age. At 18 months data on the receptive CDI measure predicted 60.8% of the variance of productive data at 18 months $R^2 = .608$, $F\ (1,19) = 32.07$, $p = .001$, and 45.3% of the variance at 24 months of age $R^2 = .453$, $F\ (1,19) = 17.57$, $p = .001$.

At 24 months of age receptive vocabulary was positively related to productive vocabulary at 24 months with data from receptive CDI predicting 81.6% of the variance of productive vocabulary, $R^2 = .816$, $F\ (1,19) = 47.69$, $p = .001$.

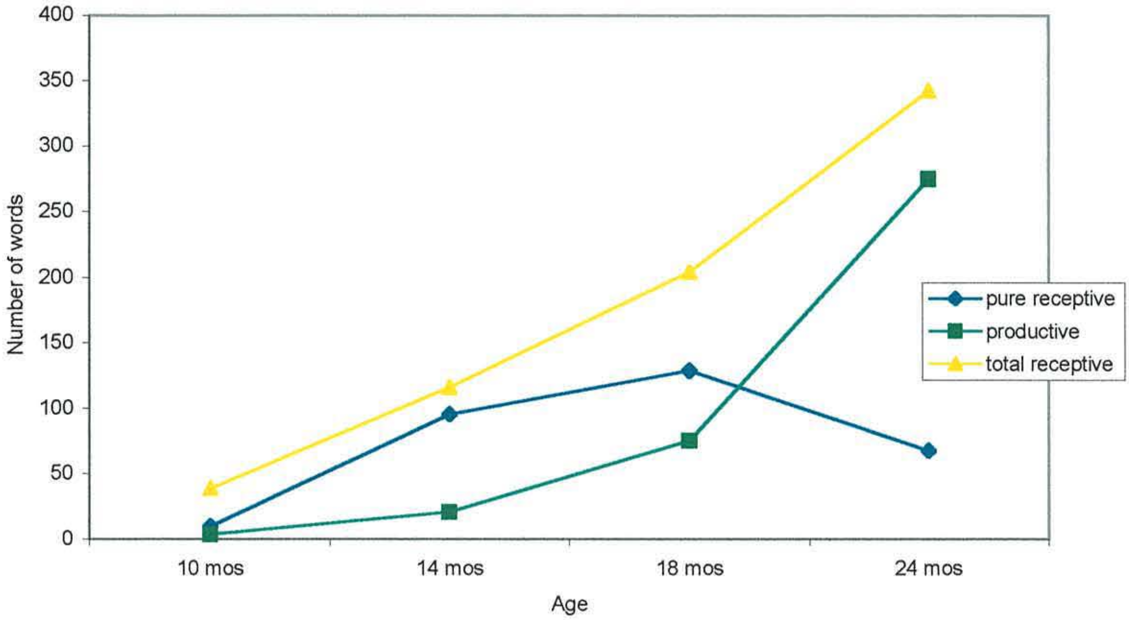

Figure 6.1. Mean receptive and productive vocabulary CDI scores, by age

Discussion of Receptive and Productive CDI Results

Receptive vocabulary and productive vocabulary were positively related, pehaps as, by the very nature of language, both measures increase over time. However, it was not expected that receptive and productive vocabulary would be related at all age levels. Receptive vocabulary does not necessarily have the strongest relationship with productive vocabulary within the same age, or subsequent age group. Presumably this is due to the fact that two different vocabulary systems, or strands, are being compared, as has been previously suggested by Bates et al. (1991).

As can be seen by Figure 6.1, receptive vocabulary increases in a more linear fashion compared to productive vocabulary, which slowly increases in a linear fashion and then sharply increases at approximately 18 months. These findings have been well documented elsewhere (For example, Fenson et al., 1994; Bates et al., 1994). However, these findings do somewhat contradict Bates et al.'s (1991) findings that a relationship at 10 months of age between comprehension and production existed, but did not exist in the older age groups, although a relationship was found between comprehension and the production of nouns or rote production. Nouns make up about half of the items on the Oxford CDI used in this study, which could have influenced the results.

Observational Versus CDI measures of Productive Vocabulary Results

There is a strong positive correlation between CDI productive vocabulary at 14 months of age and observed productive vocabulary at 14 months ($r = .563$, $N = 21, p < .01$) and 18 months of age ($r = .742, N = 21, p < .01$) and between CDI productive vocabulary at 18 months and observed productive vocabulary at 18 months ($r = .728, N = 21, p < .01$) (see Figures 6.2, 6.3 and 6.4).

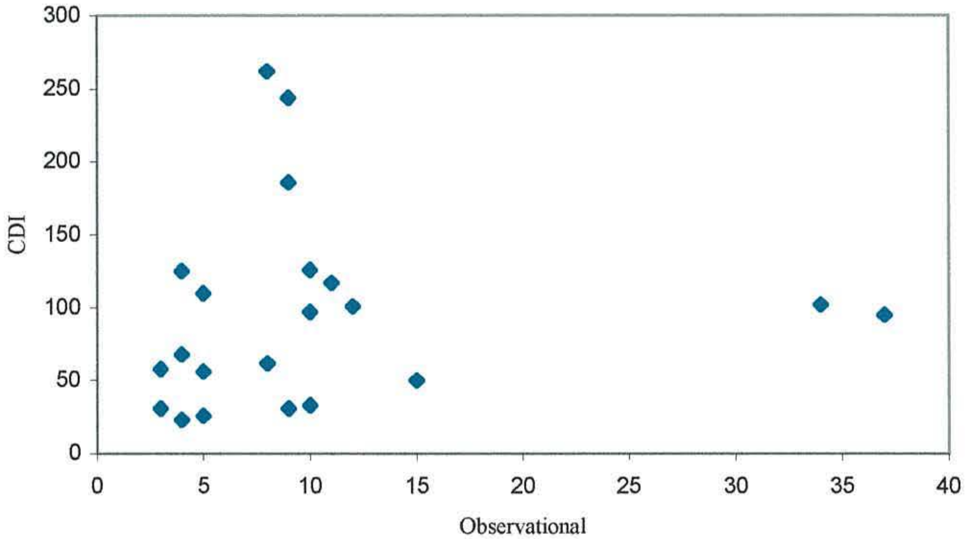

Figure 6.2. The relationship between the observational study and the CDI study at 14 months, measured by word totals.

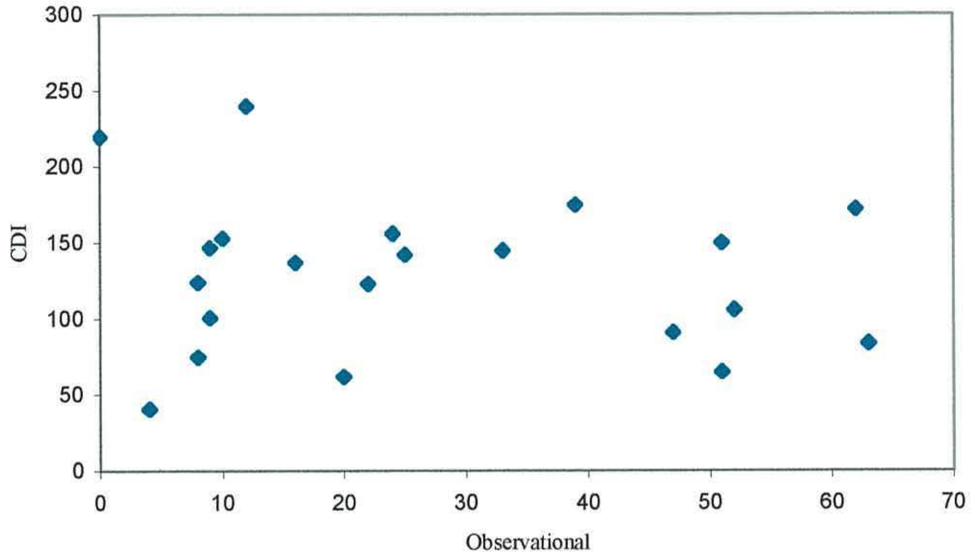

Figure 6.3. The relationship between the observational study and the CDI study at 18 months measured by word totals.

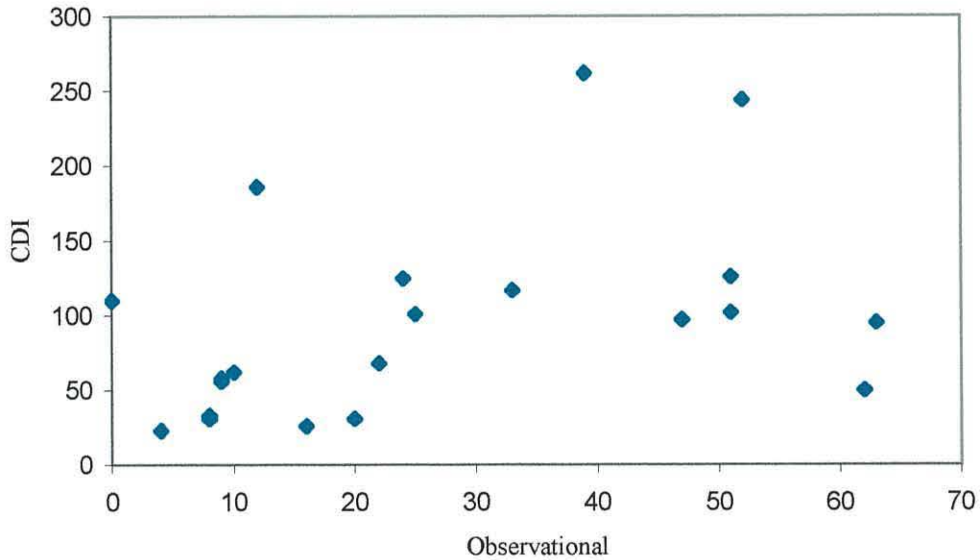

Figure 6.4. The relationship between the observational study at 14 months and the CDI study at 18 months measured by word totals.

Furthermore, if the total of word types is doubled to estimate the total words in an infant's productive vocabulary (in accordance with Vihman & McCune, 1994) the mean calculated, and then compared with the observed word production mean using *t*-test analysis, no significant difference between the measures is found for either age group. The results for the 14-month-olds are, $t(20) = .52, p = .61$ (2-tailed, paired *t*-test), and for the 18-month-olds $t(20) = 1.86, p = .09$ (2-tailed, paired *t*-test).

Discussion of Observational Versus CDI measurements

Since there are significant relationships between the CDI productive measure and the observational studies at 14 and 18 months both measures appear to be reliable methods for measuring productive vocabulary. This is further supported by the parallels drawn between this CDI study and previous CDI studies (for example, Fenson et al., 1994, Bates et al., 1994 and Barrett, 1995) in that there is a sudden increase in productive vocabulary (see Table 6.1 and Figure 6.1), whilst comprehension develops in a more linear manner (labeled as total receptive vocabulary in Figure 6.1). Furthermore, the previous CDI studies stated that infants of 18 months had approximately 110 words in their lexicon, in this study 18 infants had this number or above. At age 24 months productive vocabulary was previously shown in CDI studies to be slightly over 300 words for an average child; in the present study 13 infants had productive vocabularies of this size and above.

Bates et al. (1991) performed regression analyses on parent interviews and observed production and comprehension data in infants and found a very strong relationship. This supports the complementarity of the two types of measures. Furthermore, if the total word productions were doubled, as advocated by Vihman and McCune (1994), to give an approximation of the total number of words in a child's productive vocabulary, it appears that is no significant difference between observed word production and word production as measured by parents.

Chapter 7

Phonological Short-Term Memory Study

Phonological short-term memory has been found to be a reliable indicator of later vocabulary in studies with 5-year-olds in their native first language (Gathercole & Baddeley, 1989a; 1994), and in second language learning in adults (Speciale et al., 2004). A large memory span, as measured by nonword repetition tasks, has been demonstrated to be a major factor in advanced language learning.

Stoel-Gammon (1987) found that a typical 24-month-old is capable of producing a variety of word and syllable shapes and articulating consonantal sounds with a range of place and manner features. This implies that 24-month-olds should not have any particular problem with repeating the English word-like nonwords in this study. Furthermore, Gathercole and Adams (1993, 1995) successfully tested pre-schoolers on memory span tasks.

Methodological considerations

The phonological short-term memory study in the current study is to be carried out in the child's home in order to make the child more comfortable when playing with the researcher. The researcher had met the child on at least three previous occasions, thereby minimising any fear the child may have with a caller being in their home.

When studying individual differences in vocabulary acquisition, it is important that general cognitive ability is matched across children to study differences only in linguistic ability; as in Gathercole and Adams (1993), using McCarthy's Scales of Children's Abilities (McCarthy, 1970). This measure was applied in the present study.

Vocabulary size is usually strongly associated with a range of abilities, including general intelligence and school success (Anderson & Freebody, 1981). However, there are exceptions. Vallar and Papagno (1996) studied a girl with Down's syndrome. Despite her relatively low general intelligence she performed very well on phonological short-term memory tasks and was also fluent in three languages. She did, however, demonstrate impaired performance for associating pairs of familiar words dependent on semantic coding. PV (Baddeley, Papagno, & Vallar, 1988), as discussed earlier, demonstrated the opposite dissociation. PV was a young woman who suffered a stroke. She had an impairment of phonological working memory, specifically short-term deficits. It was suggested that PV's phonological store was defective, which led to poor retention of auditorily presented material. PV appeared not to use subvocal rehearsal to maintain the decaying representations in the phonological loop. Consequently PV was unable to repeat nonwords of more than two syllables or to learn new unfamiliar phonological material. PV was presented with eight high frequency words in her native Italian language; each word was paired with nonwords derived from Russian, for example 'Rosa-Svieti'. The experimenter verbally presented each word pair, after which PV was asked to give the corresponding Russian nonwords to each verbally presented Italian word. PV failed to learn any of the nonwords although 12 out of the 14 control participants managed to learn all nonwords by the end of the 10 learning trials. In contrast PV did learn some visually presented word-nonwords pairs and she learnt pairs of familiar words at a normal rate.

The interaction between PV's phonological working memory impairment and her long-term phonological learning deficits were highlighted in the above experiment. Her phonological loop deficits were most apparent when trying to learn words long-term. Without adequate temporary phonological storage it appears that constructing a long-term memory trace is impossible. PV therefore shows the opposite dissociation to the girl with Down's syndrome as she had very good word-nonword learning. Therefore, it appears that general intelligence is not always associated with language learning when other factors may cause limitations such as a faulty phonological working memory.

Siegal (1988) studied dyslexic children and found that some had high and some had low general intelligence levels, whilst some children with typical reading development demonstrated low general intelligence levels. This evidence suggests that verbal intelligence, or verbal ability, may differ from overall general intelligence. Furthermore, Bryant, Maclean, Bradley, & Crossland (1990) found that rhyme detection and phoneme awareness were significantly related to later spelling and reading achievement, even after age, mother's educational level and general intelligence had been accounted for. The issue of general intelligence and nonverbal intelligence will be addressed in this Chapter, and the effects intelligence may have on the longitudinal study will be discussed.

Visual Perception as a Language Learning Aid

In this study visual perception could be a possible confounding variable, therefore, whilst testing infants' nonword repetition skills, visual cues will be eliminated. Studies have shown that as soon as infants are born they love to scrutinise an adult's face, especially that of the primary caretaker (Fantz, 1963). Infants also pay particular attention to adult lip movement during infant-directed speech. An adult production of /b/ involves a highly visual, literally 'lip-smacking' movement for an infant to focus on that aids the perception of speech sounds (McGurk and MacDonald, 1976). McGurk and MacDonald (1976) investigated how sight influences perception of sound. When a spoken syllable /ba/ was dubbed onto a video of someone saying /ga/ participants reported hearing /da/. The McGurk effect demonstrates that listeners use sensory information wisely by attending to good quality information and paying less attention to less reliable information. Clear auditory information is seen to dominate, but clear visual information can have a strong influence.

To address the visual perception issue the researcher will cover their mouth to eliminate any possible confounding variables. Gathercole and Adams (1993) also controlled for visual perception in this manner.

Exclusion criteria

Exclusion criteria for the longitudinal study were plus or minus one deviation from the mean on the McCarthy Scales of Children's Abilities (1970), administered here at 24 months of age. This test ensured that the children were of a similar general intelligence level, however, as is common with general intelligence tests it is heavily reliant on linguistic abilities and includes many verbal measures. To counter this issue nonverbal intelligence will also be investigated, to ensure that any differences in language acquisition were due to purely innate linguistic ability rather than nonverbal intelligence.

Experiment 4

Method

Hypothesis: Individual differences will be apparent in the performance of the 24-month-old infants on the memory span task, due to linguistic ability not general nonverbal intelligence.

Participants

Twenty-one English infants at 24 months of age, who had participated in Experiments 1b and 2, took part in this experiment. A pilot study consisting of 12 independent English infants at 24 months of age (5 males and 7 females) was previously undertaken in order to assess test materials and test procedures. Participants received £5 plus a Toddler Scientist Certificate.

Stimuli

Gathercole and Adams' (1993; Adams & Gathercole, 1995) nonwords included consonant clusters, for example *pl* in *plurd* and *ndle* in *grindle,* which may be difficult for some infants to pronounce (see Vihman, 1996 for a review). Furthermore, the stimuli were not phonetically transcribed, making it difficult to know exactly how to pronounce the nonwords, and to maintain consistency across participants. New nonword stimuli were therefore devised for this study, and are written in both standard and International Phonetic Alphabet (IPA, see Table 7.1). Nonwords for the present nonword repetition task were devised to be as wordlike as possible to aid repetition in such a young age group. For example, tense vowels /i/, /e/, /u/, /o/ in the pretonic position were not included. Nonwords were constructed using a CVC structure for the one, two and three syllable nonwords. A pretest was carried out to establish the wordlikeness of the nonwords. The pretest was carried out with professionals working within the language, learning and development department within the School of Psychology at Bangor University. The words were deemed as sounding wordlike, that is, similar sounding to English words. Each stimuli list was randomised and each child was presented with the same randomised list.

Table 7.1. Nonword stimuli for the phonological memory task

One syllable IPA	One syllable Standard transcription	Two syllables IPA	Two syllables Standard transcription	Three syllables IPA	Three syllables Standard transcription
net	nate	bə'nu	banoo	dɪ'nofu	dinoefoo
tʌl	tull	'mefi	mayfee	tə'bini	tubeany
mɔs	maws	'suto	sootoe	kə'dego	kudaygo
wɛm	wem	'winu	weenoo	mə'sædu	musadoo
pɪb	peeb	'dofi	doefy	bə'tinə	buteener

Adams and Gathercole (1995) included real words in addition to nonwords, although they had previously stated that nonwords were a more effective measure of phonological memory as memory cannot be reliant on previous experience or exposure to the nonword. Only nonwords were used in this study to limit the length of the task and to retain the child's interest.

Apparatus

The issue of subjective online scoring has been addressed in the present study by the use of a Marantz tape recorder and microphone. This equipment was used to enable offline scoring to substantiate the earlier online scoring. A second rater also scored the audio recordings for reliability.

A nonword repetition score sheet (see Appendix 4) was used to aid online scoring. The McCarthy Scales and the South Tyneside Assessment of Phonology (STAP, Armstrong & Ainley, 1995) test were administered for certain control measures.

The McCarthy Scales

In addition to the nonword repetition task the general cognitive scale of McCarthy Scales of Children's Abilities (McCarthy, 1970, see Appendix 5) was administered to establish general cognitive ability. The rationale for administering the McCarthy Scales was to ensure the children were of a similar general intelligence level, the only difference in the experimental tasks should, therefore, be linguistic ability. Therefore, the scales were used as a control measure. This particular measure was chosen as it is one of very few tests appropriate for two-year-olds. It takes approximately 45 minutes to administer.

The McCarthy scales are grouped into six scales; verbal (V), perceptual-performance (P), quantitative (Q), general cognitive (GC), memory and motor. The first three do not overlap in content, and these three scales are those which, together, constitute the general cognitive scale, that is, V + P + Q = GC. Tasks include digit span, block building, puzzle solving, pictorial memory, word knowledge, number questions, tapping sequence, verbal memory, draw-a-design, draw-a-child, verbal fluency, counting and sorting, opposite analogies, and conceptual grouping. For each scale the infant's raw score is converted to a scaled score (using a weighting system) called an index, according to the infant's chronological age. The general cognitive index (GCI) has a mean of 100 and a standard deviation of 16. The McCarthy scales were standardized with a sample of 1000 children at ten different age ranges between two and eight and a half years of age.

The McCarthy Scales are predominantly a control measure however; regression analyses will be performed on the GCI scores, with word form recognition, receptive, productive, and nonword repetition scores. Furthermore, the relationship between the McCarthy scales GCI non-verbal scores (the scales of perceptual-performance and quantitative from the McCarthy Scales), and the other variables of this study will be examined. The rationale of the proposed analyses would be to discover whether infants' performance in word form recognition, receptive and productive vocabulary, and nonword repetition is influenced by nonverbal general intelligence, or by overall general intelligence (with linguistic ability as a contributor).

South Tyneside Assessment of Phonology

To counter criticisms leveled at coarse-grained scoring methods of the memory span task, consistent articulatory errors were tested, and controlled for, by administration of the STAP test (see Appendix 6). If a child consistently substituted one phoneme for another, for example, if a child repeatedly used /f/ instead of /s/ in everyday conversation, then the target word containing /f/ instead of /s/ would be scored correct. The STAP involves the infants looking through the STAP picture book, with the researcher asking what they could see.

Nonword repetition aids

A pilot study with 12 infants used a puppet with an opening and closing mouth to encourage the children to repeat the words. For example, "Can you help Ellie the elephant learn a new language? Can you say the new words too? It may help her. Can you say the word dofi?" However, it was found that a selection of small plastic dinosaurs and obscure, mythical animals elicited more responses from the infants than a puppet. Therefore, this set of animals was used in the current study.

Procedure

A replication of Adams and Gathercole's (1995) study is difficult due to the absence of detailed instructions, such as, how many times could the researcher say the same word to urge the child to repeat it? If no attempt was made by the infant to repeat a word would the word be disregarded, and the following word presented, or was the whole test terminated? And, lastly, how exactly was a word scored? (Adams & Gathercole, 1995, p.405) stated that, "The repetition was scored as correct if the child produced the same sequence of phonemes as the experimenter, and incorrect if phonemic difficulties were detected".

Infants were presented with each nonword three times, as follows: The infants were told the animal's name "This is Dofi. Then the child was immediately asked, "Who is this?". If a response were not forthcoming, the researcher would continue by saying "His name is Dofi. What's his name? Can you say Dofi?" If there were still no response, the researcher proceeded to the next word. To avoid visual cues the researcher covered her mouth whilst presenting the stimuli (in line with the above literature on visual perception as a facilitator of speech perception).

The participants were able to play or take a break between repetitions if they found the task tiring.

Scoring

The scoring method was based on the technique devised by Service (1992). A syllable was scored as correct only if both the onset and rime portion of the syllable was correctly repeated in the correct serial position within the nonword. Therefore, in the present study the maximum score achievable for the nonword list was 30, the total number of syllables within the list.

Results

Nine children repeated 20 or more nonword syllables out of a possible 30 (66.6% or above, correct), five children repeated between 10 and 20 syllables correctly (therefore scoring between 33.3% and 66.6% correct), and seven children repeated less than 10 syllables correctly (less than 33.3%, see Table 7.2). All children managed to repeat at least 2 syllables correctly (M = 15.19, SD = 8.51). The lowest scorer was participant 20 who repeated 2 syllables, and the highest scorer was participant 17 who repeated 28 out of the 30 syllables correctly. These results demonstrate that children of 24 months of age are capable of understanding, and undertaking, the nonword repetition task (in line with Gathercole & Adams, 1993, 1995). It further demonstrates just how varied infants can be in their linguistic abilities at this very young age.

A random sample of 3 of the 21 (14.2%) of the audio-recordings were assessed and scored by a second rater. The second rater listened to tapes of three infants and followed the scoring procedure, using a scoring sheet. A regression analysis was conducted to measure inter-rater reliability between the total of nonwords correctly repeated by the infants (see Appendix 9, Tables 7.2, 4.10 & 4.11). The results indicated that 99.5% of the variance in the scores from the first rater could be accounted for by variance in the scores from the second rater, $R^2 = .995$, $F\ (1,1) = 182.9$, $p = .047$.

Table 7.3. Nonword repetition data

Participants	PSTM NW
1	8
2	10
3	6
4	20
5	22
6	7
7	11
8	17
9	10
10	27
11	10
12	9
13	23
14	24
15	8
16	21
17	28
18	26
19	27
20	2
21	3

Note. PSTM NW is the number of syllables correctly produced, from a possible total of 30.

Analysis of General Intelligence

Some of the infants in the current study excelled in nonword repetition, and all infants managed to repeat some syllables, therefore infants of 24 months are capable of performing a nonword repetition task. Gathercole and Adams (1993) had some success in testing two to three year olds on conventional memory procedures of digit span, word and nonword repetition.

A limiting factor in both nonword repetition and vocabulary acquisition is the efficiency with which novel phonological forms can be processed and retained (Adams & Gathercole, 1995). The act of repeating an unfamiliar word can be facilitated by the activation of similar-sounding words (Gathercole & Adams, 1994). Therefore children who have a more extensive vocabulary would be expected to be more likely to have lexical representations that are phonologically similar to the nonwords (Adams & Gathercole, 1995). This suggests a highly reciprocal relationship between nonword repetition and vocabulary knowledge, firstly from the common phonological memory contribution to both nonword repetition and long-term phonological learning and, secondly, from the use of lexical knowledge to repeat nonwords (Adams & Gathercole, 1995), and as inferred from Juczyk's WRAPSA model (1993, 1997). This strongly suggests a link between receptive vocabulary and nonword repetition scores and productive vocabulary and nonword repetition scores. These analyses will be performed in the following General Results Chapter. Indeed, these relationships have been found in much of Gathercole and Baddeley's work with children, and also by Speciale et al. (2004) with adult second language learners between speech production and nonword repetition ability. Much variability has been found in the current study between infants' ability to repeat nonwords. Based on earlier research the implications here are that the infants who performed exceptionally well on the nonword task have larger memory spans than the infants who performed less well, and, therefore should possess a larger receptive and productive vocabulary.

It has been suggested that rehearsal is not used by children under the age of eight years, and that perhaps another working memory process or mechanism is responsible for the link between memory span and the word length effect (which has been taken as an indirect index of rehearsal, Gathercole & Adams, 1995). The effect may simply reflect the common influence of the child's accuracy in planning and executing a sequence of articulatory gestures on the basis of a target acoustic representation (Gathercole & Adams, 1993), facilitated by perceptual abilities of word form recognition, or at least sound pattern recognition, to enable a pre-schooler to accurately reproduce a nonword. A relationship could, therefore, be expected between word form recognition and nonword repetition performance in the next chapter.

In conclusion, the current study has established that phonological memory skills can be measured in children as young as two years of age by using conventional nonword repetition tasks. This study is, therefore, a successful replication of Adams and Gathercole's (1995) study, and Gathercole and Adams (1993) study in the testing of young children with newly devised stimuli. It could, in theory, now be possible to predict later vocabulary from the age of two years as opposed to the more typical five years. This would be beneficial to those children suffering from language delay, or language impairments, as they could receive aid at an earlier stage.

It is now possible to establish which links phonological memory shares with other aspects of early vocabulary acquisition. This is the aim of Chapter 8, the General Results Chapter. However, before arriving at Chapter 8 the issue of general intelligence remains.

General Intelligence Analyses

Since general intelligence measures usually incorporate a verbal component it is wise to establish just how much general intelligence influences outcome scores on the longitudinal measures. Below are the descriptive statistics, followed by the regression analyses, with the general cognitive index both with and without the verbal component.

Table 7.4. McCarthy Scales General Cognitive Index descriptive statistics, $N = 21$

	M	*SD*
GCI – McCarthy Scales	100	16
GCI including verbal elements	105.52	8.33
GCI nonverbal	85.05	7.26

Table 7.5. Scale index of composite raw scores for the McCarthy Scales

Participant	GCI incl. verbal	GCI nonverbal
1	116	93
2	114	93
3	106	89
4	115	100
5	109	82
6	97	73
7	100	84
8	88	70
9	107	88
10	101	82
11	101	84
12	103	84
13	110	99
14	111	84
15	95	80
16	109	83
17	116	88
18	116	84
19	110	86
20	101	80
21	91	80

The first point to notice here is that from the nonverbal intelligence descriptive statistics two infants are below one standard deviation (participants 6 and 8), and two infants are above one standard deviation from the mean (participants 4 and 13) based on nonverbal intelligence scores only. These participants are still within plus or minus one standard deviation from the mean on the McCarthy Scales of General Intelligence, so will not be excluded from the study.

By eyeballing the previous data from all of the above studies (see Table 8.1 in the following chapter for a summary of all longitudinal data), it does appear that participants 6 and 8 perform below average to average, except on the CDI measures at 18 and 24 months when they perform above average. Participants 4 and 13 perform mainly at an average to above average level. However, from the evidence below it appears that nonverbal intelligence has little bearing in the early stages of vocabulary acquisition.

From Table 7.6 (below) it can be seen that GCI scores (overall score including the verbal elements) are significantly related to receptive vocabulary at all ages, with GCI scores predicting 20% of the variance of receptive vocabulary scores at 10 months, $R^2 = .2$, $F\ (1,19) = 6.01$, $p = .024$, 29% at 14 months, $R^2 = .29$, $F\ (1,19) = 7.64$, $p = .012$, 30% at 18 months, $R^2 = .3$, $F\ (1,19) = 8.25$, $p = .01$, and 57% of data at 24 months, $R^2 = .57$, $F\ (1,19) = 24.86$, $p = .001$.

Table 7.6. Summary of regression analyses for GCI with verbal elements

Variables	B	SE B	β	R^2
Total GCI (incl. Verbal elements)		Predict WF recognition		
	.35	.32	.25	.06
		Predict 10 mos receptive		
	1.72	.7	.49 *	.2
		Predict 14 mos receptive		
	5.34	1.93	.54 *	.29
		Predict 18 mos receptive		
	5.38	1.87	.55 **	.3
		Predict 24 mos receptive		
	6.32	1.27	.75***	.57
		Predict 10 mos productive		
	.12	.15	.17	.03
		Predict 14 mos productive		
	1.52	.55	.54 *	.29
		Predict 14 mos obs prod		
	.33	.24	.31	.09
		Predict 18 mos productive		
	5.38	1.64	.6**	.36
		Predict 18 mos obs prod		
	1.54	.43	.63**	.4
		Predict 24 mos productive		
	11.65	2.0	.8***	.64
		Predict nonword repetition		
	.51	.21	.48 *	.233

Note. $*p < .05$, $**p < .01$, $***p < .001$.

GCI scores including the verbal elements are significantly related to productive vocabulary at ages 14, 18 and 24 months of age. Total GCI predicted 29% of the variance of productive vocabulary data at 14 months (CDI) $R^2 = .29$, F (1,19) = 7.6, $p = .013$, 36% at 18 months (CDI), $R^2 = .36$, F (1,19) = 10.82, $p = .004$, $R^2 = .29$, F (1,19) = 7.6, $p = .013$, 40% of observed productive data at 18 months, $R^2 = .4$, F (1,19) = 12.73, $p = .002$, and 64% of data at 24 months, $R^2 =$

.64, F (1,19) = 33.93, p = .001. There was no relationship found between GCI scores with 10 months production, nor with 14 months production.

No relationship was found between GCI (with verbal elements) and word form recognition, although a positive relationship was found to exist between GCI verbal and nonword repetition whereby GCI verbal predicted 48% of the variance of nonword repetition at 24 months, R^2 = .48, F (1,19) = 5.78, p = .027. These findings imply that word form recognition is not reliant upon general intelligence with heavily loaded linguistic aspects, but may be related to an ability less reliant on language per se. Nonverbal general intelligence scores may, therefore, have a relationship with word form recognition scores.

From Table 7.7 it can be seen that the GCI nonverbal scores are significantly related to receptive vocabulary at 24 months, observed word production at 18 months and word production at 24 months (as measured by the CDI). GCI nonverbal predicted 38% of the variance of receptive vocabulary at 24 months, R^2 = .38, F (1,19) = 11.78, p = .003, 26% of the variance of observed productive vocabulary at 18 months, R^2 = .26, F (1,19) = 6.75, p = .018, and 51% of the variance of productive data at 24 months, R^2 = .51, F (1,19) = 19.48, p = .001. From these findings it can be concluded that word form recognition is not reliant on nonverbal intelligence either. Phonological short-term memory span is also not related to nonverbal intelligence, but is related to general intelligence with verbal elements included, as stated earlier.

Table 7.7. Summary of regression analyses for GCI nonverbal elements

Variables	B	SE B	β	R^2
GCI nonverbal		Predict WF recognition		
	.39	.37	.23	.06
		Predict 10 mos receptive		
	.47	.92	.12	.01
		Predict 14 mos receptive		
	2.49	2.56	.22	.05
		Predict 18 mos receptive		
	3.38	2.45	.3	.09
		Predict 24 mos receptive		
	5.96	1.74	.62 **	.38
		Predict 10 mos productive		
	5.03	.18	.01	.001
		Predict 14 mos productive		
	.95	.72	.29	.08
		Predict 14 mos obs prod		
	.22	.28	.18	.03
		Predict 18 mos productive		
	2.7	2.27	.26	.07
		Predict 18 mos obs prod		
	1.43	.55	.51 *	.26
		Predict 24 mos productive		
	11.87	2.69	.71***	.51
		Predict nonword repetition		
	.23	.27	.19	.04
		Predict GCI incl. verbal		
	.86	.18	.75***	.56

Note. *$p < .05$, **$p < .01$, ***$p < .001$.

The verbal and nonverbal GCI scores were positively related, with nonverbal GCI scores predicting 56% of the variance of verbal GCI, $R^2 = .56$, F

$(1,19) = 24.08, p = .001$. See Appendix 7 (Table 7.8) for a summary correlation matrix.

Discussion

It is not surprising that the GCI verbal scores are highly related to the language measures used in this study as a third of the scores that make up the GCI score are language based. The GCI nonverbal scores are related to the GCI verbal scores, which is not surprising since the total general intelligence scores incorporate the nonverbal scores. It is interesting that the GCI nonverbal scores were only related to the later stages of language acquisition in this study, that is receptive vocabulary at 18 and productive and receptive vocabulary at 24 months of age. This finding suggests that perhaps nonverbal general intelligence may have some influence over language learning in later life, but has no bearing (in the current study) in the first 18 months of learning a new language.

The fact that nonverbal intelligence did not correlate with either word form recognition or nonword repetition performance appears to suggest that these abilities are purely linguistic in nature. However, whilst nonword repetition performance was strongly correlated to general intelligence (with all verbal components), word form recognition was not. Replication of this study with a larger sample is needed before any conclusions can be reached as to why word form recognition performance has no relationship with general intelligence or nonverbal intelligence.

For the purpose of the present longitudinal study the participants were plus, or minus, one standard deviation from the mean of 100 on the GCI, to ensure a comparable level of general intelligence. This general intelligence measure relied heavily on linguistic indexes; therefore a nonverbal measure of intelligence was used to establish which index has more of a relationship with the variables tested in the current study. The findings suggest that there is an overall general intelligence ability, which has some influence on language learning, however general intelligence tests rely heavily on linguistic measures. Nonverbal intelligence scores related to 'later' language learning, from 18 to 24 months of age (and possibly later).

The implications from these findings are that individuals who have an aptitude for language will score highly in all longitudinal measures regardless of their nonverbal general cognitive ability, as found by Bates et al. (1991), and Blake et al. (1994). As Blake et al. are aware, support for a general capacity model like *M*-power (Pascual-Leone, 1987) would require prediction of their language measures from a nonverbal measure of memory. They state that, " a purely speech-based model, which stresses articulatory rate, misses what we believe to be the essential abstract nature of the constraint on linguistic rules and structure, i.e. on underlying phonological, syntactic, and semantic representation" (p. 105). The authors are referring to Baddeley and Hitch's working memory model.

Blake et al. (1994) view their work as supporting a model of capacity constraints on language production. Further research is needed to strengthen the case for a causal interpretation that it is processing capacity that underlies early language acquisition. The findings of the current study, however, appear to suggest that the working memory model is a more satisfactory model to account for early language acquisition as mainly linguistics skills appear to have an impact on language learning before 18 months of age.

Chapter 8

General Results

This research has, thus far, tracked infants' language development from initial word form recognition at 10 months of age, through receptive vocabulary, speech production and finally nonword repetition performance at 24 months of age. The secondary aim of this research was to highlight any existing links between the areas of word form recognition, receptive and productive vocabulary and phonological short-term memory. This chapter begins by addressing the secondary aims, that is, analysing the relationships between the variables at 10, 14, 18 and 24 months of age using regression analyses (Table 8.2 contains all regression findings, and Table 8.3 summarises the significant findings), and proceeds to the final main analysis: the relationship between sensitivity to word forms and phonological memory. Word form recognition is expected to predict scores on the nonword repetition task and is also thought to be predictive of an infant's receptive and productive vocabulary.

Table 8.1 (below) is a summary of all the data collected from the previous chapters (with the exception of the intelligence analyses performed in Chapter 7). By eyeballing the data it appears that certain relationships exist between performance on the language measures for certain individuals, that is, it appears that some individuals perform at a consistently high level, whilst others perform at a consistently lower level. After the main analyses of the relationships between variables, individual differences will be examined. Four high scoring participants will be compared to four low scoring participants to establish whether the differences between these individuals are indeed significant. If there is such a difference then it could support evidence from the previous chapter in that there may be an innate ability for language, which is not reliant on nonverbal intelligence.

Table 8.1. Summary data for longitudinal participants

Ps	*10mos*					*14mos*			*18mos*			*24mos*		
	REC	PROD	fam	unfam	P.Ratio	REC	PROD	OBSP	REC	PROD	OBSP	REC	PROD	PST
1	57	1	20.43	14.11	0.592	131	6	4	211	55	24	409	348	8
2	17	0	50.97	42.70	0.544	77	9	4	174	51	22	411	411	10
3	99	10	37.46	12.81	0.745	219	33	9	289	49	12	403	353	6
4	23	2	30.49	16.16	0.654	114	17	10	242	151	47	385	385	20
5	67	7	31.14	23.73	0.568	288	26	8	362	187	39	412	412	22
6	22	2	28.76	33.89	0.459	113	3	5	232	12	0	377	82	7
7	18	2	36.70	41.03	0.472	39	6	10	136	12	8	253	189	11
8	19	0	36.16	35.73	0.503	34	3	3	81	19	20	182	106	17
9	15	4	32.81	11.03	0.748	132	31	12	195	53	25	370	304	10
10	0	0	50.00	19.89	0.715	26	0	5	174	37	16	339	312	27
11	26	2	26.59	21.41	0.554	129	12	11	221	76	33	371	317	10
12	38	1	47.51	28.92	0.622	58	0	3	114	13	9	317	116	9
13	16	0	49.62	38.11	0.566	82	32	15	217	45	62	405	397	23
14	58	3	40.00	38.00	0.513	125	23	34	207	57	51	368	356	24
15	8	0	25.68	29.03	0.469	26	3	4	56	15	4	227	108	8
16	22	3	32.49	25.35	0.562	37	6	9	87	12	8	258	154	21
17	87	0	66.11	44.16	0.600	327	83	9	336	230	52	368	365	28
18	95	7	24.59	21.03	0.520	173	47	10	313	248	51	386	386	26
19	62	25	56.16	24.54	0.696	173	78	37	254	170	63	405	385	27
20	32	4	26.27	10.97	0.705	65	9	5	187	40	9	295	158	2
21	32	4	30.27	12.86	0.702	69	7	8	199	46	10	256	133	3

Note: 'Ps' denotes participants, 'REC' denotes total number of words understood on the CDI, 'PROD' denotes total number of words both understood and spoken on the CDI, 'fam' and 'unfam' denote total looking times to familiar or unfamiliar type words, 'P.Ratio' denotes looking time (in seconds) to familiar word types divided by total looking time (both to familiar and unfamiliar word types), 'OBSP' denotes observed number of word types produced during 30 minutes free play, 'PSTM' is total number of nonword syllables correctly reproduced by the infant from a possible total of 30.

Table 8.2. Summary of regression analyses for the prediction of productive and receptive vocabulary by word form recognition across all ages, and the prediction of nonword repetition by all variables, $N = 21$.

Variables	B	SE B	β	R^2
		Predict 10 mos receptive		
WF recognition	.25	.56	.1	.01
		Predict 14 mos receptive		
WF recognition	1.66	1.55	.24	.06
		Predict 18 mos receptive		
WF recognition	.97	1.54	.14	.02
		Predict 24 mos receptive		
WF recognition	1.19	1.31	.2	.04
		Predict 10 mos productive		
WF recognition	.31	.49	.15	.02
		Predict 14 mos productive		
WF recognition	.27	.1	.53**	.28
		Predict 18 mos productive		
WF recognition	3.29	.04	.2	.04
		Predict 24 mos productive		
WF recognition	2.54	.02	.25	.06
		Predict 14 mos obs prod		
WF recognition	.24	.16	.31	.1
		Predict 18 mos obs prod		
WF recognition	.67	.36	.39	.15
		Predict nonword repetition		
WF recognition	.71	.27	.51*	.27
10 mos receptive	.83	.75	.25	.06
14 mos receptive	3.55	.02	.34	.11
18 mos receptive	3.65	.02	.34	.12
24 mos receptive	3.26	.03	.26	.07
10 mos productive	.34	.35	.22	.05
14 mos productive	1.55	.51	.57**	.32
18 mos productive	5.15	1.56	.6**	.36
24 mos productive	3.85	.01	.54**	.29
14 mos obs prod	.49	.21	.48*	.23
18 mos obs prod	.32	.07	.74***	.54

Note. 'WF recognition' = word form recognition task at 10 months of age. 'obs prod' = observed production. $*p < .05$, $**p < .01$, $***p < .001$.

Table 8.3. Summary of all significant regression analyses for all variables across all ages, $N = 21$.

Variables	B	SE B	β	R^2
		Predict 14 mos receptive		
10 mos receptive	2.28	.39	.8 ***	.62
		Predict 18 mos receptive		
10 mos receptive	2.02	.44	.73 ***	.5
14 mos receptive	.87	.1	.89 ***	.79
		Predict 24 mos receptive		
10 mos receptive	1.08	.49	.45 *	.16
14 mos receptive	.52	.15	.62 **	.35
18 mos receptive	.65	.13	.76 ***	.55
		Predict 10 mos productive		
10 mos receptive	8.93	.04	.47*	.18
		Predict 14 mos productive		
WF recognition	.27	.1	.53**	.28
10 mos productive	.14	.04	.59**	.34
10 mos receptive	.54	.14	.66 ***	.41
14 mos receptive	.22	.04	.75 ***	.55
		Predict 18 mos productive		
14 mos productive	2.44	.45	.78 ***	.61
10 mos receptive	1.71	.43	.67 ***	.42
14 mos receptive	.69	.13	.76 ***	.58
18 mos receptive	.73	.13	.79 ***	.61
		Predict 24 mos productive		
14 mos productive	2.95	.96	.58 **	.33
18 mos productive	1.05	.29	.65 **	.42
10 mos receptive	1.87	.85	.45 *	.16
14 mos receptive	.874	.27	.6 **	.33
18 mos receptive	1.03	.25	.69 ***	.45
24 mos receptive	.53	.08	.85 ***	.82
		Predict 18 mos observed prod		
14 mos observed prod	1.56	.493	.59**	.35
		Predict nonword repetition		
WF recognition	.71	.27	.51*	.27
14 mos productive	1.55	.51	.57**	.32
18 mos productive	5.15	1.56	.6**	.36
24 mos productive	3.85	.01	.54**	.29
14 mos obs prod	.49	.21	.48*	.23
18 mos obs prod	.32	.07	.74***	.54

Note. 'WF recognition' = word form recognition task at 10 months of age. 'obs prod' = observed production. $*p < .05$, $**p < .01$, $***p < .001$.

Word form recognition and production results

A link was found between word form recognition measured at 10 months and productive vocabulary (as measured by the CDI) at 14 months. Performance on the word form recognition task predicted 28.3% of the variance of data on the productive task at 14 months of age, $R^2 = .283$, F (1,19) = 7.5, $p = .013$ (see Tables 8.2 and 8.3. See also Appendix 8, Table 8.9 for a correlation matrix of all task comparisons in the longitudinal study).

Observation and CDI production results

It appears that Fenson's (1993) claim that the CDI is a useful and reliable indicator of a child's language is a valid one. Experiment 3 demonstrated a strong predictive link between word production observed at both 14 and 18 months of age and CDI productive measures at 10, 14, 18 and 24 months of age. This strong relationship is further demonstrated with CDI productive measures reflecting observed word production in their relationship with phonological short-term memory. The productive part of the CDI at ages 14, 18 and 24 months of age correlated highly with nonword repetition scores, where productive vocabulary performance at 14 months predicted 32.3% of nonword repetition scores $R^2 = .323$, F (1,19) = 9.07, $p = .007$, and productive vocabulary at 18 months predicted 36.4% of the variance of nonword repetition scores $R^2 = .364$, F (1,19) = 10.88, $p = .004$, and word production at 24 months predicted 28.6% of scores on the nonword repetition task at 24 months of age $R^2 = .286, F\ (1,19) = 7.61, p = .013$.

Nonword repetition and production results

Word production observed at 14 months predicted 22.8% of nonword repetition scores at 24 months of age $R^2 = .228, F\ (1,19) = 5.62, p = .028$, and word production observed at 18 months of age predicted 54.1% of nonword repetition scores at 24 months of age $\mathrm{R}^2 = .541, \mathrm{F}\ (1,19) = 22.43, \mathrm{p} = .001$.

Receptive vocabulary results

Since the receptive and productive parts of the CDI were highly correlated in Experiment 3 (these regressions are covered in full in Chapter 3), it would be reasonable to assume that the receptive CDI measure would correlate with nonword repetition performance, or word form recognition performance, as production did. However, interestingly no such links were found. Receptive vocabulary only appears to have links with itself (at all age levels) and with productive vocabulary (see Table 8.3)

Word form recognition and nonword repetition results

These results have so far indicated where existing links lie between word form recognition and productive and receptive vocabulary, and between nonword repetition and productive and receptive vocabulary (see Table 8.3 for a summary of significant findings). The last stage of this thesis, and the ultimate aim, was to ascertain whether a link existed between performance on the word form recognition and the nonword repetition tasks. A linear regression was carried out on the data from these tasks (Experiment 1b and 4), and a significant relationship was found (see Figure 8.1, below). Looking time on the word form recognition task predicted 26.5% of the variance on the nonword repetition task. $R^2 = .265$, F $(1,19) = 6.8$, $p = .017$ (see Appendix 8, Table 8.9 for a correlation matrix of all task relationships in the longitudinal study).

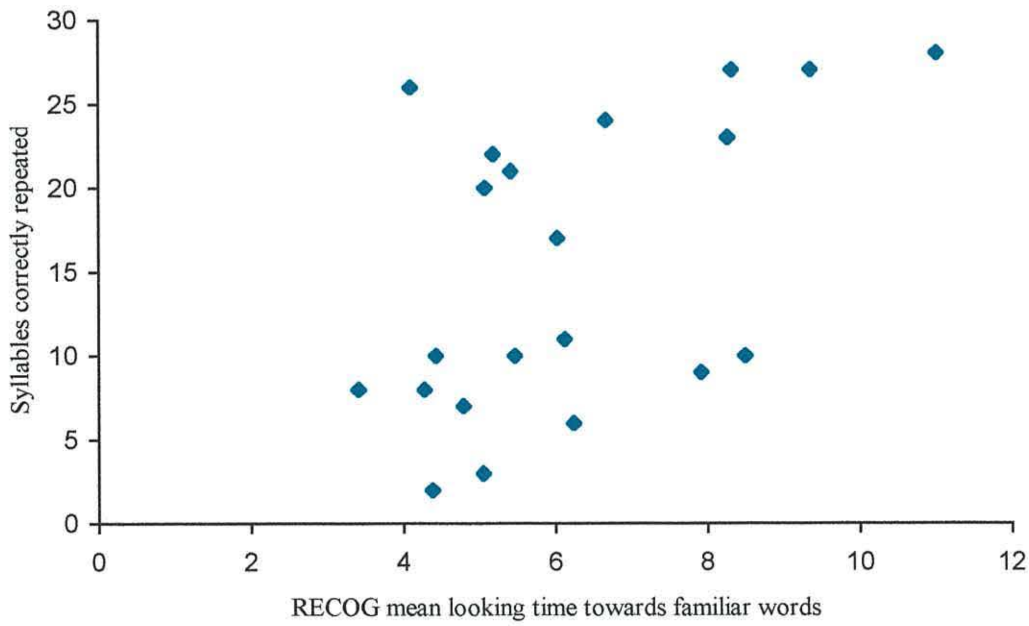

Figure 8.1. Scattergram to show the relationship between performance on the word form recognition and the nonword repetition tasks

Comparison of 'high' and 'low' linguistic performers

As stipulated in Experiment 1b, there was a significant group preference for familiar words in 10-month-olds. However, only 4 out of the original 24 infants actually showed a statistically significant looking time for familiar words using *t*-test analyses on their individual looking time data (it must be noted, however, that there were only 12 trials, six familiar and six unfamiliar, therefore statistical power is low).

The fact that these four infants showed a significant preference was probably due to their data containing less variability than the other infants, suggesting they were demonstrating more stable looking behaviour as measured by looking time, presumably as they had more stable representations of the familiar type words being presented to them. However, the low number of infants' preferences that reached statistical significance was not reflected in the numerical trends, as indexed by the purely descriptive P Ratio (P Ratios are used as a guide only, an indication of trend or preference) where 17 of the longitudinal infants (and 19 of the initial 24 infants) were found to demonstrate a longer looking time towards familiar type words (see Table 8.1).

Paired *t*-tests were carried out on individual looking times on the 12 trials, 6 familiar and 6 unfamiliar (see Table 8.4 for descriptive statistics). These individuals are participants 10, 13, 17 and 19 (see Table 8.5 for *t*-test results).

Table 8.4. Descriptive statistics for the four individual infants who looked significantly longer towards familiar words.

Participant	Total look familiar	*M* look fam/trial	*SD*	Total look unfamiliar	*M* look unfam/trial	*SD*
10	50	8.33	1.26	19.89	3.32	2.15
13	49.62	8.27	1.55	38.11	6.35	2.45
17	66.11	11.02	2.07	44.16	7.36	2.92
19	56.16	9.36	3.16	24.54	4.09	2.52

Note. Data measured in seconds. There were six trials of familiar and six trials of unfamiliar stimuli, therefore statistical power is low.

Table 8.5. Summary of significant two-tailed, paired *t*-test results for participants 10, 13, 17, and 19.

Participant	*df*	*t*	*p*
10	5	4.53	.006
13	5	2.59	.049
17	5	7.48	.001
19	5	2.69	.043

Since the whole group achieved a significant familiar preference, yet only four out of the 24 infants were significant when carrying out *t*-tests on individual data it makes sense to compare the significant four with the four infants who performed least well on the word form recognition task to establish whether infants who were either very efficient, or less efficient at language recognition at 10 months would carry over into the later measures, and possibly into later life, that is, to establish whether an innate linguistic ability exists. Unpaired, two-tailed, *t*-tests will be performed.

The eight participants' data in question have been pulled out and inserted into Table 8.6 below to make it easier to eyeball the data. By following the sample of the top four infants' (participants10, 13, 17, and 19) progress throughout the longitudinal study it appears that links exist between the areas of word form recognition, receptive and productive vocabulary and phonological short-term memory, due to the fact that these babies appeared near the top of the ranked scores in all measures. In comparison scores from four infants at the other end of the scale (participants 6, 7, 8, and 15), when followed longitudinally across the table, appear to remain low scorers throughout most measures, with the exception of child number 6 who appears to have average to high receptive vocabulary CDI scores at 14, 18, and 24 months of age.

Table 8.6. Summary of data for the four high and four low scoring infants

Ps	*10mos*					*14mos*			*18mos*			*24mos*		
	REC	PROD	fam	unfam	P.Ratio	REC	PROD	OBSP	REC	PROD	OBSP	REC	PROD	PST
LOW														
6	22	2	28.76	33.89	0.459	113	3	5	232	12	0	377	82	7
7	18	2	36.70	41.03	0.472	39	6	10	136	12	8	253	189	11
8	19	0	36.16	35.73	0.503	34	3	3	81	19	20	182	106	17
15	8	0	25.68	29.03	0.469	26	3	4	56	15	4	227	108	8
HIGH														
10	0	0	50.00	19.89	0.715	26	0	5	174	37	16	339	312	27
13	16	0	49.62	38.11	0.566	82	32	15	217	45	62	405	397	23
17	87	0	66.11	44.16	0.600	327	83	9	336	230	52	368	365	28
19	62	25	56.16	24.54	0.696	173	78	37	254	170	63	405	385	27

Observed production

It is interesting to note that three of the children (children 13, 17 and 19) achieved the most vocal productions as measured by amount of word types produced at 18 months (see Table 5.1, Chapter 5), indicating a broad vocabulary. At 14 months infant number 19 achieved the most vocal productions as measured by amount of word types produced. Infant number 13 was third from the top. Participants 6, 7, 8, and 12 scored consistently low for observed production at both age levels, the highest rank being eleventh for participant 8 at 18 months.

Observed production and CDI production measures

Findings in the CDI are similar to those in the observational studies, that is, at 14 months child number 17 ranked top for vocal productions and ranked second at 18 months. Child 19 was ranked second at 14 months and fourth at 18 months, child 13 was ranked fifth at 14 months, but dropped to thirteenth place at 18 months and child number 10 was ranked last at 14 months with no word productions, but was ranked fifteenth at 18 months. Children 13, 17 and 19 therefore appear near the top of ranked scores in the CDI measures as they had done in the observational studies, thereby suggesting a strong correlation will be found between the two measures (see Table 6.3, Chapter 6). Again, the low performers never reached above the halfway mark of two word productions.

Receptive vocabulary

For receptive vocabulary children 17 and 19 again excelled. Child 17 was ranked top at 14 months and second at 18 months. Child 19 was ranked fourth at 14 months and fifth at 18 months. Child 13 was ranked twelfth at age 14 months and ninth at 18 months. Child 10 was ranked last at 14 months but sixteenth at 18 months. The lower performers remained average to low, except for participant 6 who ranked second at 18 and 24 months of age. Participant 12 was ranked fourth at 24 months. These findings were not borne out by their productive results though, where they remained consistently low, suggesting that parents may have overestimated their children's' abilities slightly.

Nonword repetition

The four children who reached statistical significance in individual *t*-tests in Experiment 1b again were highly ranked in nonword repetition performance (see Table 7.3, Chapter 7). When all 21 children were ranked child 17 came top, 19 and 10 came joint second, and child 13 came fifth. Through following the four children 10, 13, 17, and 19 throughout the previous experiments it could be suggested that a strong positive relationship between performance on the word form recognition task and the nonword repetition task should exist, possibly mediated by productive and receptive vocabulary. The highest scoring low performer here was participant 8 who ranked ninth.

Table 8.7. Descriptive statistics for the two groups of infants to be compared

Variable		*M*	*SD*
P Ratio			
	High	.66	.08
	Low	.48	.02
Familiar			
	High	55.47	7.7
	Low	31.83	5.47
Rec 10 mos			
	High	41.25	40.26
	Low	16.75	6.08
Prod 10 mos			
	High	6.25	12.5
	Low	1.0	1.16
Rec 14 mos			
	High	152.0	131.46
	Low	53.0	40.36
Prod 14 mos			
	High	48.25	39.52
	Low	3.75	1.5
Word types 14 mos			
	High	16.5	14.27
	Low	5.5	3.11
Rec 18 mos			
	High	245.25	68.77
	Low	126.25	78.02
Prod 18 mos			
	High	120.5	95.07
	Low	14.5	3.32
Word types 18 mos			
	High	48.25	22.07
	Low	8.0	8.64
Rec 24 mos			
	High	379.25	32.0
	Low	259.75	83.49
Prod 24 mos			
	High	364.75	37.56
	Low	121.25	46.69
PSTM task			
	High	26.25	2.22
	Low	10.75	4.5

Note: 'High' denotes the high scorers in the word form recognition task and 'Low' denotes the lower scorers.

The results of the *t*-tests confirm the above findings by showing significant differences exist between the two groups across many measures (see Table 8.8), hence lending support for the theory that an infant who is efficient at recognising sound and word patterns at an early age has a distinct language learning advantage over their less efficient counterparts. Furthermore, the measures of receptive and productive vocabulary at 18 months just failed to reach significance at the .05 level. These findings, and the significant findings below imply that there may well be an innate linguistic ability.

Table 8.8. Summary of significant findings for unpaired, two-tailed, *t*-tests ($N = 4$ for each group, statistical power is therefore low).

Variable	*df*	*t*	*p*
P Ratio	6	3.94	.05
Familiar looking time	6	5.01	.002
Word types 18 mos	6	3.4	.015
Rec 24 mos	6	2.67	.037
Prod 24	6	8.1	.001
PSTM	6	6.12	.001

Discussion

Receptive vocabulary

Most results were as expected, that is, that the variables word form recognition, receptive vocabulary, productive vocabulary and memory span would be related in some way. Interestingly scores on the nonword repetition task and receptive vocabulary scores were not linked. This finding reflects findings from

Speciale et al. (2004), but contradicts later findings from Gathercole and Adams (1993). Gathercole and Adams (1993) initially did not find a relationship when they tested nonword repetition and receptive vocabulary on the same occasion, but a relationship was later found when they increased their sample size.

A possibility for the difference between the two sets of studies may be the manner in which receptive vocabulary was measured. The current study relied purely on parental measures whilst Gathercole and Adams' study used the short form of the British Picture Vocabulary Scale (BPVS, Dunn & Dunn, 1982). Speciale et al. used a typed, computer presented, list of words, whereby participants indicated if each item was believed to be a word or not (see Speciale et al., 2004 for a review and possible issues with the stimuli). If the current study were to be replicated in the future it would be wise to include an extra measure for receptive vocabulary, with a much larger sample. An extra measure for productive vocabulary was included in the current study by way of the parent child observation study. However, the observational study could not be utilised as a receptive vocabulary measure in this instance as it would be far too subjective with situational context being a possible confound.

The CDI was deemed to be an accurate measure of receptive and productive vocabulary by earlier studies. The current findings are consistent with earlier studies, therefore it could be claimed that results are accurate and receptive vocabulary simply does not correlate with nonword repetition at this early stage in the language acquisition process, this does not exclude the possibility that perhaps a relationship will be found further along the path of language acquisition. In addition, receptive vocabulary did not correlate with word form recognition. The fact that this finding appears to contradict Hallé and Boysson-Bardies' (1994) claim that the head turn procedure is a reliable and valid measure of receptive vocabulary further implies that a relationship between receptive vocabulary and word form recognition and nonword repetition performance will occur at a later stage.

Receptive vocabulary was strongly linked to productive vocabulary (and to receptive vocabulary at different age levels), thus demonstrating an association between the two variables. However, the fact that receptive vocabulary did not correlate with the variables that productive vocabulary did, namely word form recognition, and nonword repetition, then it could be concluded that there is a different pathway/mechanism to the two types of vocabulary, as proposed by Bates, et al. (1991). Therefore a dissociation also exists between receptive and productive vocabulary.

Production and phonological short-term memory

The fact that productive vocabulary, but not receptive vocabulary, is related to nonword repetition performance is not entirely at odds with Gathercole

& Adams (1993) findings. They state that repetition performance and vocabulary scores are directly influenced by the knowledge possessed by a child about the stimuli to be repeated. They do not necessarily mean 'understanding' (or receptive vocabulary) but more so an ability to retain and recognise and formulate articulatory plans to repeat the word forms (as in productive vocabulary).

The finding that infants with poor phonological memory abilities use fewer words in spontaneous speech production (as measured by number of word types produced in a 30-minute period) substantially extends previous findings of close links between phonological memory skills and measures of receptive vocabulary knowledge (Gathercole & Baddeley, 1989; Gathercole et al., 1992; Adams & Gathercole, 1995). Adams and Gathercole (1995) was the first demonstration of a relationship between phonological memory and productive vocabulary, and is consistent with the view that adequate temporary maintenance of the phonological form of a novel word in working memory is critical to its long-term learning, and thus to vocabulary acquisition (Gathercole & Baddeley, 1993).

Word form recognition and phonological short-term memory span

Between 10 and 11 months of age memory for word forms is becoming stabilised into a representation sufficient for words to sound familiar in the absence of any situational context. The difference in abilities to recognise, and prefer the sound of, familiar words over unfamiliar words may be indicative of a difference in phonological short-term memory. Do the word form recognition task and the nonword repetition task measure the same underlying mechanism? Word form recognition and phonological short-term memory attributes differ as the word form recognition task taps pure recognition of word patterns, whilst the phonological short-term memory tasks taps the ability to represent and maintain stable phonological patterns in order to produce, in this case, unfamiliar nonwords. It is possible that sensitivity to word forms is a precursor for phonological short-term memory, without the productive element (as demonstrated by the fact that word form recognition was only related to one level of productive vocabulary at 14 months and nonword repetition performance was related to productive vocabulary at all age levels, except at 10 months). That is, if an individual is more sensitive to sound patterns and co-occurring strings and is effective at recognizing word forms in the very early stages of language acquisition then this ability may either lead to, or at least facilitate, language production and a more effective phonological memory. It may even be discovered that word form recognition scores could not only predict nonword repetition scores, but, in theory, could also predict later language breadth. These results imply that word form recognition and the nonword memory tasks are tapping in to different abilities. There does not appear to be much overlap in these abilities as productive vocabulary was highly predictive of nonword repetition scores, yet only one level of production (at 14 months) was related to word form recognition. However, it is interesting to note that neither word form recognition, nor phonological short-term memory was related in any way to receptive vocabulary.

This study demonstrates that there is indeed a close relationship between word form recognition, productive vocabulary (measured by both the CDI and by observation methods), and phonological memory skill. A close relationship also exists between receptive and productive vocabulary. These findings are further substantiated by the individual analyses carried out on the four high and four low scoring infants, as these results indicate that if an infant has an aptitude for language learning it will be apparent across the majority of language measures. A priority now is to chart the causal underpinnings of these relationships. This study has gone some way to chart these underpinnings, but a larger sample is needed with the use of multiple regressions or causal pathway analysis to make any solid conclusions about the findings here.

Chapter 9

General Discussion

This study was designed to establish whether or not a link existed between infant word form recognition at 10 months of age and phonological short-term memory at 24 months. Evidence for such a link was found. Secondly, in order to gain insight into the nature of such a link, the relationship between infants' word production and comprehension to word form recognition and phonological short-term memory were also explored. Links between the following were found; performance on the word form recognition task correlated with, and was predictive of, word production, word production scores correlated with, and predicted, phonological short-term memory span, and receptive and productive vocabularies were correlated and predictive of each other. Furthermore, receptive vocabulary scores at 10 months were found to be predictive of later receptive vocabulary and productive scores, and early productive scores were indicative of later productive vocabulary. Both measures of production, that is, the observational and CDI measures were correlated at both 14 and 18 months of age. However, unexpectedly, receptive vocabulary was not found to correlate with either word form recognition or phonological short-term memory.

To recap, the main hypotheses for the longitudinal study were:

1. Word form recognition at 10 months of age, that is, the sensitivity to phonological sequences such as word forms, as indexed by the head-turn preference procedure, will be positively related to phonological short-term memory, as indexed by the repetition of English-like nonwords, at 24 months. The rationale is based on the assumption that sensitivity to word patterns underlies phonological short-term memory.
2. The same sensitivity to phonological sequences and word patterns that underlie word form recognition and phonological short-term memory will be a contributing factor to word production, as indexed by the CDI and observational studies, and the development of stable lexical representations. Performance on the word form recognition and phonological short-term memory tasks will, therefore, be positively related to an infant's productive vocabulary.
3. Receptive vocabulary as indexed by the CDI, should mediate the relationship of sensitivity to form. Therefore, receptive vocabulary will be positively related to word form recognition performance, productive vocabulary and phonological short-term memory span.

From the current findings Hypothesis 1, that sensitivity to phonological sequences such as word forms at 10 month of age would be positively related to phonological short-term memory, was supported. Hypothesis 2, that the same sensitivity to phonological sequences and word patterns that underlies word form recognition and phonological short-term memory would be a contributing factor to word production and the development of stable lexical representations was also supported. However, the third main hypothesis, that receptive vocabulary would mediate the relationship of sensitivity to form between word form recognition and word production, that is, that receptive vocabulary would be positively related to both word form recognition, word production, and nonword repetition was not fully supported. A significant relationship was found between productive and receptive vocabulary, but not between receptive vocabulary and word form recognition, nor phonological short-term memory.

This discussion will follow the order of the above hypotheses, culminating in methodological issues and possible future studies.

Word form recognition, phonological short-term memory and production

The results show that sensitivity to word forms as measured at 10 months has links with word production at 14 months, yet phonological memory, as measured at 24 months, has links with word production as measured at 14, 18, and 24 months of age.

Data from the word form recognition task predicted nearly 29% of the scores on the nonword repetition task, but what is the mechanism underlying this relationship? In light of the findings there are three possibilities:

1. Sensitivity to sound patterns forms the basis for phonological short-term memory.
2. Sensitivity to word forms and phonological short-term memory are mediated in some way through word production.
3. Phonological short-term memory and sensitivity to word forms are both innate, measurable implicit skills, which have an additive effect on language learning.

These possibilities will now be investigated.

1. Does Sensitivity to Sound Patterns Underlie Phonological Short-Term Memory?

Based on correlations between an individual's vocabulary pool and nonword repetition performance it has been argued in the past that phonological short-term memory is a robust predictor of later language learning. That is, individuals with a large phonological short-term memory make effective language learners (Gathercole & Baddeley, 1993). Snowling et al. (1991) examined the concept that phonological memory contributes to the long-term learning of new words and suggested that the opposite could be true, that is, children could use existing word pattern knowledge to enhance repetition of nonwords, especially word-like nonwords. This implies that children who are efficient phonological sequence learners, measured here by the word form recognition task, could use their stable mental representations within long-term memory to facilitate nonword repetition during the phonological short-term memory task. The present findings appear to be consonant with this reasoning. Phonological pattern and word form recognition come into play before phonological short-term memory is fully functional and before speech production usually occurs. The fact that infants followed a general trend throughout the longitudinal study, that is, consistently ranking high, middle or low in variables, seems to suggest that word form recognition may be tapping into a basic linguistic ability.

It is plausible to propose that word form recognition reflects an innate sensitivity to phonological patterns, which leads to efficient word learning and strong mental representations of those sound sequences, which in turn facilitates nonword repetition performance (which is also seen as an innate ability). The stronger and more numerous the representations contained in long-term memory, the faster the processing in phonological short-term memory and the more accurate repetition of new or nonwords will result. If a child were poor at recognising word forms, then, following the above line of thought, the child would also be less efficient at nonword repetition, as supported by the findings of this study.

Infants have demonstrated proficiency on the nonword repetition task, both in the current study and in Gathercole & Adams' work (1993, 1995). It is reasonable to assume that phonological short-term memory is functional, and testable, by age 24 months. These findings therefore contradict the suggestion that the phonological loop is not functional before the age of four years (Kail, 1990; Blake et al., 1994; Baddeley, 1986). It was only in 1993 and 1995 that the first successful trials of measuring phonological short-term memory span in very young children were made public.

From the current findings it is plausible that word form recognition could facilitate nonword repetition performance. But, could phonological short-term memory facilitate task performance on the word form recognition task at age 10 months? This would be difficult to test unless a way could be devised to firstly test phonological short-term memory before testing pure native word form recognition, that is, before much productive vocabulary has been acquired (Speciale et al., 2004, was an attempt to do so with learners of a second language).

Where does speech production fit into this developmental picture?

2. Word Form Recognition and Phonological Short-Term Memory Mediated by Production

Nonword repetition was significantly related to speech production in the present study and in Speciale et al.'s (2004) second language learning study, and in Gathercole and Adams' work (1993, 1995), thereby validating this link.

Blake et al. (1994) studied various complex behaviours, including language in two- to five-year-olds. They investigated the relationship between word span and language imitation to verify whether individual differences in memory span would predict speech production. Blake et al., in line with the present research findings, found that memory span and word production were correlated. Furthermore, it was found that those children who were adept at manipulating complex chunks of language, for example at formulating complex word combinations, were also more adept at manipulating and performing other complex behaviours such as motoric behaviours, and it was further found that these complex behaviours were linked to an individual's memory span.

A relationship between word form recognition and speech production was found in the current study. This link has been found, or alluded to in the past; Vihman (1993) assumes a relationship between perception and word production in her articulatory filter. Bishop (1997) found a relationship between speech perception deficits and poor speech production as measured by phonological memory span, implying that there should be a relationship between exceptional perceptual skills and exceptional productive skills, at least as measured by the nonword repetition task. The current results therefore support Bishop's findings.

In this study word form recognition has been linked to both production, and phonological short-term memory, but does the ability to represent articulatory forms and then produce them mediate the two different language processes? Expanding upon the above line of reasoning it is straightforward to propose that, if a child has a sensitivity to phonological patterns, which leads to stronger mental representations, then these representations would possibly enable an infant to embark on the road to production earlier than infants who are less able to learn sequence patterns. In turn, this aptitude for speech production would impact upon phonological short-term memory and the accurate recall of nonwords. For instance, if an infant has learnt the phonological pattern /bɑ/ as a common and familiar sound sequence, this sequence may be recognised within other sound or word patterns such as *baa-baa (black sheep)*, *Barbie*, *bath*, and so on. If an infant recognises these sound sequences as commonly occurring strings and if that infant can recognise those strings which make up certain word forms, then this sensitivity to sound patterns and words could lead to words being processed and recognised more quickly, implying strong, stable representations are in existence. These strong representations and flexibility, and sensitivity, to sound sequences should lead to more accurate word productions, and also a greater number of word types within that infant's vocabulary. Advanced word production skills could therefore facilitate nonword repetition if the nonwords conform to the phonotactic regularities of the English language, that is, if they contain commonly occurring sound sequences that some infants may perceive as familiar sound patterns. Such a relationship was found in the current study.

The link between the three variables; word form recognition, word production and phonological short-term memory, is supported by Aitchison and Chiat's (1981) work involving recall errors in children. It was found that the children demonstrated recall errors when learning new words that were similar to those of infants learning their first words. Perceptual salience was taken to be the main factor underlying recall errors. This suggests a link between word form recognition, speech production and phonological short-term memory. In the current study the 24-month-olds, when repeating nonwords, occasionally carried over part of the previously presented nonword to the repetition of the subsequent nonword. These recall errors appear to incorporate perceptual salience as a feature of recall.

3. Phonological Short-Term Memory and Word Form Recognition as Independent, additive, contributors to Language Acquisition.

Gathercole and Baddeley (1990) found individual differences in language learning, whilst ruling out environmental differences in their study by controlling auditory exposure to novel words, and found that children with a larger phonological short-term memory learnt novel words more effectively than children with a more limited memory span. Gathercole and Baddeley view phonological short-term memory as instrumental in language learning. Phonological short-term memory has previously been found to have strong links with both receptive and productive vocabulary. Vocabulary has, therefore, been viewed as a product of phonological memory span, in that a large memory span leads to a large vocabulary. However, sensitivity to native word forms, in the very early stages of language acquisition, has not, thus far, been tested as a predictor of later language acquisition. Both sensitivity to sound patterns and word forms, and phonological short-term memory span, might be innate abilities predicting later language development, which, although highly correlated, could function independently.

Both the present study and the study by Speciale et al. (2004) imply that some individuals have a distinct language learning advantage. The phonological sequence index (PSI, a task presenting new sounds and sounds 'heard before' in the session), in Speciale et al.'s study, and the word form recognition task, are measures of sensitivity to and the learning of phonological sequences.

Participants who rapidly acquired the phonological sequences of the target items in PSI discriminated earlier between new and 'heard before' items implying these individuals had an aptitude for sequence learning. In the word form recognition task at 10 months some infants were able to recognise the phonological sequences of familiar word types out of context more readily than others. Although a correlation was not found (although was expected) between PSI and phonological short-term memory in the second language learning studies by Speciale et al. (2004), it is possible that, when learning a native language for the first time, the learning of sound/word patterns and phonological short-term memory have a closer, more tightly integrated relationship, as suggested by the present findings. The fact that PSI and nonword repetition performance were not correlated there it is further inferred that word form recognition and phonological short-term memory are separable. As stated earlier it is likely that sensitivity to word patterns has an impact on phonological short-term memory rather than vice versa as sensitivity to word forms comes into play much earlier on in language development than phonological short-term memory. Further investigation is needed to clarify this relationship.

Segmentation abilities appear to be more involved with long-term representations bypassing the rehearsal process in short-term memory, suggesting exposure is enough for sound pattern learning and subsequent recognition to take place, evidence comes from studies by Saffran et al. (1997) and Jusczyk and Aslin (1995b), as well as from the word form recognition task in the present study. Priming appears to affect recognition – the more an individual hears a word or phonological sequence, the quicker it is recognised in subsequent speech (Jusczyk & Aslin, 1995b). Further evidence comes from studies showing that the words heard with most frequency in the preverbal stage are usually the first words to be articulated (Huttenlocher, 1995).

Priming also affects phonological short-term memory. If a word is vaguely familiar (as some sections or strings of the word may have been 'heard before' and stored in long-term memory) more time may be available for processes such as articulatory assembly and blending to take place. However, once a word is firmly fixed in long-term memory phonological short-term memory becomes redundant and therefore priming will have no effect on phonological short-term memory in aiding articulation of familiar words.

Additional evidence for the separability of word form recognition and phonological short-term memory comes from the studies of language disordered adults and children. From this study it is clear that if an individual has a large phonological short-term memory they are likely to be effective sound pattern learners with good word form recognition abilities and will probably have a broad vocabulary and a flair for languages. However, what happens when there is a breakdown in one of the contributing factors? Mentioned earlier was the paradoxical case of SR (Baddeley et al., 1998) who had a good vocabulary despite having a deficit in phonological short-term memory from an early age. Baddeley et al (1998) suggested that SR's ability to develop a good vocabulary was probably due to his 'motivation and general intelligence'; results from this study suggest that although SR's phonological short-term memory was defective his segmentation and word form recognition skills may have aided his vocabulary development and compensated for his phonological memory deficit.

Bishop (2002) demonstrated that nonword repetition and an auditory processing task (Tallal, Sainberg & Jernigan, 1991) measured separate processes. SLI could be caused by an additive effect of more than one deficit that is, impairments in speech perception or in phonological short-term memory. Bishop found that deficits in speech perception showed no evidence of genetic influence, whereas the nonword repetition deficit was highly heritable.

Word form recognition appears to be an implicit skill and it has been proposed that it could be reliant upon individual differences in the ability to learn statistical regularities (Saffran et al., 1996), thereby inferring that early word form recognition has a problem solving aspect to it. If this were so we would have expected word form recognition abilities to correlate with nonverbal general intelligence measures, such as number literacy and grouping. However, this was not the case. This finding appears to contradict Saffran et al. (1996) at first glance, however, nonverbal intelligence was measured only by the nonverbal components of the measures from the McCarthy Scales of Children's Abilities. A pure test of nonverbal intelligence specifically designed for 2- to 3-years olds would need to be administered before any conclusions can be drawn from this particular finding.

Nonverbal intelligence was found only to contribute to receptive vocabulary at 18 months and to productive vocabulary at 18 and 24 months of age, not to word form recognition at 10 months of age, nor to nonword repetition performance at 24 months. It is interesting to note that the nonverbal intelligence scores related to the later stages of receptive and productive vocabulary, thereby suggesting that nonverbal intelligence may have some effect on later language learning, as suggested by the case of SR (Baddeley et al., 1998).

The above literature has now covered findings and evidence pertaining to the first and second main hypotheses. Receptive vocabulary, in relation to the third hypothesis, will now be discussed.

Receptive Vocabulary

Receptive and productive vocabulary

The ability to acquire new words in receptive vocabulary occurs long before the naming explosion, or vocabulary spurt, thereby implying that comprehension and production are separately activated systems (Shafer & Plunkett, 1998). Infants at the preverbal or early verbal stage and second language learners, demonstrate that they recognise more 'familiar' sound patterns than they can articulate. The present findings support this separability view as production correlated with nonword repetition and word form recognition performances, whilst receptive vocabulary did not. The two strands of vocabulary, therefore, differ in their relationship with word form recognition and phonological short-term memory.

This separability of vocabulary strands is supported by Bates et al. (1991), who proposed two partially dissociable strands of language development, one for comprehension and one for picking up new forms in the sound stream for immediate use in language production. The first strand appears to have much in common with comprehension and recognition, whilst the second strand has more in common with production and phonological short-term memory. Changes in receptive vocabulary have been proposed as being due to conceptual changes, whilst changes in productive vocabulary have been proposed to be due to changes in memory (Bates et al., 1991). It is appealing, and intuitive, to consider that word form recognition would be related to receptive vocabulary as both are reliant on slightly 'fuzzy' representations of words, in the guise of sound patterns, that infants know they have 'heard before'. These representations may be related to a contextual setting, routine or referent in early receptive vocabulary. A change in receptive vocabulary comes about when an infant gradually realises that everything can be referred to by a word or sound. This insight may occur as infants begin to form more stable representations, which then leads to the growth of a productive vocabulary. Memory plays a part in speech production, as the infant has to 'hold' on to a word form to be able to make an articulatory plan in order to produce the word representation accurately.

Further evidence for the dissociable nature of receptive and productive vocabulary derives from the CDI work of Hamilton et al. (2000). It was found that whilst a vocabulary spurt is evident in production, comprehension develops in a more linear fashion, as reflected in the present findings. Ellis and Beaton (1993) also illustrate this separability of factors involved in receptive and productive vocabulary learning, with pronounceability of foreign words affecting productive but not receptive vocabulary learning, implying that strong, stable, mental representations are needed to accurately produce a word and to include that word as part of the productive vocabulary, yet such a strong, accurate, mental representation is not always needed for a word to have a place within a person's receptive vocabulary. An abstract concept and a general understanding that a certain sound pattern or word form pertains to some object or action is all that is needed.

Receptive vocabulary and phonological short-term memory

High correlations between word and nonword repetition tasks and receptive vocabulary knowledge have been previously demonstrated by Gathercole and Adams (1993). However, this relationship did not occur when the two variables were tested for on the same occasion, and then a relationship was only found when the sample size was increased. Such a link was expected in the present study, more so as receptive and productive vocabularies were significantly correlated, the fact that receptive and productive vocabularies are related, however, is not surprising as both vocabularies ultimately increase over time.

Receptive vocabulary and word form recognition

Gleitman (1994) implied that word form recognition and comprehension are separable by stating that children have to achieve knowledge of the concepts that words express, but must first be able to extract recurrent phonological patterns from incoming speech. The present study lends further evidence for this separability. Receptive vocabulary did not correlate with word form recognition, yet productive vocabulary did.

The findings have demonstrated that receptive vocabulary has strong links with productive vocabulary, presumably as the 'fuzzy' representations become more accurate in representation so that infants can then hold the information long enough in short-term memory to formulate an articulatory plan. Furthermore, receptive vocabulary can predict both later receptive and productive vocabulary, but it is not related to word form recognition at 10 months and nonword repetition at 24 months of age. Possible reasons as to the lack of a relationship with word form recognition and nonword repetition have been outlined in Chapter 8; a brief summation will now follow.

When beginning to learn a language phonological store capacity and sound/word pattern recognition abilities are readily separable. However, as exposure to language increases, the degree to which a learner begins to recognise phonological sequences and regularities partially determines the extent of long-term knowledge that will result from this exposure. In short, the greater the learning rate, the greater the resultant receptive vocabulary. It is unlikely, but possible, that infants at 10, 14, 18 and 24 months of age still need more exposure to their native language in order for their receptive vocabulary to correlate with their word form recognition and nonword repetition abilities. Perhaps if the same children were tested at 30 months positive correlations would be found. It could be speculated that age 24 months is the age when language learning begins to accelerate, that is, when sensitivity to word forms, phonological short-term memory and production begin to come into alignment. But it may not be until later, for example at 30 months, that receptive vocabulary enters into alignment. Alternatively, since receptive vocabulary had the highest scores it could possibly be too advanced to relate to word form recognition and nonword repetition scores. This explanation is highly unlikely, as previous studies have found correlations with receptive vocabulary and phonological short-term memory in older participants who have a much larger receptive vocabulary.

More plausibly, the CDI, as a measure of receptive vocabulary, was not as reliable a predictor as the CDI for production, that is the findings could be due to parents overestimating infants' receptive vocabulary on the CDI by assuming receptive knowledge by observing infant responses in a contextual setting or within a routine. In hindsight it would have been advantageous to incorporate another method of testing receptive vocabulary such as the Short Form of the British Picture Vocabulary Scale (Dunn & Dunn, 1982). The McCarthy Scales (1970) did include some receptive language indexes such as getting the infant to point to objects on a card when asked, for example, 'where is the lady?' but these were utilised only as part of the general intelligence test. It would have been difficult to deduce infants' receptive vocabulary from this measure to compare with the CDI results as only eight pictures were used to assess receptive vocabulary in the McCarthy Scales.

Alternatively, receptive vocabulary could have been measured through observation studies similar to the productive observation study. However, an observed receptive study would be very subjective, for example, if a child was asked to 'put the ball in the box' and the child did so, would we be able to ascertain whether the child knew all of the words or just 'ball' and 'box'?

Methodological Issues and Future Studies

The current study has highlighted individual differences in language learning skills. Bishop (1997) stipulates that individual differences in linguistic ability play an important role in language acquisition, implying that individual differences are maintained throughout later life. One limitation of the present study, which cannot be addressed here, is whether the head start demonstrated by high scores on the word form recognition task, production scores and the link to nonword repetition scores is retained throughout later life in native, and possibly second, language learning. In line with previous research by Gathercole and Baddeley it would be interesting to ascertain whether the nonword repetition scores attained at two years in the present research could predict nonword repetition scores at five years of age. Five years of age is the age that nonword repetition scores, as a measure of phonological short-term memory, have been demonstrated to predict an individual's later vocabulary pool. If such a predictive link is found then it follows that the vocabulary pool could be predicted at the much earlier age of two years. Furthermore, the current results imply that scores on a nonword repetition task at 24 months of age could be predicted as early as 10 months, which further implies that an individual's later vocabulary size could be predicted before a child reaches one year of age.

Finally, a major limitation of the present study was the relatively small number of participants involved. A replication of the longitudinal study with a larger number of participants would therefore be advantageous before reaching any solid conclusions regarding the current findings.

Summary

The study has been successful in establishing a link between sensitivity to word forms and phonological short-term memory, thereby giving a clearer developmental picture of what early abilities or sensitivities may possibly lead to a larger, rapidly growing vocabulary in later life. Word production was linked to both word form recognition and phonological short-term memory and it was suggested that sensitivity to word forms influences speech production, and therefore phonological short-term memory. This study challenged existing views about phonological short-term memory and its influence on language learning by suggesting that sensitivity to word patterns is more influential in learning languages by facilitating phonological short-term memory. Surprisingly, receptive vocabulary was only found to correlate with itself across different ages and with word production. It was suggested that this finding might possibly change at an older age or with a larger sample. Further longitudinal empirical research into individual differences in infant sensitivity to word forms, production, comprehension and phonological memory is needed to integrate these areas more fully. There is potential for application in developing early prediction measures for language impairments and treatments of such impairments and language-learning difficulties.

This study has added to previous research by finding that the formation of mental representations of sound sequences, such as familiar words, exists in English infants at 10 months of age, a month younger than was previously found with French infants (Hallé & Boysson Bardies, 1994). This study has also demonstrated that 24-month-olds are capable of understanding and undertaking a nonword repetition task, demonstrating that phonological short-term memory can be successfully measured at this age.

Finally, this study has investigated the relationship between sensitivity to phonological sequences, receptive and productive vocabulary and phonological short-term memory in a single longitudinal study, therefore extending and combining previous work in an attempt to present a more complete developmental picture and to distinguish the different abilities, or processes, needed to acquire native vocabulary. However, further work needs to be conducted before the, still slightly blurred, distinction can be drawn more clearly between the ability to recognise words and an individual's phonological short-term memory and the interdependence, or the relationship, between these two processes.

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Appendices

Appendix 1

Table 4.1. Vowel Frequencies based on Mines, Hanson & Shoup (1978)

vowels	Mines et al.	familiar	unfamiliar	familiar	unfamiliar
ə	19.15	5	6	95.75	114.9
ɪ	13.51	5	3	67.55	40.53
i	9.68	4	3	38.72	29.04
ɛ	8.41	3	0	25.23	0
ɑɪ	7.79	2	2	15.58	15.58
æ	5.91	1	3	5.91	17.73
o - əʊ	4.85	1	0	4.85	0
e - eɪ	4.13	0	1	0	4.13
ʌ	3.84	1	3	3.84	11.52
ɑ - ɒ	3.75	1	0	3.75	0
u	2.97	0	1	0	2.97
ɔ	2.01	1	0	2.01	0
ʊ	1.99	0	1	0	1.99
ɑ - ɑɹ	3.75	0	1	0	3.75
totals		**24**	**24**	**263.19**	**242.14**
averages				**10.966**	**10.089**

Appendix 2

The Oxford CDI

OXFORD UNIVERSITY BABYLAB

Communicative Development Inventory

- A UK adaptation of the MacArthur CDI * -

Dear parent,

The following is a list of words that are typical in children's vocabularies.

For words that your child **understands but does not yet say**, place a mark in the first column, labelled "**U**".

	U	U/S
crocodile	●	○

For words that your child **understands and also says**, place a mark in the second column, labelled "**U/S**".

	U	U/S
crocodile	○	●

If your child uses a different pronunciation of a word (e.g., 'bickie' for biscuit, or 'telly' for television) - mark the word anyway.

Occasionally we list two alternative forms - please **underline** the one your child understands and/or produces.

	U	U/S
pool/pond	○	●

Please fill in the whole circle exactly as shown above, do not just tick or partly fill the circle.

correct marking - ● incorrect markings - ✓ or ⊙

This inventory is a comprehensive "catalogue" of words that are used by many different children across a wide age range, so do not worry if your child knows only a few of them at the moment!

If you have any additional comments or information that you think we should consider, please add these at the end of this inventory.

Thank you very much!

* For information and original copies of the MacArthur CDI, please contact the Developmental Psychology Lab, San Diego State University, San Diego, CA 92182, USA.

OXFORD UNIVERSITY BABYLAB
Communicative Development Inventory

Subject code:

Your name: ....

Child's name: .... Male/female: ....

Birth date of child: ...../....../...... Today's date: ..../......./.......

Animal sounds	U	U/S		U	U/S
baa baa	O	O	ouch	O	O
choo choo	O	O	quack	O	O
cockadoodledoo	O	O	uh oh	O	O
grr	O	O	vroom	O	O
meow	O	O	woof	O	O
moo	O	O	yum	O	O

Animals	U	U/S		U	U/S
animal	O	O	horse	O	O
bear	O	O	kitten	O	O
bee	O	O	lamb	O	O
bird	O	O	lion	O	O
bunny / rabbit	O	O	monkey	O	O
butterfly	O	O	mouse	O	O
cat	O	O	owl	O	O
chicken	O	O	penguin	O	O
cow	O	O	pig	O	O
deer	O	O	pony	O	O
dog	O	O	puppy	O	O
donkey	O	O	sheep	O	O
duck	O	O	spider	O	O
elephant	O	O	squirrel	O	O
fish	O	O	tiger	O	O
frog	O	O	turkey	O	O
giraffe	O	O	turtle	O	O
goose	O	O			

Vehicles	U	U/S		U	U/S
aeroplane / plane	O	O	bus	O	O
bicycle / bike	O	O	car	O	O
boat	O	O	fire engine	O	O
lorry / truck	O	O	pushchair	O	O
motor-bike	O	O	train	O	O

- page 2 -

Toys	U	U/S		U	U/S
ball	O	O	doll	O	O
balloon	O	O	pen	O	O
block / brick	O	O	teddy bear	O	O
book	O	O	toy	O	O
bubble	O	O			

Food and Drink	U	U/S		U	U/S
apple	O	O	food	O	O
banana	O	O	ice cream	O	O
biscuit	O	O	jam	O	O
bread	O	O	juice	O	O
butter	O	O	meat	O	O
cake	O	O	milk	O	O
carrot	O	O	orange	O	O
cereal	O	O	pasta / spaghetti	O	O
cheese	O	O	peas	O	O
chicken	O	O	pizza	O	O
chips	O	O	sweets	O	O
coffee	O	O	tea	O	O
drink	O	O	toast	O	O
egg	O	O	water	O	O
fish	O	O			

Body Parts	U	U/S		U	U/S
arm	O	O	hair	O	O
belly button / tummy button	O	O	hand	O	O
cheek	O	O	head	O	O
ear	O	O	knee	O	O
eye	O	O	leg	O	O
face	O	O	nail	O	O
finger	O	O	nose	O	O
foot	O	O	toe	O	O
tongue	O	O	tummy	O	O
tooth	O	O	mouth	O	O

Clothes	U	U/S		U	U/S
bib	O	O	dress	O	O
boot(s)	O	O	glasses / specs	O	O
button	O	O	hat	O	O
coat	O	O	jacket	O	O

Clothes	U	U/S		U	U/S
jeans	O	O	shoe	O	O
jumper / sweater	O	O	shorts	O	O
nappy	O	O	sock	O	O
necklace	O	O	trousers	O	O
pyjamas	O	O	zip	O	O
shirt	O	O			

Furniture and Rooms	U	U/S		U	U/S
bath / bathtub	O	O	living room	O	O
bathroom	O	O	play pen	O	O
bed	O	O	potty	O	O
bedroom	O	O	refrigerator / fridge	O	O
chair	O	O	rocking chair	O	O
cooker / stove / oven	O	O	settee / sofa	O	O
cot	O	O	sink	O	O
door	O	O	stairs	O	O
drawer	O	O	table	O	O
garage	O	O	TV / television	O	O
high chair	O	O	window	O	O
kitchen	O	O			

Outside	U	U/S		U	U/S
beach	O	O	outside	O	O
bucket	O	O	park	O	O
church	O	O	party	O	O
flower	O	O	pool	O	O
garden	O	O	rain	O	O
house	O	O	school	O	O
moon	O	O	shop	O	O
sky	O	O	swing	O	O
slide	O	O	tree	O	O
snow	O	O	wall	O	O
spade	O	O	water	O	O
star	O	O	work	O	O
stone	O	O	zoo	O	O
sun	O	O			

Household items	U	U/S		U	U/S
bin	O	O	bowl	O	O
blanket	O	O	box	O	O
bottle	O	O	broom	O	O

Household items	U	U/S		U	U/S
brush	O	O	paper	O	O
clock	O	O	penny	O	O
comb	O	O	picture	O	O
cup	O	O	pillow	O	O
dish	O	O	plant	O	O
dummy	O	O	plate	O	O
fork	O	O	purse	O	O
glass	O	O	radio	O	O
hammer	O	O	rubbish	O	O
hoover / vacuum	O	O	scissors	O	O
jug	O	O	soap	O	O
key	O	O	spoon	O	O
lamp	O	O	telephone	O	O
light	O	O	toothbrush	O	O
medicine	O	O	towel	O	O
money	O	O	watch	O	O
mug	O	O			

People	U	U/S		U	U/S
aunt	O	O	girl	O	O
baby	O	O	grandma	O	O
boy	O	O	grandpa	O	O
brother	O	O	lady	O	O
child	O	O	man	O	O
daddy	O	O	mummy	O	O
doctor	O	O	nanny	O	O
friend	O	O	people	O	O
person	O	O	teacher	O	O
policeman	O	O	uncle	O	O
sister	O	O			

Games and Routines	U	U/S		U	U/S
bath	O	O	no	O	O
breakfast	O	O	pat-a-cake	O	O
bye bye	O	O	peekaboo	O	O
dinner	O	O	please	O	O
don't	O	O	shh / hush / shush	O	O
hello	O	O	tea	O	O
hi	O	O	thank you	O	O
lunch	O	O	wait	O	O
nap	O	O	want to	O	O
night night	O	O	yes	O	O

Action Words	U	U/S		U	U/S
bite	O	O	know	O	O
blow	O	O	like	O	O
break	O	O	look	O	O
bring	O	O	love	O	O
bump	O	O	make	O	O
call	O	O	open	O	O
carry	O	O	play	O	O
catch	O	O	pull	O	O
clean	O	O	push	O	O
cry	O	O	put	O	O
cuddle	O	O	read	O	O
cut	O	O	ride	O	O
dance	O	O	run	O	O
draw	O	O	say	O	O
drink	O	O	scratch	O	O
drive	O	O	see	O	O
drop	O	O	show	O	O
eat	O	O	shut / close	O	O
fall	O	O	sing	O	O
feed	O	O	sleep	O	O
find	O	O	smile	O	O
finish	O	O	splash	O	O
get	O	O	stop	O	O
give	O	O	swim	O	O
go	O	O	swing	O	O
have	O	O	take	O	O
hear	O	O	tell	O	O
help	O	O	throw	O	O
hit	O	O	tickle	O	O
hug	O	O	walk	O	O
hurry	O	O	wash	O	O
jump	O	O	watch	O	O
kick	O	O	wipe	O	O
kiss	O	O	write	O	O

Descriptive Words	U	U/S		U	U/S
all gone	O	O	clean	O	O
asleep	O	O	cold	O	O
bad	O	O	dark	O	O
big	O	O	dirty	O	O
blue	O	O	dry	O	O
broken	O	O	empty	O	O
careful	O	O	fast	O	O

- page 6 -

Descriptive Words	U	U/S		U	U/S
fine	O	O	old	O	O
gentle	O	O	pretty	O	O
good	O	O	red	O	O
green	O	O	sad	O	O
happy	O	O	scared	O	O
hard	O	O	sick	O	O
hot	O	O	sleepy	O	O
hungry	O	O	soft	O	O
hurt	O	O	thirsty	O	O
little	O	O	tired	O	O
nasty	O	O	wet	O	O
naughty	O	O	yellow	O	O
nice	O	O			

Question words	U	U/S		U	U/S
how	O	O	where	O	O
what	O	O	who	O	O
when	O	O	why	O	O

Time	U	U/S		U	U/S
day	O	O	now	O	O
later	O	O	today	O	O
morning	O	O	tomorrow	O	O
night	O	O	tonight	O	O

Pronouns	U	U/S		U	U/S
her	O	O	my	O	O
his	O	O	that	O	O
I	O	O	this	O	O
it	O	O	you	O	O
me	O	O	your	O	O
mine	O	O			

Prepositions	U	U/S		U	U/S
away	O	O	on	O	O
back	O	O	out	O	O
down	O	O	there	O	O
in	O	O	under	O	O
inside	O	O	up	O	O
off	O	O			

Quantifiers	U	U/S		U	U/S
all	O	O	not	O	O
again	O	O	other	O	O
another	O	O	same	O	O
more	O	O	some	O	O
none	O	O			

Extra words	U	U/S		U	U/S
	O	O		O	O
	O	O		O	O
	O	O		O	O
	O	O		O	O
	O	O		O	O
	O	O		O	O

Additional Questions:

Does anyone speak to your child in a language other than English (if so, which language)?

Has your child ever had any hearing problems, including glue ear?

Was your child born more than six weeks premature?

Thank you for your help.
If you have any further comments, please write them below.

Appendix 3

CDI Results

Table 6.6. Correlation Matrix of CDI Results

	REC10	PROD10	REC14	PROD14	REC18	PROD18	REC24	PROD24
REC10		r = .466 p = .033	r = .802 p = .001	r = .659 p = .001	r = .725 p = .001	r = .671 p = .001	r = .449 p = .041	r = .45 p = .04
PROD10	r = .466 p = .033		r = .359 ns	r = .587 p = .005	r = .378 ns	r = .401 ns	r = .309 ns	r = .286 ns
REC14	r = .802 p = .001	r = .359 ns		r = .754 p = .001	r = .892 p = .001	r = .775 p = .001	r = .62 p = .003	r = .599 p = .004
PROD14	r = .659 p = .001	r = .587 p = .005	r = .754 p = .001		r = .664 p = .001	r = .779 p = .001	r = .466 p = .033	r = .577 p = .006
REC18	r = .725 p = .001	r = .378 ns	r = .892 p = .001	r = .664 p = .001		r = .792 p = .001	r = .755 p = .001	r = .693 p = .001
PROD18	r = .671 p = .001	r = .401 ns	r = .775 p = .001	r = .779 p = .001	r = .792 p = .001		r = .496 p = .022	r = .645 p = .002
REC24	r = .449 p = .041	r = .309 ns	r = .62 p = .003	r = .466 p = .033	r = .755 p = .001	r = .496 p = .022		r = .816 p = .001
PROD24	r = .45 p = .04	r = .286 ns	r = .599 p = .004	r = .577 p = .006	r = .693 p = .001	r = .645 p = .002	r = .816 p = .001	

Note: REC refers to CDI receptive vocabulary and PROD refers to CDI productive vocabulary

Appendix 4

PSTM Score Sheet

PSTM Task

Name:
DOB:
Test Date:
Participant Code:

Table 1. Nonword stimuli for phonological memory task

randomised	score	randomised	score	randomised	score
mefi		pɪb		dɪ'nofu	
mə'sædu		bə'tinʌ		net	
wɛm		winu		bɒ'nu	
tʌl		mɔs		kə'dego	
'dofi		tə'bini		'sʌto	

Table 2. Real word stimuli for phonological memory task

randomised	score	randomised	score	randomised	score
rabbit		arm		picture	
bird		elephant		latter	
alphabet		driver		potato	
hate		pull		pot	
newspaper		button		holiday	

Appendix 5

McCarthy's Scales of Children's Abilities Score Sheet (1970)

McCARTHY SCALES OF CHILDREN'S ABILITIES

NAME________________________________AGE________SEX________

HOME ADDRESS____

NAMES OF PARENTS OR GUARDIAN________________________________

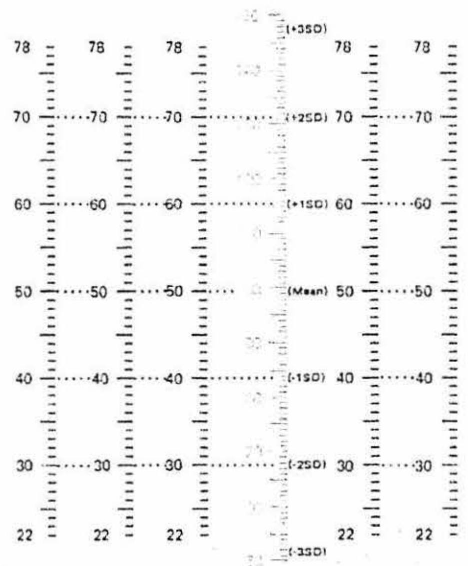
SCHOOL________________________________GRADE________________

PLACE OF TESTING________________________TESTED BY________________

REFERRED BY____

Enter the 6 Scale Indexes on the appropriate lines below. Then circle the mark representing the Index for each Scale. Draw a line connecting the circles. Note that the values for GC are different from those for the other Scales.

	Verbal	Perceptual-Performance	Quantitative		Memory	Motor
SCALE INDEX	____	____	____	____	____	____



	Year	Month	Day
Date Tested	____	____	____
Date of Birth	____	____	____
Age	____	____	____

Enter the composite raw scores from the back cover. *Obtain the composite raw score for GC by adding V + P + Q.* Determine the corresponding Scale Indexes from Table 16. (See page 151 of manual for detailed directions.)

Scale	Composite Raw Score	Scale Index
Verbal (V)	____	____
Perceptual-Performance (P)	____	____
Quantitative (Q)	____	____
	____	____
Memory (Mem)	____	____
Motor (Mot)	____	____

(Enter information from Laterality Summary on page 5.)

Hand________________

Eye________________

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Discontinue after failure on both trials of 2 consecutive items

	Score Trial 1	Score Trial 2	Best Score
1. Tower	(0-3)	(0-3)	(0-3)
2. Chair	(0-2)	(0-2)	(0-2)
3. Building	(0-2)	(0-2)	(0-2)
4. House	(0-3)	(0-3)	(0-3)
		Total	Max. = 10

Discontinue after 3 consecutive failures

	Time Limit	Performance Time	Circle Obtained Score*
1. Cat	30"		0 1
2. Cow	30"		0 1
3. Carrot	30"		0 1 2
4. Pear	60"	(0"-60")	0 1 2 3 4 5 (1"-20")
5. Bear	90"	(0"-90")	0 1 2 3 4 5 6 7 8 (31"-45") 9 (1"-30")
6. Bird	120"	(0"-120")	0 1 2 3 4 5 6 7 8 (31"-60") 9 (1"-30")

*For items 4-6, bonus points for quick performance are given *only if the child completes the puzzle perfectly.*

Total [Max 27] × ½ =

(Round half-scores up)

Exposure Time	Response Time	Response	Score
Allow 10"	Allow 90"	Button ☐ Fork ☐ Paper Clip ☐ Horse ☐ Padlock ☐ Pencil ☐	(0-6)

Discontinue if score on Part I is less than 6. Discontinue Part II after 4 consecutive failures on that part.

Card	Response	Score
1. Apple ☐ Tree ☐ House ☐ Woman ☐ Cow ☐		(0-5)
2. Clock		(0-1)
3. Sailboat		(0-1)
4. Flower		(0-1)
5. Purse		(0-1)
	Total (Part I)	Max. = 9

Discontinue Part II after 4 consecutive failures.

	Response	Score (0-2)
1. Towel		
2. Coat		
3. Tool		
4. Thread		
5. Factory		
6. Shrink		
7. Expert		
8. Month		
9. Concert		
10. Loyal		
	Total (Part II)	Max. = 20

For age 5, start at the indicated item. If items 1 and 2 of Part II are passed, give 9 points for Part I. (See manual.)

Part I + Part II =

Discontinue after 4 consecutive failures

	Right Answer	Response	Score (0-1)
1. Ears	Two		
2. Noses	One		
3. Heads	One		
4. Toys	Three		
5. Balloons	Two		
6. Candy	Six		
7. Pennies	Seven		
8. Apples	Twelve		
9. Crayons	Six		
10. Ball	Eighty		
11. Secret	Four		
12. Cookies	Three		
		Total	Max. = 12

Total × 2 =

	Tapping Order	Score: Trial 1 (0-2)	Trial 2 (0-2)	Trial 3 (0-2)	Best Score (0-2)
1.	1 - 2 - 3 - 4				

Continue only if child plays item 1 correctly and discontinue after 2 consecutive failures on items 2-8.

		Score (0-1)
2.	1 - 3 - 4	
3.	2 - 4 - 1	
4.	4 - 1 - 2 - 3	
5.	2 - 3 - 1 - 4	
6.	1 - 4 - 3 - 2 - 3	
7.	4 - 2 - 3 - 1 - 2	
8.	1 - 2 - 4 - 3 - 2 - 1	
	Total	Max. = 9

Discontinue Part I after 3 consecutive failures. If child earns 8 or more points (out of 30) on Part I, give Part II.

	Score
1. toy - chair - light	(0-3)
2. doll - dark - coat	(0-3)
3. after - color - funny - today	(0-4)
4. around - because - under - never	(0-4)
Do NOT stress the underlined words in items 5 and 6.	
5. The boy said good-bye to his dog every morning before he went to school.	(0-7)
6. The girl tied a pretty pink ribbon on her doll before she went out.	(0-9)
Total (Part I)	Max. = 30

× ½ = (Round half-scores up)

Give Part II if child earned 8 or more points (out of 30) on Part I.

	Response	Score (0-1)
1. Term used for Bob		
2. Term used for the woman		
3. Term used for the letters		
4. Bob walking to store		
5. Bob saw woman		
6. Wind blew letters		
7. Bob shouted, "I'll get them for you!"		
8. Bob was careful		
9. Bob picked up letters		
10. Woman was happy		
11. Woman thanked Bob		
	Total (Part II)	Max. = 11

Administer only to children aged 5 and above. Discontinue after failure on 5 consecutive items.

	Score (0-1)
1. Show me your right hand.	
2. Which is your left ear?	
*3. Touch your right eye with your left hand.	
4. Put your chin in your left hand.	
5. Cross your left knee over your right one.	
6. Show me Roger's left knee.	
7. Show me Roger's right elbow.	
*8. Show me Roger's left foot with your right hand.	
*9. Put your right hand on Roger's right shoulder.	
Total	Max. = 12

*Enter score for each part separately. *Both* parts must be failed for the item to be considered a failure.

Discontinue after item 5 if both trials of items 1-5 are failed.

	Score		Best Score	Notes
	Trial 1	Trial 2		
1. Walking backwards	(0-2)	(0-2)	(0-2)	
2. Walking on tiptoe	(0-2)	(0-2)	(0-2)	
3. Walking a straight line	(0-2)	(0-2)	(0-2)	
4. Standing on one foot	(0-2)	(0-2)	(0-2)	
5. Standing on other foot	(0-2)	(0-2)	(0-2)	
6. Skipping	(0-3)	(0-3)	(0-3)	
		Total	Max. = 13	

Give Part II even if Part I is failed. Discontinue Part II if all 3 trials of item 1, Part II, are failed. Give Part III even if Part II is failed.

Trial 1		Trial 2		Best Score	Preferred Hand
Number of Bounces	Score	Number of Bounces	Score		
(0-15)	(0-7)	(0-15)	(0-7)	(0-7)	R L B
				(Part I)	

Number of Bounces	Score
15	7
12-14	6
9-11	5
6-8	4
3-5	3
2	2
1	1
0	0

Give Part II even if Part I is failed. Discontinue Part II if all 3 trials of item 1 are failed.

	Trial	Score (0-1)	
1. Both hands	1		
	2		
	3		
2. Preferred hand	1		Preferred Hand R L
	2		
	3		
3. Other hand	1		
	2		
	3		
Total (Part II)		Max. = 9	

Give Part III even if Part II is failed.

	Trial	Score (0-2)	
1. Preferred hand	1		Preferred Hand R L
	2		
	3		
2. Other hand	1		
	2		
	3		
Total (Part III)		Max. = 12	

	Score (0-1)	
1. Cross feet		
2. Fold hands		
3. Twiddle thumbs		
4. Sight through tube		Eye Used R L
Total	Max. = 4	

Part I + Part II + Part III =

[illegible] Discontinue after 3 consecutive failures.

	Pass-Fail	Score	Preferred Hand
1.		(0-1)	R L B
2.		(0-1)	R L B
3.		(0-1)	R L B
4.		(0-2)	R L B
5.		(0-2)	R L B
6.		(0-3)	R L B
7.		(0-3)	R L B
8.		(0-3)	R L B
9.		(0-3)	R L B
Total		Max.=19	

[illegible] Administer only if child earned 1 or more points on Test 12.

	Score (0-2)	Preferred Hand	Child's Comments
1. Head		R L B	
2. Hair			
3. Eyes			
4. Nose			
5. Mouth			
6. Neck			
7. Trunk			
8. Arms and hands			
9. Attachment of arms			
10. Legs and feet			
Total	Max.=20		

Test 10, Part I	Ball bouncing	R	L	B
Test 10, Part II, item 2	Beanbag catch	R	L	
Test 10, Part III, item 1	Beanbag throw	R	L	
Tests 12 & 13, all items	Drawing	R	L	B
	Totals	R	L	B

Check one: (See pages 148-149 of manual.)

- ☐ Dominance Established (Right-Handed)
- ☐ Dominance Established (Left-Handed)
- ☐ Dominance Not Established
- ☐ Not Scorable

(Test 11, item 4)

Check one: (See page 149 of manual.)

- ☐ Right
- ☐ Left
- ☐ Not Scorable

14. NUMERICAL MEMORY — Discontinue Part I after failure on *both* trials of any item. If child earns 3 or more points on Part I, give Part II and discontinue after failure on *both* trials of any item.

PART I: FORWARD SERIES

	Trial 1	Trial 2	Score (0-2)
1.	5 - 8	4 - 9	
2.	6 - 9 - 2	5 - 8 - 3	
3.	3 - 8 - 1 - 4	6 - 1 - 8 - 5	
4	4 - 1 - 6 - 9 - 2	9 - 4 - 1 - 8 - 3	
5.	5 - 2 - 9 - 6 - 1 - 4	8 - 5 - 2 - 9 - 4 - 6	
6.	8 - 6 - 3 - 5 - 2 - 9 - 1	5 - 3 - 8 - 2 - 1 - 9 - 6	
		Total (Part I)	Max. =12

PART II: BACKWARD SERIES

	Trial 1	Trial 2	Score (0-2)
1.	9 - 6	4 - 1	
2.	1 - 8 - 3	2 - 5 - 8	
3.	5 - 2 - 4 - 9	6 - 1 - 8 - 3	
4.	1 - 6 - 3 - 8 - 5	6 - 9 - 5 - 2 - 8	
5.	4 - 9 - 6 - 2 - 1 - 5	3 - 8 - 1 - 6 - 2 - 9	
		Total (Part II)	Max. =10

× 2 =

15. VERBAL FLUENCY

	Time Limit	Record Responses Verbatim	Score (0-9)
1. Things to eat Examples: bread potatoes	20"		
2. Animals Examples: cat bear	20"		
3. Things to wear Example: shoes	20"		
4. Things to ride Example: bus	20"		
		Total	Max. =36

[illegible] — If child passed 9 or more items on Test 3, give full credit on Test 16. Otherwise, administer Test 16 and discontinue after 4 consecutive failures.

	Score (0-1)
1. Takes 2 blocks	
2. Takes 3 more blocks	
3. Answer: 5	
4. Puts 2 blocks on each card	
5. Answer: 2	
6. Puts 5 blocks on each card	
7. Answer: 5	
8. Point: 2nd block from left	
9. Point: 4th block from right	
Total	Max. =9

[illegible]	
	Score (0-1)
1. The sun is *hot*, and ice is ________.	
2. I throw the ball *up*, and then it comes ________.	
Continue only if child answers at least one of items 1 and 2 correctly, and discontinue after 3 consecutive failures on items 3-9.	
3. An elephant is *big*, and a mouse is ________.	
4. Running is *fast*, and walking is ________.	
5. Cotton is *soft*, and rocks are ________.	
6. A lemon is *sour*, and candy is ________.	
7. Feathers are *light*, and stones are ________.	
8. Syrup is *thick*, and water is ________.	
9. Sandpaper is *rough*, and glass is ________.	
Total	Max. 9

× 2 =

[illegible] Discontinue after 4 consecutive failures.				
				Score
1. Little, big				(0-1)
2. Red, yellow, blue				(0-1)
3. Square, round				(0-1)
	Number Right	Number Wrong	Right Minus Wrong	
4. Square blocks	(0-6)	(0-6)	(0-6)	(0-2)
5. Big yellow blocks	(0-2)	(0-10)	(0-2)	(0-2)
6. Big round red block				(0-1)
7. Small blue square				(0-1)
8. Large blue square				(0-1)
9. Large yellow circle and small yellow square				(0-2)
Total				Max. = 12

COMPUTATION OF COMPOSITE RAW SCORES

1. Enter the *weighted raw scores* which are in the shaded boxes on pages 2-7 of the record form. For each test, enter the score in the box(es) bearing that test's number. (For example, the score for Test 3 is entered in 2 boxes.)
2. Sum the scores in each of the 5 columns. Enter the totals in the *composite raw score* boxes at the foot of the page.
3. Transfer the *composite raw scores* to the front cover. (Open the booklet and turn it over so that the front and back covers are side by side.) Enter the scores in the Composite Raw Score column in the box labeled "Composite Raw Scores and Scale Indexes."

(For more detailed directions on the completion of the record form, see Chapter 7 of manual.)

WEIGHTED RAW SCORES

	V	P	Q	Mem	Mot
1. Block Building		1			
2. Puzzle Solving		2			
3. Pictorial Memory	3			3	
4. Word Knowledge, I+II	4				
5. Number Questions			5		
6. Tapping Sequence		6		6	
7. Verbal Memory, I	7I			7I	
" " , II	7II			7II	
8. Right-Left Orientation (Ages 5 and over ONLY)		8			
9. Leg Coordination					9
10. Arm Coordination, I+II+III					10
11. Imitative Action					11
12. Draw-A-Design		12			12
13. Draw-A-Child		13			13
14. Numerical Memory, I			14I	14I	
" " , II			14II	14II	
15. Verbal Fluency	15				
16. Counting and Sorting			16		
17. Opposite Analogies	17				
18. Conceptual Grouping		18			
COMPOSITE RAW SCORE					
	V	P	Q	Mem	Mot

132 133 134 135 136 A B C D E

Appendix 6

The STAP Score and Analyses Sheets

PHONOLOGICAL SAMPLING

NAME: AGE:

PICTURE DATE:

1	HOUSE	
	SUN	
	SKY	
	GRASS	
	GREEN	
	FLOWER	
	SMOKE	
2	BUS	
	RED	
3	CARS	
	THREE	
	CRASH	
4	TEDDY	
	SLEEPING	
	BED	
5	GIRL	
	DRESS	
	BLUE	
	SOCK	
	DOLL	

6	CLOWN	
	MOUTH	
	TEETH	
	LIPS	
	NOSE	
7	TELLY	
8	ROCKET	
9	MONEY	
10	BABY	
	MOTHER	
	BAG	
	PUSHING	
	PRAM	
11	CHAIR	
	DOG	
12	SNAKE	
13	HAND	
	FINGER	
	RING	
	THUMB	
	GLOVE	
	WATCH	
14	SPIDER	
	WEB	
15	FISH	
	SWIMMING	
16	FROG	
	CROWN	

17	VEST	
18	TABLE	
	PLATE	
	KNIFE	
	FORK	
	SPOON	
	CUP	
	COFFEE	
	SAUCER	
	SUGAR	
19	JAM	
20	ORANGE	
21	ENGINE	
	TRAIN	
	BRIDGE	
22	LETTER	
	STAMP	
23	ZIP	
24	COOKER	
	OVEN	
	PAN	
	KITCHEN	
25	TEACHER	
26	SCISSORS	
	MEASURE	
27	SWEETIES	

PHONOLOGICAL ANALYSIS 1

NAME: AGE: DATE:

	Acceptable Forms			Realisations			Omissions		
	I	M	F	I	M	F	I	M	F
p									
b									
t									
d									
k									
g									
m									
n									
ŋ									
f									
v									
θ									
ð									
s									
z									
ʃ									
ʒ									
tʃ									
dʒ									
l									
r									
w									
j									
h									

PHONOLOGICAL ANALYSIS 2

NAME: AGE: DATE:

	Acceptable Form	Problems		Acceptable Form	Problems
pl			fl		
pl			fr		
bl			Θr		
br			sp		
tr			st		
dr			sk		
kl			sm		
kr			sn		
gl			sw		
gr			sl		

DISTRIBUTION

Appendix 7

Table 7.8. Correlation Matrix for GCI verbal and nonverbal scores, N = 21

Variables	GCI Verbal	GCI nonverbal
word form recognition	r = .25 p = .284	r = .23 p = .308
10 mos receptive	r = .49 p = .024	r = .12 p = .61
14 mos receptive	r = .54 p = .012	r = .22 p = .343
18 mos receptive	r = .55 p = .01	r = .3 p = .184
24 mos receptive	r = .75 p = .001	r = .62 p = .003
10 mos productive	r = .17 p = .454	r = .01 p = .98
14 mos productive	r =.54 p = .013	r = .29 p = .202
14 mos observed prod	r =.31 p = .178	r = .18 p = .437
18 mos productive	r = .6 p = .004	r = .26 p = .248
18 mos observed prod	r = .63 p = .002	r = .51 p = .018
24 mos productive	r = .8 p = .001	r = .71 p = .001
nonword repetition	r = .48 p = .027	r = .19 p = .405
GCI verbal		r = .75 p = .001

Appendix 8

Summary of Significant Results for the Longitudinal Study

Table 8.9. Correlation Matrix of longitudinal findings, N = 21

	REC10	PROD10	RECOG	REC14	PROD14	OBSP14	REC18	PROD18	OBSP18	REC24	PROD24	PSTM
REC10		r = .466 p = .033	r = .101 ns	r = .802 p = .001	r = .659 p = .001	r = .274 ns	r = .725 p = .001	r = .671 p = .001	r = .413 ns	r = .449 p = .041	r = .45 p = .04	r = .247 ns
PROD10	r = .466 p = .033		r = .146 ns	r = .359 ns	r = .597 p = .005	r = .656 p = .001	r = .378 ns	r = .401 ns	r = .36 ns	r = .309 ns	r = .286 ns	r = .215 ns
RECOG	r = .101 ns	r = .146 ns		r = .239 ns	r = .532 p = .013	r = .314 ns	r = .143 ns	r = .204 ns	r = .393 ns	r = .203 ns	r = .248 ns	r = .513 p = .017
REC14	r = .802 p = .001	r = .359 ns	r = .239 ns		r = .754 p = .001	r = .236 ns	r = .892 p = .001	r = .775 p = .001	r = .53 p = .014	r = .62 p = .003	r = .599 p = .004	r = .338 ns
PROD14	r = .659 p = .001	r = .587 p = .005	r = .532 p = .013	r = .754 p = .001		r = .563 P = .008	r = .664 p = .001	r = .779 p = .001	r = .742 p = .001	r = .466 p = .033	r = .577 p = .006	r = .568 p = .007
OBSP 14	r = .274 ns	r = .656 p = .001	r = .314 ns	r = .236 ns	r = .563 p = .008		r = .252 ns	r = .286 ns	r = 652 p = .001	r = .317 ns	r = .412 ns	r = .478 p = .028
REC18	r = .725 p = .001	r = .378 ns	r = .143 ns	r = .892 p = .001	r = .664 p = .001	r = .252 ns		r = .792 p = .001	r = .583 p = .006	r = .755 p = .001	r = .693 p = .001	r = .341 ns
PROD18	r = .671 p = .001	r = .401 ns	r = .204 ns	r = .775 p = .001	r = .779 p = .001	r = .286 ns	r = .792 p = .001		r = .728 p = .001	r = .496 p = .022	r = .645 p = .002	r = .603 p = .004
OBSP18	r = .413 ns	r = .36 ns	r = .393 ns	r = .53 p = .014	r = .742 p = .001	r = .652 p = .001	r = .583 p = .006	r = .728 p = .001		r = .566 p = .007	r = .777 p = .001	r = ..736 p = .001
REC24	r = .449 p = .041	r = .309 ns	r = .203 ns	r = .62 p = .003	r = .466 p = .033	r = .317 ns	r = .755 p = .001	r = .496 p = .022	r = .566 p = .007		r = .816 p = .001	r = .261 ns
PROD24	r = .45 p = .04	r = .286 ns	r = .248 ns	r = .599 p = .004	r = .577 p = .006	r = .412 ns	r = .693 p = .001	r = .645 p = .002	r = .777 p = .001	r = .816 p = .001		r = .535 p = .013
PSTM	r = .247 ns	r = .215 ns	r = .513 p = .017	r = .338 ns	r = .568 p = .007	r = .478 p = .028	r = .341 ns	r = .603 p = .004	r = .736 p = .001	r = .261 ns	r = .535 p = .013	

Note: RECOG refers to word form recognition at 10 months, REC refers to CDI receptive vocabulary, PROD refers to CDI productive vocabulary, OBSP refers to observed word productions, PSTM refers to phonological short-term memory.

Appendix 9

Table 4.5. Inter-rater reliability data for 11 month-olds' looking time preferences (92.2%)

Participant	Familiar looking time Rater 1	Familiar looking time Rater 2	Unfamiliar looking time Rater 1	Unfamiliar looking time Rater 2
2	28.59	23.89	11.78	8.76
5	59.08	64.78	45.19	50.09
7	48.97	41.01	43.03	49.67

Note. Time is measured in seconds and is total looking time.

Table 4.9. Inter-rater reliability data for 10 month-olds' looking time preferences (91.2%)

Participant	Familiar looking time Rater 1	Familiar looking time Rater 2	Unfamiliar looking time Rater 1	Unfamiliar looking time Rater 2
3	37.46	36.1	12.81	17.99
8	36.16	39.71	35.73	40.87
20	26.27	22.99	10.97	7.05

Note. Time is measured in seconds and is total looking time.

Table 4.10. Summary of inter-rater reliability regression analyses

Variables	B	SE B	β	R^2
Rater 1		**Rater 2**		
		Looking time preferences 11-month-olds		
	1.16	.168	.96	.922
		Looking time preferences 10-month-olds		
	1.08	.168	.96	.912
		Observed word productions 14 month-olds		
	.726	.08	.98	.956
		Observed word productions 18 month-olds		
	1.03	1.63	.95	.91
		Nonword repetition 24-month-olds		
	.78	.06	.997	.997

Table 4.11. Summary correlation matrix for inter-rater reliability

Condition	R1 & R2 Inter-rater Reliability
R1 looking time 11 mos	r = .96 p = .002
R1 looking time 10 mos	r = .955 p = .003
R1 obs word prods 14 mos	r = .978 p = .001
R1 obs word prods 18 mos	r = .954 p = .003
R1 nonword reps 24 mos	r = .997 p = .047

Table 5.3. Inter-rater reliability data for 14 month-olds' observed word productions (95.6%)

Participant	Word tokens Rater 1	Word tokens Rater 2	Word types Rater 1	Word types Rater 2
3	19	13	9	12
18	16	24	10	12
19	80	64	37	31

Table 5.4. Inter-rater reliability data for 18 month-olds' observed word productions (91%)

Participant	Word tokens Rater 1	Word tokens Rater 2	Word types Rater 1	Word types Rater 2
1	65	54	24	21
10	30	39	16	19
11	83	96	33	37

Table 7.2. Inter-rater reliability data for nonword repetition (99.5%)

Participant	Nonword repetitions Rater 1	Nonword repetitions Rater 2
10	27	21
12	9	6
20	2	2

Note Page