A Developmental Perspective on Processing Semantic Context: Preliminary Evidence from Sentential Auditory Word Repetition in School-Aged Children

Author

Mahler, NA, Chenery, HJ

Published

2019

Journal Title

Journal of Psycholinguistic Research

Version

Accepted Manuscript (AM)

DOI

10.1007/s10936-018-9591-6

Rights statement

Downloaded from

Griffith Research Online

A developmental perspective on processing semantic context: Preliminary evidence from sentential auditory word repetition in school-aged children

Abstract

Purpose: The current investigation examined the developmental changes involved in processing semantic context in auditorily presented sentences, as well as underlying attentional and suppression mechanisms.

Method: Thirty-nine typically developing school-aged children aged 6;0 to 14;0 years participated in the current cross-sectional sentential auditory word repetition study. Component processes involved in auditory word recognition were examined and their respective developmental trajectories systematically delineated. Experimental manipulations included semantic congruity (congruous, incongruous), sentence constraint (high, low), cloze probability (high, low), and processing mode.

Results: High sentence constraints elicited top-down pre-potency type effects, which resulted in active suppression of anticipated cloze words and longer naming latencies of perceived cloze words when violated with conflicting bottom-up information. In addition, developmental changes in component processes reflected underlying changes in attention, with evidence that suppression mechanisms remained relatively constant with age.

Conclusions: Findings are interpreted in line with the Trace (McClelland & Elman, 1986) model of auditory word recognition.

Keywords

Auditory word recognition, development, children, semantic context, suppression

Introduction

Despite the centrality of auditory word recognition in day to day communication, significant questions about the nature and interaction of component processes remain unanswered, especially in relation to language development. A plethora of theoretical and empirical work spanning several decades indicates that auditory word recognition is not a unitary concept, with component processes and their relationship to each other often debated (Dahan & Gaskell, 2007; Gaskell & Marslen-Wilson, 1997; Marslen-Wilson, 1987; McClelland & Elman, 1986; Rodriguez Fornells, Schmitt, Kutas, & Muente, 2002; Tyler, Voice, & Moss, 2000). It is crucial to understand these relationships, their role in recognition, and potential loci of breakdown in the recognition process. This knowledge is central in informing remediation of communication disorders where auditory word recognition is implicated, for example, a perceptual deficit such as hearing loss, or neurological deficit such as traumatic brain injury.

Existing theoretical frameworks have largely focused on explaining component processes of auditory word recognition in adult populations, with an emerging body of evidence documenting developmental populations (e.g., Atchley et al., 2006; Church & Fisher, 1998; Coch, Maron, Wolf, & Holcomb, 2002; Grieco-Calub, Saffran, & Litovsky, 2009; Holcomb, Coffey, & Neville, 1992; Kooijman, Junge, Johnson, Hagoort, & Cutler, 2013; McMurray, Munson, & Tomblin, 2014; Mayor & Plunkett, 2014; Swannell & Dewhurst, 2012; Thierry & Vihman, 2008). Insight gained into word recognition processes through these studies indicates that the word recognition system undergoes many changes from infancy throughout childhood, and possibly into the teenage years, with many developmental stages still poorly understood (McMurray, Munson, & Tomblin, 2014; Wang, Allen, Lee, & Hsieh, 2015). Knowledge of typical developmental patterns of auditory word recognition and the component processes encompassed are paramount in understanding and efficiently remediating communication disorders. To address this gap in knowledge, and as a preliminary step to investigate school-aged populations evidencing disordered communication, the current study examined the development of component processes of auditory word recognition in typically-developing children aged six to fourteen years.

It is well-documented that listeners are able to recognise auditorily presented words before perceiving the entirety of the word, with recognition occurring the moment a word is distinct from its phonemic neighbours and uniquely identifiable as itself (e.g., Marslen-Wilson, 1987, 1989; Marslen-Wilson & Welsh, 1978; Tyler, Moss, Galpin, & Voice, 2002). Some models of auditory word recognition, such as the Cohort model (Marslen-Wilson, 1987, 1989; Marslen-Wilson & Welsh, 1978), are critiqued for their heavy reliance on bottom-up processing (eg Dahan & Tanenhaus, 2004). Other models, such as the Trace model (McClelland & Elman, 1986), provide alternative frameworks incorporating substantial top-down influences.

Since these early models, the dominance of bottom-up and top-down processes during auditory word recognition has been extensively debated (eg Dahan & Gaskell, 2007; Dahan & Tanenhaus, 2004). Research into language processing has increasingly provided evidence of the centrality of top-down contextual effects in auditory word recognition, with the onset of these effects occurring earlier than initially predicted (Dahan & Tanenhaus, 2004; Gow & Olson, 2015; Kotz, Cappa, von Cramon, & Friederici, 2002; Kutas & Federmeier, 2000; Moss, McCormick, & Tyler, 1997; Perrin & Garcia-Larrea, 2003; Sajin & Connine, 2014; Tyler et al., 2000, 2002; van den Brink, Brown, & Hagoort, 2001; van den Brink & Hagoort, 2004; van den Brink, Brown, & Hagoort, 2006; Van Petten, Coulson, Rubin, Plante, & Parks, 1999; Wingfield, Aberdeen, & Stine, 1991). Van den Brink and colleagues (2006) showed that in adults, the onset of an Event-Related Potential (ERP) component indicative of violations of semantic expectancies, the N400 (Kutas & Hillyard, 1980), occurred prior to cloze words' isolation points in incongruous sentence completions, that is, while the cohort of potential word candidates still contained a number of activated competitors. This finding supported contextual pre-potency and the presence of cascading processes aiding the rapid integration of targets into the higher order representation of the sentence (van den Brink et al., 2006).

Contextual pre-activation of lexical representations can be explained by the Trace model (McClelland & Elman, 1986). This interactive framework consists of units organised on three levels, representing phonemic features, phonemes and words, respectively[1]. Processing in the Trace model consists of bidirectional excitatory connections between congruous units on different levels, and inhibitory connections between incongruous units within the same level of the architecture. In principle, then, the Trace model promotes the concept of top-down activation in mutually supportive units between levels.

According to the Trace model (McClelland & Elman, 1986), auditory word recognition occurs as follows. As the acoustic-phonetic input is perceived, convergent featural units are activated. This activation exerts an excitatory effect on phonemes and words consistent with the activated units, whereas features inconsistent with these units are inhibited. As additional input is computed, the activations of candidates which no longer match the input are reduced while activations are increased for convergent candidates. In highly constraining contexts, pre-activation is thought to be initiated prior to the presentation of bottom-up input for a particular lexeme, thus allowing rapid word recognition. Pre-activation is thought to increase efficiency by optimising the confluence of bottom-up and top-down activation to achieve early recognition of words consistent with probabilistic predictions (Kutas & Federmeier, 2000; McClelland & Elman, 1986; van den Brink et al., 2006).

Developmental theories suggest that patterns of semantic processing evolve throughout childhood (Booth et al., 2003; Ciechanowicz, 1978; Friedrich & Friederici, 2004; Nelson,

[1] McClelland and Elman demonstrated that the model could also successfully process a sentence stimulus, with activation from an additional, higher level of processing. The importance of contextual variables was substantiated and recognised as improving the accuracy of the whole processing system (McClelland, 1987).

1979). At 10 months of age, infants can tune in to linguistic context cues (Junge, Kooijman, Hagoort, & Cutler, 2012; Kooijman, Junge, Johnson, Hagoort, & Cutler, 2013), which by 12 months is measurable as a lexical context effect in the integration of picture and auditorily presented single word stimuli (Friederici, 2006). By 19 months, children are able to integrate words into simple sentences (Friederici, 2006). Developmental changes in N400 effects have provided evidence for significantly earlier and smaller auditory context effects in older children compared with younger children, interpreted as a decrease in reliance on context for sentential processing with increasing age (Atchley et al., 2006; Hahne et al., 2004; Holcomb et al., 1992; Juottonen et al., 1996). Context effects continue to develop throughout the school years, with children's sensitivity to different types of semantic information reportedly changing (Hahne et al., 2004; Holcomb et al., 1992; Juottonen et al., 1996; Nelson, 1979; Tyler & Marslen-Wilson, 1981) to possibly becoming closely aligned to those of adults around 15 years of age (Ciechanowicz, 1978). In addition, auditory context effects appear earlier during word recognition with increasing age, indicating increasing efficiency in children's ability to integrate contextual information with increasing age (e.g., Atchley et al., 2006; Hahne et al., 2004; Holcomb et al., 1992; Juottonen et al., 1996; Liu et al., 1997; Tyler & Marslen-Wilson, 1981). Such changes in underlying semantic and contextual processing during language acquisition are expected to be reflected in priming patterns and the subject of investigation of the current study (Balsamo, Xu, & Gaillard, 2006; Booth et al., 2003; Hahne et al., 2004; Holcomb et al., 1992; Hurtado & Marchman, 2006; Liu et al., 1997; Mills et al., 2004; Nelson, 1979; Petrey, 1977; Roe et al., 2000; Trueswell, Sekerina, Hill, & Logrip, 1999). Of the studies investigating sentential auditory word recognition, only a handful explored the development evidenced by school-aged children (Atchley et al., 2006; Hahne, Eckstein, & Friederici, 2004; Holcomb et al., 1992; Juottonen, Revonsuo, & Lang, 1996; Liu et al., 1997; Popescu, Fey, Lewine, Finestack, & Popescu, 2009). A complex developmental pattern of sentential context effects emerged from these studies. One interpretation involves different component processes being the source of activation resulting in the observed context effects, with each displaying a unique developmental trajectory (Holcomb et al., 1992). By systematically manipulating variables related to congruity and cloze probability effects, the current experiment aimed to tease apart possible sources of activation and related developmental trajectories. Specifically, semantic context processes and cognitive control processes are investigated, discussed subsequently.

The auditory word repetition paradigm requires participants to simply repeat a word they hear (Bates & Liu, 1996; Liu et al., 1997). A priming effect is exhibited when the presentation of the prime stimulus results in greater activation and faster recognition of the target as compared to other lexemes, which leads to faster repetition reflected in faster naming latencies (NLs). Auditory word recognition forms the receptive component of the auditory word repetition task and involves the processes currently under investigation. The production component of the auditory word repetition task, in the absence of articulatory deficits, is considered to contribute minimally to resultant NLs and not at all to priming effects (Bates & Liu, 1996; Liu et al., 1997). In the current experiment, an auditory sentential paradigm was created in order to allow investigation of auditory context effects. This paradigm is a naturalistic task which does not recruit literacy or metalinguistic processes (Bates & Liu, 1996; Liu et al., 1997), and is thus ideally suited to investigating semantic processing in children with communication difficulties, whose literacy and metalinguistic skills are emerging and vulnerable.

There are a number of potential processes by which a listener may maximise the extraction of information from contextual variables as the sentence is unfolding acoustically, two of which will be the focus of the current investigation.[2] Firstly, lexical representations within a competitor cohort may be continuously evaluated for most-likely candidates based on

[2]The authors acknowledge that parsing operations are likely to have an impact on aspects of sentence processing; however, due to the similarity of the sentence stimuli across experimental conditions and the lack of ambiguities, these operations are expected to be extremely rapid and highly transitory (Mitchell, 1994), impacting minimally on word recognition processes in the current experiment.

language experience and world knowledge, and the activations of elements of the cohort weighted accordingly (Moss et al., 1997). Although *bone* and *stick* are both plausible, semantically congruous completions of the carrier sentence, *The dog buried the* ___ , they have different cloze probabilities. The resultant advantage of congruous high cloze targets (*bone*) over low cloze targets (*stick*) in highly constraining carrier sentences (*The dog buried the* ___) is termed the cloze probability effect. While cloze probability is a term that is commonly used by researchers to refer to the "probability that the target is predictable given a sentence context" (Liu, Bates, Powell, & Wulfeck, 1997, p. 165), it has not previously been referenced as an effect which compares two prime levels. The current study endeavoured to investigate and estimate the congruity and cloze probability effects *separately*, with both effects relying on a sentence's inherent level of semantic constraint.

The Trace model's inclusion of the concept of prepotency, that is, the contextually-induced activation of lexemes prior to any or sufficient acoustic input to identify a lexeme, provides a platform for contextual processes such as the cloze-probability effect to have a large influence on auditory word recognition. Extending the Trace model to include an additional processing level for semantic context, top-down activation to word level units would occur for highly constraining sentences (Elman & McClelland, 1988; McClelland, 1987). A summation of activation leading to a high cloze word would lead to stronger top-down activation as opposed to low cloze words given the model's conceptualisation of connections being weighted according to the degree of overlap of word units. This in turn would lead to stronger within-level inhibition of word units inconsistent with the target word. As a result, the Trace model would predict the presence of a cloze-probability effect (Prediction 1).

Secondly, the summation of a sentence's underlying meaning information can act to narrow down a cohort of potential targets (van den Brink et al., 2006). When a semantically incongruous word completes a highly constraining sentence (*The dog buried the air*), the cloze word does not receive top-down excitatory activation but only same-level inhibitory input as it is incongruous with activated units and the sentence hence leads the listener down the lexical garden path (Davis, Marslen-Wilson, & Gaskell, 2002). This divergence from probabilistic predictions results in a slowing of the word recognition process as a listener needs to suppress and re-route any contextually induced top-down activation in favour of phonetically congruent bottom-up input (Holcomb et al., 1992; van den Brink et al., 2006). This advantage in processing expected for low cloze targets (*stick*) compared with incongruous cloze targets (*air*) in highly constraining carrier sentences (*The dog buried the*___) is termed the congruity effect. This terminology differs to previous uses of the term to refer to comparisons of high cloze targets with incongruous targets (van den Brink et al., 2006). Suppression mechanisms can also be measured directly by comparing incongruous sentences (*The dog buried the air*) with neutral sentences *(You can now say the word ____)*.

The Trace model predicts the presence of a congruity effect. Given sentences' comparable level of constraint, a comparable expectation of the target word is created prior to its presentation irrespective of prime level, with the exception of neutral. This expectation is not fulfilled in either congruous low cloze or incongruous sentence types, however, congruous cloze words are consistent with the context, and could hence receive some top-down activation (Elman & McClelland, 1988). In contrast, no top-down effects from a sentential level exist for the incongruous cloze words, as there are no inhibitory connections between levels in the Trace model. As bottom-up excitatory connections flowing from the perception of the presented target can be assumed to be comparable across prime levels, NL differences across low cloze and incongruous prime levels are likely due to differences in either same-level inhibitory connections or lingering top-down activation resulting from semantic congruity. Since differences in sentences across the low cloze and incongruous prime levels hinge on the presence of semantic congruity between the carrier sentence and the cloze word, any differences in activations at word level, whether due to inhibitory within-level or excitatory between-level activation, are thought to originate from this difference in congruity, in other words, be top-down in origin. The presence of a congruity effect thus would confirm top-down excitatory connections to result in differences in NLs for low cloze and incongruous prime levels (Prediction 2).

In addition to language-specific processes, efficient word recognition also requires cognitive control processes (Dahan & Gaskell, 2007; Gaskell & Marslen-Wilson, 1997; Gernsbacher & Faust, 1991; Marslen-Wilson, 1987; McClelland & Elman, 1986; Tyler et al., 2000). Cognitive control involves inhibitory and attentional processes, which work in concert to achieve efficient task completion (Anderson, Fenwick, Manly, & Robertson, 1998; Aydelott & Bates, 2004; Dagenbach & Kubat-Silman, 2003; Dempster, 1992; Diamond, 2004; Gaskell & Dumay, 2003; Harnishfeger, 1995; McClelland & Elman, 1986; Mirman, McClelland, & Holt, 2005; Rafal & Henik, 1994; Roe et al., 2000; Trueswell, 2006). As children demonstrate considerable changes in cognitive processing with age (Anderson, 1998; Case, 1992, 1995; Case & Okamoto, 1996; Wang et al., 2015), but resources available for processing are thought to remain constant with age (Case, 1985), developmental trajectories result from changing processing efficiency (Dempster, 1992; Harnishfeger, 1995). Processing efficiency is maximised by the inhibition of task-irrelevant information, leading to a measurable effect on actions and cognitions (Coch, Sanders, & Neville, 2005; Crosson, Benjamin, & Levy, 2007; Dagenbach & Kubat-Silman, 2003; Roe et al., 2000), as for example relevant for lexical selection discussed previously. As a result, the flow of activation to nonessential information is impeded and attentional processes are focused (Dagenbach & Kubat-Silman, 2003; Harnishfeger & Bjorklund, 1993; Harnishfeger, 1995; Lorsbach, Wilson, & Reimer, 1996). Generally, studies have shown that cognitive control develops throughout childhood and early adolescence, with most change occurring when children are between the ages of six and twelve years (Anderson, 1998; Kolb & Whishaw, 1996; Welsh, Pennington & Groisser, 1991). The current study was designed to give insight into the effects of attentional and inhibitory effects separately in an attempt to delineate their individual trajectoreal contribution underpinning auditory word recognition development. An experimental manipulation, processing mode, was introduced to differentially engage attentional processes. Furthermore, selected variables were manipulated to either increase (enhance) or decrease (suppress) word activations (Crosson et al., 2007).

The aim of the current experiments was to investigate auditory word recognition in highly constraining sentential environments in typically developing children aged 6 to 14 years. Insight was sought into the trajectories of priming patterns, including suppression and enhancement, and the role of context effects under investigation, namely congruity and cloze probability effects.

Specifically, the current experiment aimed to

(a) determine developmental changes of context and priming effects, specifically the trajectories of suppression, enhancement, congruity and cloze probability effects during auditory word recognition processes of access, selection and integration (Marslen-Wilson, 1987). Resultant data were hypothesised to be consistent with previous studies, such as Holcomb et al. (1992) and Liu et al. (1997), which found significant context effects in this age group, with younger children evidencing later and larger pre-potency effects. The current experimental design built on a proposition by Holcomb and colleagues (1992) regarding a possible fractionation of contextual priming effects and was specifically constructed to lend insight into differential contributions of congruity, cloze probability and suppression mechanisms. In the Trace model, pre-potency results from top-down excitatory activations during the word selection process. These are either strengthened by convergent bottom-up activation (high cloze sentences), or rely on same level inhibitory effects to reduce activations for units incongruous with the bottom-up input. Since both inhibitory and attentional processes evidence developmental patterns (Anderson, 1998; Kolb & Whishaw, 1996; Welsh, Pennington & Groisser. (1991), it is hypothesised that those effects reliant on inhibitory processes, namely congruity and suppression, evidence a strong decrease in NLs with age.

(b) investigate the attentional characteristics and temporal activation of context and priming effects by manipulating processing conditions. Given that attentional strategies have a strong developmental component (Case, 1985; Case & Okamoto, 1996; Coch et al., 2005; Ridderinkhof & van der Stelt, 2000), divergent trajectories were expected for processing mode effects with increasing age, with a stronger decline in attentional resource expected for experimental tasks which are attention-thirsty compared with tasks which require little attentional resources. Additionally, the degree of reliance on attentional processing has been shown to affect processing mechanisms such as enhancement and suppression, both of which are thought to be greater in tasks with increasing attentional requirements (Holcomb et al., 1992).

and (c) evaluate the ability of the Trace model (McClelland & Elman, 1986) to account for the specific patterns of context and priming effects evidenced by the current data.

Materials and Methods

Participants

The current experiment involved 19 girls and 20 boys aged between 6;0 and 14;0 years (*M* = 10.06, *SD* = 2.26). Informed written consent was obtained from the parents of all participants; in addition, participants gave verbal consent to participate. The children were all native monolingual speakers of English with age-appropriate language skills, had no remarkable medical or developmental history, and no personal or family history of speech, language, hearing or learning difficulties as determined through a detailed parental questionnaire specifically tailored for this study, following guidelines by Shipley and McAfee (2004).

Stimuli

A list of 80 highly constraining sentences ranging from five to nine words in length was constructed. Twenty-six of these sentences originated from Bloom and Fischler (1980), with eight modified to suit the regional vocabulary. Most sentences were novel, with a predominant grammatical structure of Subject Verb Object Adverb (SVOA) or SVOO. Clausal and phrasal complexity ranged from levels two to six on the Language Assessment, Remediation and Screening Procedure (LARSP) (Crystal, Fletcher, & Garman, 1976). Sentence constraint values and cloze probabilities for potential targets were obtained through a pre-test using a sentence completion task with 16 typically-developing children aged 6;0 to 13;11. Sentence constraint was measured as the proportion of pre-test participants who responded with the target word, for example *"bone"*, when auditorily presented with the sentence stem, for example *"The dog buried the ___"*. Sentence constraint is considered to be a characteristic of the sentence stem, that is, the probability with which the sentence stem will prime a *specific* target. In contrast, cloze probability applies to the whole sentence. It reflects the probability with which the sentence stem will prime the *actual* target presented in the sentence.

The current study constructed sentence stems which were matched in sentence constraint across prime levels, hence creating the same expectancy potential for final word completions in each prime level (with the exception of neutral sentences). Table 1 summarises the characteristics of the four different types of sentence stimuli, or prime levels, which were constructed by manipulating the cloze probabilities of the sentence final words. Semantically congruous high cloze (HC) sentences, eg. *The dog buried the bone*, evidenced high sentence constraint and cloze probability, meaning the primed target was presented as the actual target.

Semantically congruous low cloze (LC) sentences, eg. *They saw lots of animals at the park*, evidenced comparably high sentence constraint, but low cloze probability, meaning the actual target differed to the primed target. Incongruous sentences, eg. *The pigs rolled in the bottle*, also evidenced comparably high sentence constraint but low cloze probability, with the actual target not semantically congruous with the sentence stem. Finally, the neutral sentences, eg. *You can now say the word pillow,* evidenced low sentence constraint as well as low cloze probability. By using sentence stems which were matched for congruity across prime levels, the same expectancy potential for final word completions was created irrespective of whether the sentence would end in a congruous or incongruous target. As a result, measurement focus was clearly placed on the fulfilment or violation of this primed expectancy.

An acoustic software package, Acoustica 2.11 (Aagedal, 2000), was used for digitally recording (sampling rate of 44.1 kHz with 16 bit resolution) and editing stimuli. Sentences were spoken by a native female and male speaker of Australian English and cross-spliced to obtain a sentence stem in the female voice and target in the male voice, with pauses inserted at required interstimulus intervals (ISI).

Experimental design

The experimental design for the current cross-sectional sentential auditory word repetition study consisted of two within-subject factors, processing mode with two levels, and prime level with four levels, and one between-subject factor, age, with four levels, described below. This combination of experimental manipulations allowed for a systematic delineation of changes with age in semantic context and cognitive control processes involved in recognition.

Processing mode

Two experimental blocks were constructed, one with a low expectancy proportion (EP) and a short ISI (low EP/short ISI) and one with a high EP and a long ISI (high EP/long ISI). These blocks were chosen to minimally and maximally recruit attentional processing, respectively. Additional blocks of low expectancy proportion and a long ISI or high expectancy proportion and a short ISI were not constructed. While these would have provided interesting information, it was essential that the experimental battery remain manageable for children whose attentional processing was limited; in addition, these additional blocks were not expected to add critical information on processing characteristics. Expectancy proportion describes the proportion of highly constraining sentences which end in high cloze probability target words, corresponding to the current congruous high cloze prime level. The low EP/short ISI experimental block consisted of 15 sentences at each prime level, resulting in an EP of .33, and an ISI of 50 ms (Appendix A). In contrast, the high EP/long ISI block consisted of 38 congruous high cloze sentences (9 critical and 29 fillers), 9 congruous low cloze, 9 incongruous and 15 neutral sentences, resulting in an EP of .68, and an ISI of 1000 ms (Appendix B). Cloze words were counterbalanced across sentence types as much as possible given uneven numbers of sentences across experimental blocks. No repetition of cloze words occurred within blocks.

Prime level

Sentence stimuli were matched across prime levels and experimental blocks on sentence constraint (pre-test statistics, see Table 1), sentence length (words), clausal and phrasal complexity (LARSP levels, Crystal et al., 1976), target word length in phonemes and syllables, and target frequency (Kucera & Francis, 1967). A Kruskal-Wallis test provided evidence that matching variables were not significantly different across the four prime levels in each of the experimental blocks, $0.129 < p > 0.999$. Care was taken to differ word-initial phonemes between expected and presented targets, allowing for minimal feature and phoneme overlap to influence activations.

Table 1 Sentence characteristics for the four prime levels in the sentential auditory word repetition tasks

Characteristics	Prime level			
	Congruous (HC)	Congruous (LC)	Incongruous	Neutral
Sentence constraint	High; >.87	High; >.87	High; >.87	Low; = 0
Cloze probability	High; >.87	Low; <.07	Low; = 0	Low; = 0
Semantically congruous	Yes	Yes	No	Yes
Syntactically congruous	Yes	Yes	Yes	Yes

Characteristics	Prime level			
	Congruous (HC)	Congruous (LC)	Incongruous	Neutral
Sentence constraint	High; >.87	High; >.87	High; >.87	Low; = 0
Cloze probability	High; >.87	Low; <.07	Low; = 0	Low; = 0
Semantically congruous	Yes	Yes	No	Yes
Syntactically congruous	Yes	Yes	Yes	Yes

Note. HC = high cloze; LC = low cloze. Sentence constraints and cloze probabilities are reported as proportions

Age

For ease of interpretation of the statistical analysis, participants' ages were categorised into four 2-year age-bands. This division resulted in 8 participants aged 6-8 years (*M* = 6.78), 11 participants aged 8-10 years (*M* = 9.20), 11 participants aged 10-12 years (*M* = 10.88), and 9 participants aged 12-14 years (*M* = 13.03). The number of participants in each age-band was comparable to similar studies (Holcomb et al, 1992; Liu et al, 1997).

Version

For each experimental block, two pseudo-randomisation versions were constructed using a randomisation table (May, Masson, & Hunter, 1990). The same carrier sentence-target word combinations in a different sequence appeared in each of the two versions. Participants were randomly allocated to either of the versions.

Procedure

Participants were tested individually in a quiet environment with a minimum of two weeks between the presentations of the experimental blocks. Participants were fitted with binaural sound-attenuating earcups and a super-cardioid boom microphone. Naming latencies were measured off voice-onset. Six practice items with equivalent EP and ISI as the experimental blocks preceded the test items. The test sentences were presented through the headphones at a comfortable level with a constant microphone distance of 1 to 1.5 cm. Participants were instructed to say what the man says quickly, but clearly.

The experimental task required participants to listen to sentences and repeat the target, signalled by a voice shift. If no response was obtained within 10 seconds, the experiment proceeded to the next item. If a response was obtained, then the next item was presented after an inter-trial interval (ITI) of 3.5 seconds. While participants responded verbally, the experimenter noted accuracy, with the origin of errors coded as being either mechanical or performance-based. Incorrect responses, inaccurate onsets, or false starts, and no responses were classified as performance errors. In contrast, equipment-based errors and response-unrelated sounds triggering measurement were classified as mechanical errors.

The experimental paradigm was constructed in LabVIEW™ (National Instruments Corporation, 1998). Stimuli were presented in the pseudo-randomised sequence, with the program measuring NLs in milliseconds from a target word's uniqueness point, described in terms of the first phoneme which sets the word apart from its phonemic neighbours (Marcus & Frauenfelder, 1985). If participants responded prior to hearing the uniqueness point of the target, this procedure resulted in the recording of a negative NL value.

Results

Prior to data analysis, the data were cleaned by removing erroneous NLs and outliers. Errors consisted of 11.1 % of all trials, 1.5% of which were performance errors, which were not further analysed. Mechanical errors such as equipment errors and errors in measurement triggered by response-unrelated sounds made up the remaining 9.6% of errors. Outliers above 2000 ms and below -400 ms were removed, comprising 0.2 % of NLs. A full factorial mixed design analysis of variance was conducted on the remaining data using a statistical software package, SPSS (Norussis, 1990), with age-band (6-8, 8-10, 10-12 and 12-14 years) as a between subject factor, and processing mode (low EP/short ISI and high EP/long ISI) and prime level (congruous high cloze, congruous low cloze, incongruous and neutral) as within-subject factors. Version (A or B) did not result in a significant between-subject effect, providing evidence that sequence of stimulus presentation was not a contributing variable, and thus data was collapsed across versions.

Naming latency analysis

Table 2 provides a summary of the raw NL data for each of the prime levels and experimental blocks across age-bands. The NL data were normally distributed as determined by inspection of Q-Q plots. The likelihood ratio test revealed inconsistencies across variances for different age bands, $L(4) = 151.458$, $p < .001$, with the variance for the youngest age-band larger than for the other three age-bands. This sample characteristic was addressed by choosing a linear mixed model for analysis (Brown & Prescott, 1999).

A linear mixed model analysis with age-band, processing mode and prime level as fixed effects, and subject as a random effect was conducted on the data set. This analysis revealed main effects for age-band, $F(3, 35) = 12.54$, $p < .001$, processing mode, $F(1, 3448) = 101.55$, $p < .001$, and prime level, $F(3, 3447) = 97.93$, $p < .001$. The data did, however, evidence significant two-way interactions, processing mode by prime level, $F(3, 3447) = 4.40$, $p =$

.004, age-band by processing mode, $F(3, 3448) = 6.05$, $p < .001$, and age-band by prime level, $F(9, 3447) = 2.11$, $p = .026$. The three-way interaction for age-band by processing mode by prime level was not statistically significant.

The current data were investigated for standard planned comparisons in priming studies, suppression (Supp) and enhancement (Enh). The NLs for the neutral sentences served as the baseline for these comparisons. Suppression was defined as the comparison between resulting NLs for incongruous and neutral sentences, with the former anticipated to be slower. Enhancement was defined as the comparison between NLs for congruous (either HC or LC) sentences and NLs for neutral sentences, with the former expected to be faster. A further contrast of interest was congruous high cloze sentence NLs compared with congruous low cloze sentence NLs, referred to as the cloze probability (ClozeP) effect. Lastly, the congruity effect consisted of a comparison of congruous low cloze and incongruous cloze words, which did not differ in their cloze probability ($p < .001$).

Table 2 Mean NLs (*SD*s) for participants (*n* = 39) in a sentential auditory word repetition experiment as a function of prime level, processing mode and age-band

Age (yrs)	Low EP/ Short ISI				High EP/ Long ISI			
	Con(HC)	Con(LC)	Incon	N	Con(HC)	Con(LC)	Incon	N
6-8	294 (207)	349 (234)	462 (279)	310 (240)	345 (234)	445 (240)	499 (203)	417 (204)
8-10	238 (163)	284 (174)	382 (175)	254 (153)	306 (140)	324 (169)	414 (166)	322 (143)
10-12	161 (155)	207 (174)	268 (178)	158 (154)	245 (156)	275 (176)	313 (136)	268 (200)
12-14	74 (122)	125 (134)	191 (138)	97 (131)	54 (140)	125 (162)	225 (152)	155 (190)
Marginal Mean	193 (180)	241 (194)	326 (217)	205 (187)	238 (201)	292 (215)	363 (191)	291 (204)

Note. NL = naming latency (in milliseconds); Yrs = years; EP = expectancy proportion; ISI = interstimulus interval; Con(HC)= Congruous (high cloze); Con(LC)= Congruous (low cloze); Incon= Semantically Incongruous; N= Neutral.

Within-subject effect

The significant two-way interaction of processing mode by prime level was further investigated using several contrasts, summarised in Figure 1. Suppression was a significant process for both low EP/short ISI and high EP/long ISI tasks, *Supp* = 121.46, *SE* = 9.81, *t* (3447) = 12.38, *p* < .001, and *Supp* = 72.60, *SE* = 11.20, *t*(3447) = 6.48, *p* < .001, respectively. The difference in suppression was statistically significant across the two processing modes, *Difference* = 48.86, *SE* = 14.89, *t*(3447) = 3.28, *p* = .001. The presence of a cloze probability effect, characterised by faster processing of sentences ending in high cloze words as compared to low cloze words, was found for both the low EP/short ISI task, *ClozeP* = 49.83, *SE* = 9.65, *t*(3447) = 5.16, *p* < .001, as well as the high EP/long ISI task, *ClozeP* = 54.75, *SE* = 12.53, *t*(3447) = 4.37, *p* < .001. The cloze probability effect was, however,

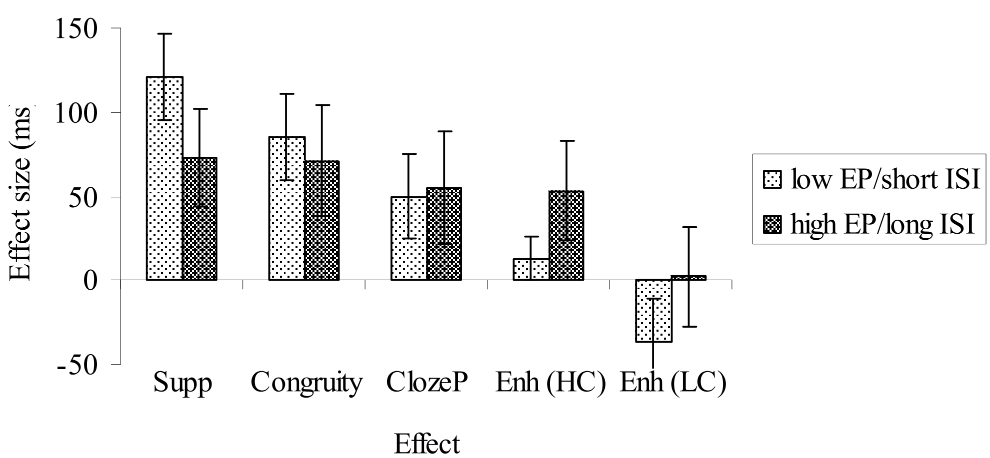

Figure 1 Mean experimental effects (in milliseconds) and standard means for participants (*n* = 39) in a sentential auditory word repetition experiments as a function of processing mode.

Note. Supp = operationally-defined suppression; ClozeP = cloze probability; Enh (HC) = enhancement (high cloze); Enh (LC) = enhancement (low cloze); EP = expectancy proportion; ISI = interstimulus interval. Negative values indicate effect sizes occurred counter to expected direction. NLs were measured from the acoustic uniqueness point of the target. Error bars denote 95% confidence intervals.

not different across processing modes. The data also evidenced a significant congruity effect for both the low EP/short ISI task, *Congruity* = 84.69, *SE* = 9.77, $t(3447) = 8.67$, $p < .001$, as well as the high EP/long ISI task, *Congruity* = 70.67, *SE* = 12.54, $t(3447) = 5.64$, $p < .001$, which was not statistically different across processing modes. For congruous high cloze sentences, participants did not evidence significant enhancement in the low EP/short ISI task, *Enh* = 13.05, *SE* = 9.69, $t(3447) = 1.35$, $p =.178$, which contrasted with significant enhancement for the high EP/long ISI task, *Enh* = 52.82, *SE* = 11.19, $t(3447) = 4.72$, $p < .001$. The difference in enhancement (HC) was significant across processing modes, *Difference* = 39.77, *SE* = 14.80, $t(3447) = 2.69$, $p = .007$. There was a significant difference between congruous low cloze and neutral sentences for the low EP/short ISI block, *Enh* = -36.77, *SE* = 9.77, $t(3447) = -3.76$, $p < .001$, although the direction of this difference was contrary to the anticipated outcome, referred to as active suppression. There was no significant difference between congruous low cloze and neutral sentences for the high EP/long ISI block.

Developmental effect

Two interactions involving age-band as a factor indicated that there was a developmental component involved in the processing of the current sentential auditory word repetition task. Age-band interacted with both processing mode as well as prime level, with results reported separately.

Processing mode. The significant two-way interaction of age-band by processing mode was investigated by comparing NLs for the high EP/long ISI block with those for the low EP/short ISI block (Figure 2). With the exception of 12 to 14 year olds, participants exhibited a significant processing mode effect at each age-band, 6-8 year olds, *PMeffect* = 72.39, *SE* = 12.10, $t(3449) = 5.98$, $p < .001$, 8-10 year olds, *PMeffect* = 52.14, *SE* = 10.13, $t(3447) = 5.15$, $p < .001$, and 10-12 year olds, *PMeffect* = 77.78, *SE* = 10.14, $t(3448) = 7.57$, $p < .001$.

Differences in processing mode effects across age-bands were only significant between 12-14 year olds and each of the younger age-bands, $p \leq .001$, although less distinctly so for 10-12 year olds, $p = .022$.

Polynomial contrasts were used in order to further investigate the effect of age-band on processing mode. The data evidenced a strong linear trend indicating an average reduction of 44 ms per age-band for the low EP/short ISI block, $B = -43.96$, $SE = 7.96$, $t(3465) = -5.52$, $p < .001$, and 51 ms for the high EP/long ISI block, $B = -51.21$, $SE = 8.04$, $t(3465) = -6.37$, $p < .001$.

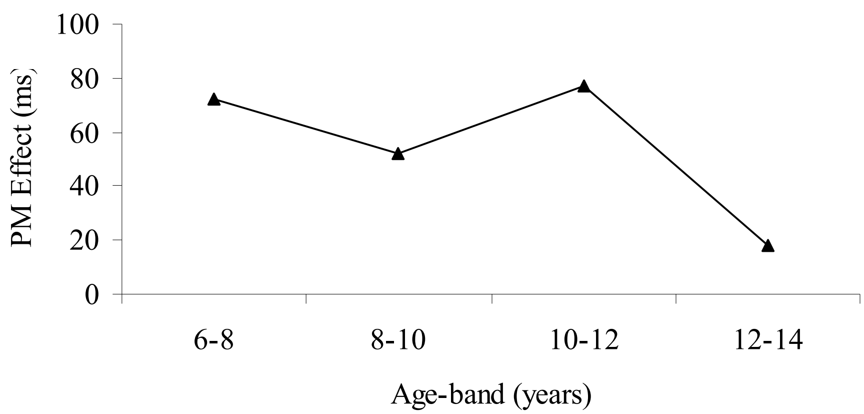

Figure 2 Processing mode (PM) effect (in milliseconds) for participants ($n = 39$) as a function of age-band (in years) in a sentential auditory word repetition experiment.

Note. NLs were measured from the acoustic uniqueness point of the target.

Priming patterns. A summary of how priming patterns changed with age is provided in Figure 3. Operationally-defined suppression was significant at all age-bands, $p < .001$, although not significantly different between age-bands, $p \geq .072$. Cloze probability and congruity effects were significant at all age-bands, $p \leq .009$, with cloze probability for 8-10 year olds only being significant at a less stringent alpha level, $p = .029$. A developmental pattern in cloze probability and congruity was not apparent (Figure 3). Enhancement (HC) was statistically significant for participants aged 6-8 and 12-14 years, $p \leq .007$, but not for participants aged 8-12 years, $p \geq .254$. The data evidenced a trend of greater enhancement (HC) for 12-14 year olds compared with 8-12 year olds, $p \leq .023$. Active suppression, initially termed enhancement (LC), was not statistically significant for any of the age bands, $p \geq .045$, nor were there differences between age-bands, $p \geq .127$.

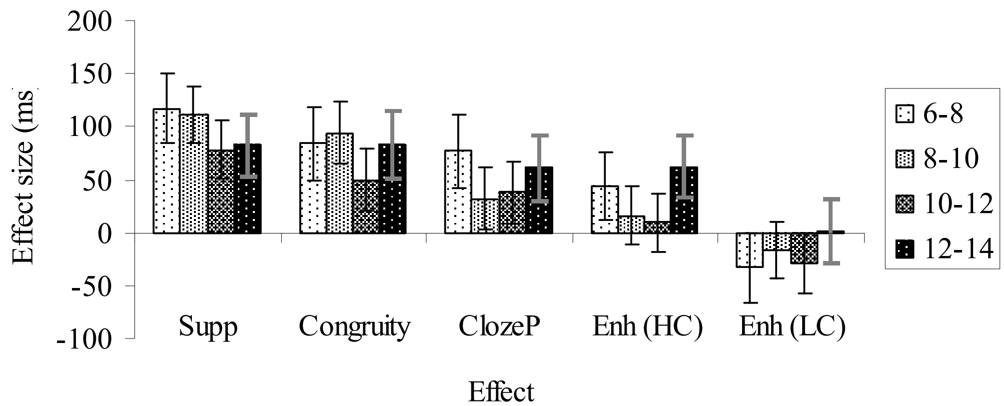

Figure 3 Mean experimental effects (in milliseconds) for participants (*n* = 39) in a sentential auditory word repetition experiment as a function of age-band (in years).

Note. Supp = operationally-defined suppression; ClozeP = cloze probability; Enh (HC) = enhancement (high cloze); Enh (LC) = enhancement (low cloze). Negative values indicate effect sizes occurred counter to expected direction. NLs were measured from the acoustic uniqueness point of the target. Error bars denote 95% confidence intervals.

Discussion

In keeping with research in adults (van den Brink et al., 2006) and children (Atchley et al., 2006), the current data provided evidence that sentential context exerts an effect on several stages of auditory word recognition in school-aged children. Highly constraining sentence environments akin to the current stimuli, for example, *The dog buried the* ___ , facilitated rapid integration of cloze words into the higher level sentential representations mediated via context effects. Furthermore, such context effects may play a pivotal role in predictive evaluations of lexemes yet to be perceived, as manifested by the faster auditory word repetition for congruous high cloze targets as compared with targets in other prime levels. School-aged children's ability to form such probabilistic predictions remained largely unchanged with age and different stages of language development between 6 and 14 years of age. The primary source of developmental change in the current preliminary auditory word repetition data was attributable to attentional demands of tasks, with additional developmental differences evident in measured enhancement effects. Differences in processing with age emerged for these two factors independently. Results are discussed in turn, followed by an evaluation of experimental predictions based on the Trace model (McClelland & Elman, 1986).

Developmental and priming effects

As has been found consistently in paediatric investigations, overall, NLs decreased with increasing age, a phenomenon which is generally accepted to reflect increased automaticity of component processes underlying tasks (Atchley et al., 2006; Case, Kurland, & Goldberg, 1982; Case & Okamoto, 1996; Holcomb et al., 1992; Liu et al., 1997). In addition, age-related processing differences in children's auditory word repetition in the current highly constraining sentences evidenced disparate slopes of change when attentional requirements were manipulated. These slopes of change were quantified as a linear decrease of 51 ms per age band for the high EP/long ISI block and 44 ms for the low EP/short ISI block. While underlying maturational changes leading to increased automaticity of auditory word recognition processes were thought to affect the slopes for both tasks, the difference in slopes was attributed to changes in attentional processing. Specifically, this developmental effect reflected the consistently slower NLs for the high EP/long ISI task compared with the short ISI/low EP task in children aged 6 to 12 years, while children aged above 12 years evidenced comparable NLs across these tasks (see Figure 2).

Changes in attentional processing requirements also resulted in divergent priming patterns in the current data. While significant effects of congruity, cloze probability and operationally-defined suppression were evidenced in both experimental blocks, the short ISI/low EP task in addition evidenced active suppression, while the long ISI/high EP task evidenced enhancement. In line with previous research (Crosson et al., 2007), suppression dominated the task with low attentional requirements, while enhancement dominated the task which recruited more attention. Significant differences between experimental blocks were limited to suppression and enhancement effects, with context effects comparable across blocks. Although both short ISI/low EP and long ISI/high EP tasks evidenced significant operationally-defined suppression, this value was more than doubled in the short ISI/low EP task. This result stood in contrast to previous findings in children's auditory word recognition (Holcomb et al., 1992).

On the basis of the Trace account of auditory word recognition (McClelland & Elman, 1986), these data suggest that contextual integration occurs with little attentional resource requirements to focus activation on few congruous lexemes, with a high level of competition existing among within-level units. Evidence from active suppression, significant for the short ISI/low EP but not the long ISI/high EP task, as well as cloze probability, further indicates that this focus of activation applies primarily to the high cloze lexeme, irrespective of whether it is acoustically perceived or not, that is, is supported through bottom-up input. In the current examination, an increase in attentional resources resulted in the elimination of active suppression and reduction of operationally-defined suppression, possibly indicating that with time, activation is more widespread to include a greater array of congruous cloze words, thus reducing within-level inhibition. With the increased availability of attentional resources, enhancement contributed significantly to the recognition of congruous high cloze targets. The pattern of operationally-defined suppression, bearing in mind additional attentional resources, is consistent with the predictions of the Trace model, reducing significantly from an average of 121 ms at the short ISI to 73 ms at the long ISI.

The presence of significant cloze probability effects and congruity effects for both short ISI/low EP and long ISI/high EP tasks is testimony to the centrality of contextual effects irrespective of attentional processing in highly constraining sentential contexts. In order to optimise top-down activation, these two processes may work in concert by activating semantically congruous words in order to segregate them from incongruous words and applying differentially weighted activation to these according to their cloze probability within a highly constraining sentence. Similar findings in the visual modality resulted in the suggestion of a graded activation system based on featural overlap between high cloze targets and congruous low cloze targets (Kutas & Federmeier, 2000). Although the current data indicate a graded mechanism of activation in line with cloze probability, the stimuli were not constructed to investigate the role of featural overlap. Perusal of the congruous low cloze targets and their high cloze competitors indicates that high featural overlap was present for some items, for example, *The pirate had a patch over his head* (HC target: eye), but not others, for example, *The baby drank the milk from the mother* (HC target: bottle). Distinguishing between the degree of featural overlap within congruous low cloze stimuli would allow the investigation of the importance of this factor in predictive processes and would pose an informative line of inquiry for future research.

The current investigation further allowed probing of developmental changes in experimental effects, with particular interest in context effects and suppression. In interpreting the developmental data, it is important to keep in mind their preliminary nature due to the relatively small number of participants per age band. While children in each age band evidenced significant suppression, congruity and cloze probability effects, differences were not significant across age bands. In contrast, enhancement contributed significantly to processing for the youngest and oldest age groups, but not significantly differently for the two. The anticipated changes with age for congruity and cloze probability effects on the basis of Holcomb et al's (1992) and Liu et al's (1997) findings of an increased contextual effect for younger children were not statistically substantiated by the current findings. In the current data, neither the cloze probability nor the congruity effect, which were expected to evidence different developmental trajectories, changed consistently as a function of age-band. The present experiment investigated whether cloze probability and congruity effects may be two different contributors to contextual processing as proposed by Holcomb et al. (1992). Although no clear developmental effects resulted for either, this finding is possibly due to limited statistical power and further research with more participants per age band may be warranted. In order to measure developmental effects arising from these contextual processes, prime level differences were averaged across processing modes. It remains a possibility that strong effects of attentional processing camouflaged possible developmental effects arising from context. The data suggested a trend of larger context effects in younger children through changes in the congruity effect for the low EP/short ISI experimental block, from 113ms in 6-8 year old children to nearly half (66ms) in 12-14 year old children. This pattern was mirrored by the trend of reduced suppression with increasing age (operationally-defined suppression evidenced a *p*-value of .072, and active suppression a *p*-value of .045). A more informative time course may have allowed measurement of changes in congruity and cloze probability effects with age. Hence, future investigations of context effects in children's auditory word recognition would benefit from collecting data with greater temporal resolution.

Experimental predictions

Cloze probability effect

Faster naming latencies for congruous high cloze (*bone*) compared with congruous low cloze (*stick*) sentence completions in the current highly constraining sentence stems (*The dog buried the*) are evidence for significant cloze probability effects, indicating a clear advantage of high cloze targets over low cloze targets. Bottom-up processes are not able to explain differences in naming latencies between these prime levels as sentences and targets are matched on variables which might contribute to bottom up differences, such as target length and frequency, and phonological neighbours, with NLs measured from uniqueness points. As congruity is comparable in congruous high cloze and low cloze sentences, differential processing between these two prime levels cannot be attributed to top-down advantages resulting from congruity. Thus a significant cloze probability effect suggests that the activation levels of the lexemes in the word-initial cohort are weighted on the basis of predictive processes resulting from language experience and world knowledge, and the presence of a cloze probability effect is likely to represent a prediction violation.

The Trace model's (McClelland & Elman, 1986) excitatory connections between congruous units on different levels, and inhibitory connections between incongruous units within the same level leads to weighted activations in line with congruent top-down processes. According to this model, a highly constraining sentence stem (*The dog buried the*) skews activation towards congruous targets with high cloze probability (*bone*), creating pre-potency, with targets incongruous with this prediction (*stick*) receiving inhibitory input. A violation of the pre-potency (presentation of *stick* rather than *bone*) results in slowed NLs due to the time lag of bottom-up excitatory activation needed to overcome the within-level inhibition and override the pre-potent response. The predicted slowing of NLs for congruous low cloze compared to congruous high cloze targets represents a cloze probability effect and is substantiated by the current data (Prediction 1).

Congruity effect

The current data evidenced a processing advantage of low cloze lexemes (*stick*) over semantically incongruous lexemes (*air*) in highly constraining sentence stems (*The dog buried the*), substantiating the presence of a semantic congruity effect. Over the acoustic life-time of the sentence, the sentence's underlying meaning information is synthesised to form a pre-potent response, the high cloze lexeme. When this prediction is violated, competitors which are semantically congruous to the sentence stem evidence faster NLs than those which are not. This result suggests that while high cloze targets received the lion-share of top-down excitatory activation, semantically congruous low cloze targets also received some, setting them apart from incongruous targets. This pattern of activation occurs regardless of attentional resources available, as demonstrated by comparable congruity effects across processing modes (Prediction 2).

Overall, these data indicate that including an additional layer of units relating to semantic context within the Trace model – with excitatory connections to word level units - may assist to account for the pattern of activations occurring in auditory word recognition in sentential environments. Methodologies with greater temporal resolution could be valuable in investigating contextually induced excitatory and inhibitory connections further.

Conclusion

In summary, typically developing children aged between 6 and 14 years evidenced comparable context effects across processing conditions in highly constraining sentence environments. Significant context effects indicated that during auditory word recognition tasks akin to the current experiment, top-down contextual information may be involved in firstly, constructing a cohort of semantically congruous candidates, and secondly, is paramount in weighting levels of activations of members of the cohort. Patterns of congruity and cloze probability were consistent with predictions of the Trace model (McClelland & Elman, 1986). The current findings are in line with research by van den Brink and colleagues (2006), who concluded that the processes of lexical selection and semantic integration are a combination of top-down (context-driven) and bottom-up (acoustic) analyses, with the contribution of each depending on the nature of the sentences (highly constrained or not) and cloze words (high or low cloze).

The current pattern of results indicates that under optimal listening conditions, and in the absence of distractors or interference, a cohort of typically developing school-aged children evidenced attentional changes with age in a foundational communication task, auditory word recognition. Consequently, conditions in which children's processing is challenged, for example in the presence of perceptual deficits, semantic deficits, processing deficits, or in sub-optimal listening or processing conditions, will likely either slow down or interfere in the auditory word recognition process. Investigating children's auditory word recognition in populations who are vulnerable to such break downs poses a valuable future line of enquiry and will further delineate the possible levels of breakdown in auditory word recognition present in children's communication disorders.

Acknowledgements

The authors would like to acknowledge the contributions of Professor Bruce Murdoch throughout this work. Furthermore, they would like to extend thanks to the participants and their families for their support of this project, the Gap and Kenmore State Schools for their assistance in the recruitment of participants, and Dion Scott, Peter Condie and Tom Johnsen for technical support at the University of Queensland's School of Health and Rehabilitation

Sciences. Some of the data reported here previously appeared in the doctoral thesis *Auditory word recognition in school-aged children with and without mild Traumatic Brain Injury* by N. Mahler.

APPENDIX A

Sentence constraint and cloze probabilities for sentence stimuli across prime levels in the low EP/ short ISI sentential auditory word repetition experiments

Prime level	Sentence stimulus (with expected cloze word)	Target	Sentence constraint	Cloze P
Incongruous				
	The children went outside to (play).	wear	0.875	0
	Water and sunshine help plants (grow).	play	0.875	0
	The petrol station is down the (road).	finger	0.938	0
	The paint was the wrong (colour).	book	1.000	0
	The pigs rolled in the (mud).	bottle	1.000	0
	Pam did not have any clothes to (wear).	grow	0.938	0
	When you go to bed turn off the (lights).	garden	1.000	0
	The boy ate his soup with a (spoon).	door	1.000	0
	Every day the chicken lays an (egg).	eye	1.000	0
	They cut the paper with (scissors).	feet	1.000	0
	The pilot flew the (plane).	letter	0.813	0
	She counted the stars in the (sky).	help	1.000	0
	Lots of roses grew in her (garden).	scissors	0.875	0
	He slept with his head on the (pillow).	name	0.875	0
	She unlocked the door with the (key).	road	0.938	0
Congruous (HC)				
	The kids fed the ducks some stale bread.	bread	0.938	0.938
	The baker put the dough in the hot oven.	oven	0.938	0.938
	She liked hearing the church bells ring.	ring	0.875	0.875
	The boy made a sandcastle at the beach.	beach	0.875	0.875
	He looked at his watch to see the time.	time	1.000	1.000
	She put the rubbish in the bin.	bin	1.000	1.000
	The dog buried the bone.	bone	1.000	1.000
	The funny joke made him laugh.	laugh	0.938	0.938
	He paid the shopkeeper the money.	money	0.875	0.875
	The bird flapped its wings.	wings	1.000	1.000
	The umbrella got wet in the rain.	rain	1.000	1.000
	The giraffe has a long neck.	neck	0.938	0.938
	The boy bounced the ball.	ball	1.000	1.000
	His mother is cooking in the kitchen.	kitchen	0.875	0.875
	Pigs have a curly tail.	tail	0.938	0.938
Congruous (LC)				
	The girl wrote Santa a (letter).	note	0.875	0.0625
	At night the old woman locked the (door).	window	0.938	0.0625
	The chair has four (legs).	parts	1.000	0
	They saw lots of animals at the (zoo).	park	0.938	0.0625

Prime level	Sentence stimulus (with expected cloze word)	Target	Sentence constraint	Cloze P
Congruous (LC)				
	The baby drank the milk from the (bottle).	mother	0.938	0.0625
	The man took the dog for a (walk).	ride	0.938	0.0625
	He put his shoes on his (feet).	bed	0.875	0.0625
	The pizza was too hot to (eat).	hold	1.000	0
	He went to the pool for a (swim).	drink	0.938	0.0625
	The bird lay its eggs in the (nest).	tree	0.875	0.0625
	The boy was reading a good (book).	story	0.938	0.0625
	The island is surrounded by (water).	sharks	0.875	0.0625
	She wore a ring on her (finger).	pinkie	0.875	0.0625
	The family live in a big (house).	home	0.938	0.0625
	The pirate had a patch over his (eye).	head	0.875	0.0625
Neutral				
	You can now say the word knife.	knife	0	0
	You can now say the word song.	song	0	0
	You can now say the word hill.	hill	0	0
	You can now say the word house.	house	0	0
	You can now say the word farm.	farm	0	0
	You can now say the word sleep.	sleep	0	0
	You can now say the word dream.	dream	0	0
	You can now say the word dress.	dress	0	0
	You can now say the word pillow.	pillow	0	0
	You can now say the word table.	table	0	0
	You can now say the word games.	games	0	0
	You can now say the word water.	water	0	0
	You can now say the word bridge.	bridge	0	0
	You can now say the word moon.	moon	0	0
	You can now say the word glass.	glass	0	0

Note. Cloze P = cloze probability; HC = high cloze; LC = low cloze.

APPENDIX B

Cloze probabilities (P) for sentence stimuli across prime levels in the high EP/long ISI sentential auditory word repetition experiments

Prime level	Sentence stimulus (with expected cloze word)	Target	Sentence constraint	Cloze P
Incongruous				
	The pigs rolled in the (mud).	scissors	1	0
	Every day the chicken lays an (egg).	axe	1	0
	They cut the paper with (scissors).	feet	1	0
	She counted the stars in the (sky).	walk	1	0
	He slept with his head on the (pillow).	name	0.875	0
	The children went outside to (play).	shut	0.875	0
	Water and sunshine help plants (grow).	play	0.875	0
	Lots of roses grew in her (garden).	head	0.875	0
	When you go to bed turn off the (lights).	garden	1	0
Congruous (HC)				
Critical	She liked hearing the church bells ring.	ring	0.875	0.875
	The boy made a sandcastle at the beach.	beach	0.875	0.875
	The petrol station is down the road.	road	1	1
	The umbrella got wet in the rain.	rain	1	1
	His mother is cooking in the kitchen.	kitchen	0.875	0.875
	The island is surrounded by water.	water	0.875	0.875
	Pam did not have any clothes to wear.	wear	0.9375	0.9375
	The boy bounced the ball.	ball	1	1
	At night the old woman locked the door.	door	0.9375	0.9375
Fillers				
	The giraffe has a long neck.	neck	0.9375	0.9375
	The kids fed the ducks some stale bread.	bread	0.9375	0.9375
	He looked at his watch to see the time.	time	1	1
	She put the rubbish in the bin.	bin	1	1
	The boy ate his soup with a spoon.	spoon	1	1
	She unlocked the door with the key.	key	0.9375	0.9375
	Father carved the turkey with a knife.	knife	0.867	0.867
	The pirate had a patch over his eye.	eye	0.875	0.875
	The paint was the wrong colour.	colour	1	1
	The girl wrote Santa a letter.	letter	0.875	0.875
	He went to the pool for a swim.	swim	1	1
	The dog buried the bone.	bone	1	1
	Pigs have a curly tail.	tail	0.9375	0.9375
	He paid the shopkeeper the money.	money	0.875	0.875
	The bird flapped its wings.	wings	1	1
	The funny joke made him laugh.	laugh	0.9375	0.9375

Prime level	Sentence stimulus (expected cloze word)	Target	Sentence constraint	Cloze P
Congruous (HC)				
Fillers	The baker put the dough in the hot oven.	oven	0.9375	0.9375
	The baby drank the milk from the bottle.	bottle	0.9375	0.9375
	The book has 92 pages.	pages	0.8	0.8
	The budgie lived in a cage.	cage	0.8	0.8
	The teacher wrote the sum on the board.	board	0.8125	0.8125
	John felt sorry, but it was not his fault.	fault	0.8125	0.8125
	Dad drives to work in his car.	car	0.8125	0.8125
	He was scared and shouted for help.	help	0.8125	0.8125
	The pilot flew the plane.	plane	0.8125	0.8125
	She cut her foot on the broken glass.	glass	0.8125	0.8125
	The lady sang a lovely song.	song	0.8125	0.8125
	The children played lots of games.	games	0.8125	0.8125
	The astronauts walked on the moon.	moon	0.8125	0.8125
Congruous (LC)				
	The pizza was too hot to (eat).	hold	0	1
	They saw lots of animals at the (zoo).	park	0.0625	0.9375
	She wore a ring on her (finger).	pinkie	0.0625	0.875
	The man took the dog for a (walk).	ride	0.0625	0.9375
	He put his shoes on his (feet).	bed	0.0625	0.875
	The chair has four (legs).	parts	0	1
	The bird lay its eggs in the (nest).	tree	0.0625	0.875
	The boy was reading a good (book).	story	0.0625	0.9375
	The family live in a big (house).	home	0.0625	0.9375
Neutral				
	You can now say the word grow.	grow	0	0
	You can now say the word legs.	legs	0	0
	You can now say the word hill.	hill	0	0
	You can now say the word house.	house	0	0
	You can now say the word farm.	farm	0	0
	You can now say the word sleep.	sleep	0	0
	You can now say the word dream.	dream	0	0
	You can now say the word dress.	dress	0	0
	You can now say the word pillow.	pillow	0	0
	You can now say the word table	table	0	0
	You can now say the word eat.	eat	0	0
	You can now say the word present.	present	0	0
	You can now say the word bridge.	bridge	0	0
	You can now say the word sky.	sky	0	0
	You can now say the word book.	book	0	0

Note. Cloze P = cloze probability; HC = high cloze; LC = low cloze.

References

Aagedal, S. (2000). Acoustica (Version 2.11 English). Norway: Acon AS. Retrieved from http:\\www.aconas.de

Anderson, V. (1998). Assessing executive functions in children: Biological, psychological, and developmental considerations. *Neuropsychological Rehabilitation, 8*(3), 319-349.

Anderson, V., Fenwick, T., Manly, T., & Robertson, I. (1998). Attentional skills following traumatic brain injury in childhood: a componential analysis. *Brain Injury, 12*(11), 937-949.

Atchley, R. A., Rice, M. L., Betz, S. K., Kwasny, K. M., Sereno, J. A., & Jongman, A. (2006). A comparison of semantic and syntactic event related potentials generated by children and adults. *Brain and Language, 99*(3), 236-246.

Aydelott, J., & Bates, E. (2004). Effects of acoustic distortion and semantic context on lexical access. *Language and Cognitive Processes, 19*(1), 29-56.

Balsamo, L. M., Xu, B., & Gaillard, W. D. (2006). Language lateralization and the role of the fusiform gyrus in semantic processing in young children. *Neuroimage, 31*(3), 1306-1314.

Bloom, P. A., & Fischler, I. (1980). Completion norms for 329 sentence contexts. *Memory and Cognition, 8*(6), 631-642.

Booth, J. R., Burman, D. D., Meyer, J. R., Lei, Z., Choy, J., Gitelman, D. R., . . . Mesulam, M. M. (2003). Modality-specific and -independent developmental differences in the neural substrate for lexical processing. *Journal of Neurolinguistics, 16*(4-5), 383-405.

Brown, H., & Prescott, R. (1999). *Applied Linear Mixed Models in Medicine*. London: John Wiley & Sons.

Case, R. (1985). *Intellectual Development: Birth to Adulthood*. Orlando: Academic Press.

Case, R. (1992). The role of the frontal lobes in the regulation of cognitive development. *Brain and Cognition, 20*(1), 51-73.

Case, R. (1995). Capacity-based explanations of working memory growth: A brief history and reevaluation. In F. E. Weinert & W. Schneider (Eds.), *Memory performance and competencies: Issues in growth and development* (pp. 23-44). Hillsdale, NJ: Lawrence Erlbaum Associates.

Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology, 33*(3), 386-404.

Case, R., & Okamoto, Y. (1996). The role of central conceptual structures in the development of children's thought. *Monographs of the Society for Research in Child Development, 61*(1-2), v-265.

Church, B. A., & Fisher, C. (1998). Long-term auditory word priming in preschoolers: Implicit memory support for language acquisition. *Journal of Memory and Language, 39*(4), 523-542.

Ciechanowicz, A. (1978). Changes in the associative structure of the semantic field between ages 2 and 15. *Polish Psychological Bulletin, 9*(4), 215-222.

Coch, D., Maron, L., Wolf, M., & Holcomb, P. J. (2002). Word and picture processing in children: An event-related potential study. *Developmental Neuropsychology, 22*(1), 373-406.

Coch, D., Sanders, L. D., & Neville, H. J. (2005). An event-related potential study of selective auditory attention in children and adults. *Journal of Cognitive Neuroscience, 17*(4), 605-622.

Crosson, B., Benjamin, M., & Levy, I. (2007). Role of the basal ganglia in language and semantics: Supporting cast. In J. Hart & M. Kraut (Eds.), *Neural Bases for Semantic Memory* (pp. 219-243). Cambridge: Cambridge University Press.

Crystal, D., Fletcher, P., & Garman, M. (1976). *The grammatical analysis of language disability: A procedure for assessment and remediation*. London: Edward Arnold.

Dagenbach, D., & Kubat-Silman, A. K. (2003). The principle of inhibition. In R. H. Kluwe, G. Luer & F. Roesler (Eds.), *Principles of Learning and Memory* (pp. 207-221). Basel: Birkhäuser Verlag.

Dahan, D., & Gaskell, M. (2007). The temporal dynamics of ambiguity resolution: Evidence from spoken-word recognition. *Journal of Memory and Language, 57*(4), 483-501.

Dahan, D., & Tanenhaus, M. K. (2004). Continuous mapping from sound to meaning in spoken-language comprehension: Immediate effects of verb-based thematic constraints. *Journal of Experimental Psychology-Learning Memory and Cognition, 30*(2), 498-513.

Davis, M. H., Marslen-Wilson, W. D., & Gaskell, M. G. (2002). Leading up the lexical garden path: Segmentation and ambiguity in spoken word recognition. *Journal of Experimental Psychology-Human Perception and Performance, 28*(1), 218-244.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review, 12*, 45-75.

Diamond, A. (2004). The development of prefrontal cortex and executive control functions: Genetic, biochemical and environmental modulation. In J. Douglas & R. Tate (Eds.), *Brain Impairment – A Multidisciplinary Journal of the Australian Society for the Study of Brain Impairment: Vol. 5 (Supp). Abstracts of the 2004 Meeting of the Australian Society for the Study of Brain Impairment (ASSBI) and the International Neuropsychological Society (INS)* (p. 102). Brisbane, Australian Academic Press.

Elman, J.L. & McClelland, J.L. (1988). Cognitive penetration of the mechanisms of perception: Compensation for co-articulation of lexically restored phonemes. *Journal of Memory and Language, 27*, 143-165.

Friederici, A. D. (2006, March). *Event-related brain potentials as a window to children's language processing: From syllables to sentences*. Paper presented at the On-line methods in children's language processing, New York, New York.

Friedrich, M., & Friederici, A. D. (2004). N400-like semantic incongruity effect in 19-month-olds: Processing known words in picture contexts. *Journal of Cognitive Neuroscience, 16*(8), 1465-1477.

Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition, 89*(2), 105-132.

Gaskell, M. G., & Marslen-Wilson, W. D. (1997). Integrating form and meaning: A distributed model of speech perception. *Language and Cognitive Processes, 12*(5-6), 613-656.

Gaskell, M. G., & Marslen-Wilson, W. D. (2002). Representation and competition in the perception of spoken words. *Cognitive Psychology, 45*(2), 220-266.

Gernsbacher, M. A., & Faust, M. E. (1991). The Mechanism of Suppression - a Component of General Comprehension Skill. *Journal of Experimental Psychology-Learning Memory and Cognition, 17*(2), 245-262.

Gow, D. W., Jr., & Olson, B. B. (2015). Lexical mediation of phonotactic frequency effects on spoken word recognition: A Granger causality analysis of MRI-constrained MEG/EEG data. *Journal of Memory and Language, 82*, 41-55.

Grieco-Calub, T. M., Saffran, J. R., & Litovsky, R. Y. (2009). Spoken word recognition in toddlers who use cochlear implants. *Journal of Speech, Language, and Hearing Research, 52*(6), 1390-1400.

Hahne, A., Eckstein, K., & Friederici, A. D. (2004). Brain signatures of syntactic and semantic processes during children's language development. *Journal of Cognitive Neuroscience, 16*(7), 1302-1318.

Harnishfeger, K. K. (1995). The development of cognitive inhibition: Theories, definitions and research evidence. In F. N. Dempster & C. I. Brainerd (Eds.), *Interference and inhibition in cognition* (pp. 175-204). New York: Academic Press.

Harnishfeger, K. K., & Bjorklund, D. F. (1993). The ontogeny of inhibition mechanisms: A renewed approach to cognitive development. In M. L. Howe & R. Pasnak (Eds.), *Emerging themes in cognitive development: Volume 1. Foundations* (pp. 28-49). New York: Springer Verlag.

Holcomb, P. J., Coffey, S. A., & Neville, H. (1992). Visual and auditory sentence processing: A developmental analysis using Event-Related Brain Potentials. *Developmental Neuropsychology, 8*(2 & 3), 203-241.

Hurtado, N., & Marchman, V. A. (2006, March). *Developmental gains in spoken word recognition by Latino children learning Spanish as their first language.* Paper presented at the On-line methods in children's language processing, New York, New York.

Junge, C., Kooijman, V., Hagoort, P., & Cutler, A. (2012). Rapid recognition at 10 months as a predictor of language development. *Developmental Science, 15*(4), 463-473.

Juottonen, K., Revonsuo, A., & Lang, H. (1996). Dissimilar age influences on two ERP waveforms (LPC and N400) reflecting semantic context effect. *Cognitive Brain Research, 4*(2), 99-107.

Kolb, B., & Whishaw, I. Q. (1996). *Fundamentals of human neuropsychology* (4th ed ed.). New York: W. H. Freeman and Co.

Kooijman, V., Junge, C., Johnson, E. K., Hagoort, P., & Cutler, A. (2013). Predictive brain signals of linguistic development. *Frontiers in Psychology Vol 4 Feb 2013, ArtID 25, 4.*

Kotz, S. A., Cappa, S. F., von Cramon, D. Y., & Friederici, A. D. (2002). Modulation of the lexical-semantic network by auditory semantic priming: An event-related functional MRI study. *Neuroimage, 17*(4), 1761-1772.

Kucera, H., & Francis, W. N. (1967). *Computational Analysis of Present-Day American English*. Providence: Brown University Press.

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4*(12), 463-470.

Kutas, M., & Hillyard, S. A. (1980). Reading Senseless Sentences - Brain Potentials Reflect Semantic Incongruity. *Science, 207*(4427), 203-205.

Liu, H., Bates, E., Powell, T., & Wulfeck, B. (1997). Single-word shadowing and the study of lexical access. *Applied Psycholinguistics, 18*(2), 157-180.

Lorsbach, T. C., Wilson, S., & Reimer, J. F. (1996). Memory for relevant and irrelevant information: Evidence for deficient inhibitory processes in language/learning disabled children. *Contemporary Educational Psychology, 21*(4), 447-466.

Marcus, S. M., & Frauenfelder, U. H. (1985). Word recognition-uniqueness or deviation? A theoretical note. *Language and Cognitive Processes, 1*(2), 163-169.

Marslen-Wilson, W. D. (1987). Functional parallelism in spoken word-recognition. *Cognition, 25*(1-2), 71-102.

Marslen-Wilson, W. D. (1989). Access and integration: Projecting sound onto meaning. In W. Marslen-Wilson (Ed.), *Lexical representation and process* (pp. 3-24). Cambridge: The MIT Press.

Marslen-Wilson, W. D., & Tyler, L. K. (1980). The temporal structure of spoken language understanding. *Cognition, 8*(1), 1-71.

Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology, 10*(1), 29-63.

May, R. B., Masson, M. E. J., & Hunter, M. A. (1990). *Application of Statistics in Behavioural Research*. New York: Harper & Row, Publ.

Mayor, J. & Plunkett, K. (2014). Infant word recognition: Insights from Trace simulations. *Journal of Memory and Language, 71*, 89-123.

McClelland, J. L. (1987). The case for interactionism in language processing. In M. Coltheart (Ed), *Attention and Performance 12: The Psychology of Reading* (3-36). Hillsdale: Lawrence Erlbaum Associates.

McClelland, J. L., & Elman, J. L. (1986). The Trace Model of Speech-Perception. *Cognitive Psychology, 18*(1), 1-86.

McMurray, B., Munson, C., & Tomblin, J. (2014). Individual differences in language ability are related to variation in word recognition, not speech perception: Evidence from eye movements. *Journal of Speech, Language, and Hearing Research, 57*(4), 1344-1362.

Mills, D. L., Prat, C., Zangl, R., Stager, C. L., Neville, H. J., & Werker, J. F. (2004). Language experience and the organization of brain activity to phonetically similar words: ERP evidence from 14-and 20-month-olds. *Journal of Cognitive Neuroscience, 16*(8), 1452-1464.

Mirman, D., McClelland, J. L., & Holt, L. L. (2005). Computational and behavioral investigations of lexically induced delays in phoneme recognition. *Journal of Memory and Language, 52*(3), 416-435.

Moss, H. E., McCormick, S. F., & Tyler, L. K. (1997). The time course of activation of semantic information during spoken word recognition. *Language and Cognitive Processes, 12*(5-6), 695-731.

National Instruments Corporation. (1998). *LabView*^{TM} (Version 2). Austin: National Instruments Corporation.

Nelson, K. (1979). Explorations in the development of a functional semantic system. In W. A. Collins (Ed.), *Children's Language and Communication* (Vol. 12, pp. 47-81). Hillsdale: Lawrence Erlbaum Associates.

Norussis, M. J. (1990). SPSS/PC + Statistics (Version 11.0). Chicago: SPSS Inc.

Perrin, F., & Garcia-Larrea, L. (2003). Modulation of the N400 potential during auditory phonological/semantic interaction. *Cognitive Brain Research, 17*(1), 36-47.

Petrey, S. (1977). Word associations and the development of lexical memory. *Cognition, 5*(1), 57-71.

Popescu, M., Fey, M. E., Lewine, J. D., Finestack, L. H., & Popescu, E.-A. (2009). N400 responses of children with primary language disorder: Intervention effects. *NeuroReport: For Rapid Communication of Neuroscience Research, 20*(12), 1104-1108.

Rafal, R., & Henik, A. (1994). The neurology of inhibition: Integrating controlled and automatic processes. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory Processes in Attention, Memory, and Language* (pp. 1-51). San Diego: Academic Press.

Ridderinkhof, K. R., & van der Stelt, O. (2000). Attention and selection in the growing child: views derived from developmental psychophysiology. *Biological Psychology, 54*(1-3), 55-106.

Rodriguez Fornells, A., Schmitt, B. M., Kutas, M., & Muente, T. F. (2002). Electrophysiological estimates of the time course of semantic and phonological encoding during listening and naming. *Neuropsychologia, 40*(7), 778-787.

Roe, K., Jahn-Samilo, J., Juarez, L., Mickel, N., Royer, I., & Bates, E. (2000). Contextual effects on word production: A lifespan study. *Memory and Cognition, 28*(5), 756-765.

Sajin, S. M., & Connine, C. M. (2014). Semantic richness: The role of semantic features in processing spoken words. *Journal of Memory and Language, 70*, 13-35.

Shipley, K. G., & McAfee, J. G. (2004). *Assessment in speech-language pathology. A resource manual* (3rd ed.). Clifton Park, NY: Thomson Delmar Learning.

Swannell, E. R., & Dewhurst, S. A. (2012). Phonological false memories in children and adults: Evidence for a developmental reversal. *Journal of Memory and Language, 66*(2), 376-383.

Thierry, G. & Vihman, M. M. (2008). The onset of word-form recogniition – A behavioural and neurophysiological study. In G. Thierry (Ed), *Early Language Development: Bridging brain and behaviour* (pp. 115-135). John Benjamins Publishing Company.

Trueswell, J. C. (2006, March). *The use of eye movements to study the development of spoken language comprehension.* Paper presented at the On-line methods in children's language processing, New York, New York.

Trueswell, J. C., Sekerina, I., Hill, N. M., & Logrip, M. L. (1999). The kindergarten-path effect: studying on-line sentence processing in young children. *Cognition, 73*(2), 89-134.

Tyler, L. K., & Marslen-Wilson, W. D. (1981). Children's processing of spoken language. *Journal of Verbal Learning & Verbal Behavior, 20*(4), 400-416.

Tyler, L. K., Moss, H. E., Galpin, A., & Voice, J. K. (2002). Activating meaning in time: The role of imageability and form-class. *Language and Cognitive Processes, 17*(5), 471-502.

Tyler, L. K., Voice, J. K., & Moss, H. E. (2000). The interaction of meaning and sound in spoken word recognition. *Psychonomic Bulletin & Review, 7*(2), 320-326.

van den Brink, D., Brown, C. M., & Hagoort, P. (2001). Electrophysiological evidence for early contextual influences during spoken-word recognition: N200 versus N400 effects. *Journal of Cognitive Neuroscience, 13*(7), 967-985.

van den Brink, D., Brown, C. M., & Hagoort, P. (2006). The Cascaded Nature of Lexical Selection and Integration in Auditory Sentence Processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(2), 364-372.

van den Brink, D., & Hagoort, P. (2004). The influence of semantic and syntactic context constraints on lexical selection and integration in spoken-word comprehension as revealed by ERPs. *Journal of Cognitive Neuroscience, 16*(6), 1068-1084.

Van Petten, C., Coulson, S., Rubin, S., Plante, E., & Parks, M. (1999). Time course of word identification and semantic integration in spoken language. *Journal of Experimental Psychology-Learning Memory and Cognition, 25*(2), 394-417.

Wang, S., Allen, R. J., Lee, J. R., & Hsieh, C.-E. (2015). Evaluating the developmental trajectory of the episodic buffer component of working memory and its relation to word recognition in children. *Journal of Experimental Child Psychology, 133*, 16-28.

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A Normative Developmental-Study of Executive Function - a Window on Prefrontal Function in Children. *Developmental Neuropsychology, 7*(2), 131-149.

Wingfield, A., Aberdeen, J. S., & Stine, E. A. L. (1991). Word onset gating and linguistic context in spoken word recognition by young and elderly adults. *Journals of Gerontology, 46*(3), 127-129.