Reading aloud is not automatic: Processing capacity is required to generate a phonological code from print

by

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Abstract

The process of generating a phonological code from print is widely described as automatic. This claim is tested in Chapter 1 by assessing whether phonological recoding uses central attention in the context of the Psychological Refractory Period (PRP) paradigm. Task 1 was a tone discrimination task and Task 2 was reading aloud. Nonword letter length and grapheme-phoneme complexity yielded additive effects with SOA in Experiments 1 and 2 suggesting that *assembled phonology* uses central attention. Neighborhood density (N) yielded additive effects with SOA in Experiments 3 and 4, suggesting that one form of lexical contribution to phonological recoding also uses central attention. Taken together, the results of these experiments are *inconsistent* with the widespread claim that phonological codes are computed automatically. Chapter 2 begins by reconsidering the utility of "automaticity" as an explanatory framework. It is argued that automaticity should be replaced by accounts that make more specific claims about how processing unfolds. Experiment 5 yielded underadditivity of long-lag word repetition priming with decreasing SOA, suggesting that an early component of the lexical contribution to phonology does not use central attention. There was no evidence of Task 1 slowing with decreasing SOA in Experiments 6 and 7, suggesting that phonological recoding processes are postponed until central attention becomes available. Theoretical development in this field (and others) will be facilitated by abandoning the idea that skilled performance inevitably means that all the underlying processes are automatic.

Acknowledgements

Firstly, many thanks need to be extended to my family and friends without whose support this thesis would have been impossible. An extra-special thanks to my wife, without whom, life would be no where near as exciting.

Secondly, many additional thanks must be extended to Kate Stewart and other members of the lab, without whom, I would have lost my mind collecting data. One can only hear people read aloud nonsense words so many times before insanity encroaches.

An extra-special thanks to Derek Besner, whose commitment to excellence and passion for research inspires his students to dive into the unknown, wrestle with it, and illuminate a little piece of the darkness for those destined to follow.

Dedication

To W. Cynthia Chan Reynolds

Table of Contents

List of Tables

List of Figures

General Introduction

The concept of "automaticity" has a long history of shaping how researchers understand and investigate the processes underlying visual word recognition. As Brown, Gore and Carr (2002, p. 220) note, "the assumption of automated word recognition in the mature reader is the 'standard' or 'received' view in cognitive science". This assumption is evident in many verbal and computational models that exist in the literature. For example, McCann, Remington, and Van Selst (2000, p. 1352) note that most computational models of visual word recognition "are fully self contained; they make no computational demands on any exterior processing mechanism or resource and have not yet specified a mechanism through which top-down control can be exercised over their functioning. Architecturally, then, these models fulfill all the requirements for automaticity."

Chapter 1 of this thesis examines the extent to which phonological recoding can be considered automatic (Experiments 1 – 4). The outcomes of these experiments are inconsistent with the widespread claim that phonological recoding occurs automatically. Chapter 2 begins by arguing that "automaticity" should be abandoned as an explanatory mechanism and replaced by more specific claims about how processing unfolds. Three additional experiments examine how central attention affects phonological recoding in more detail.

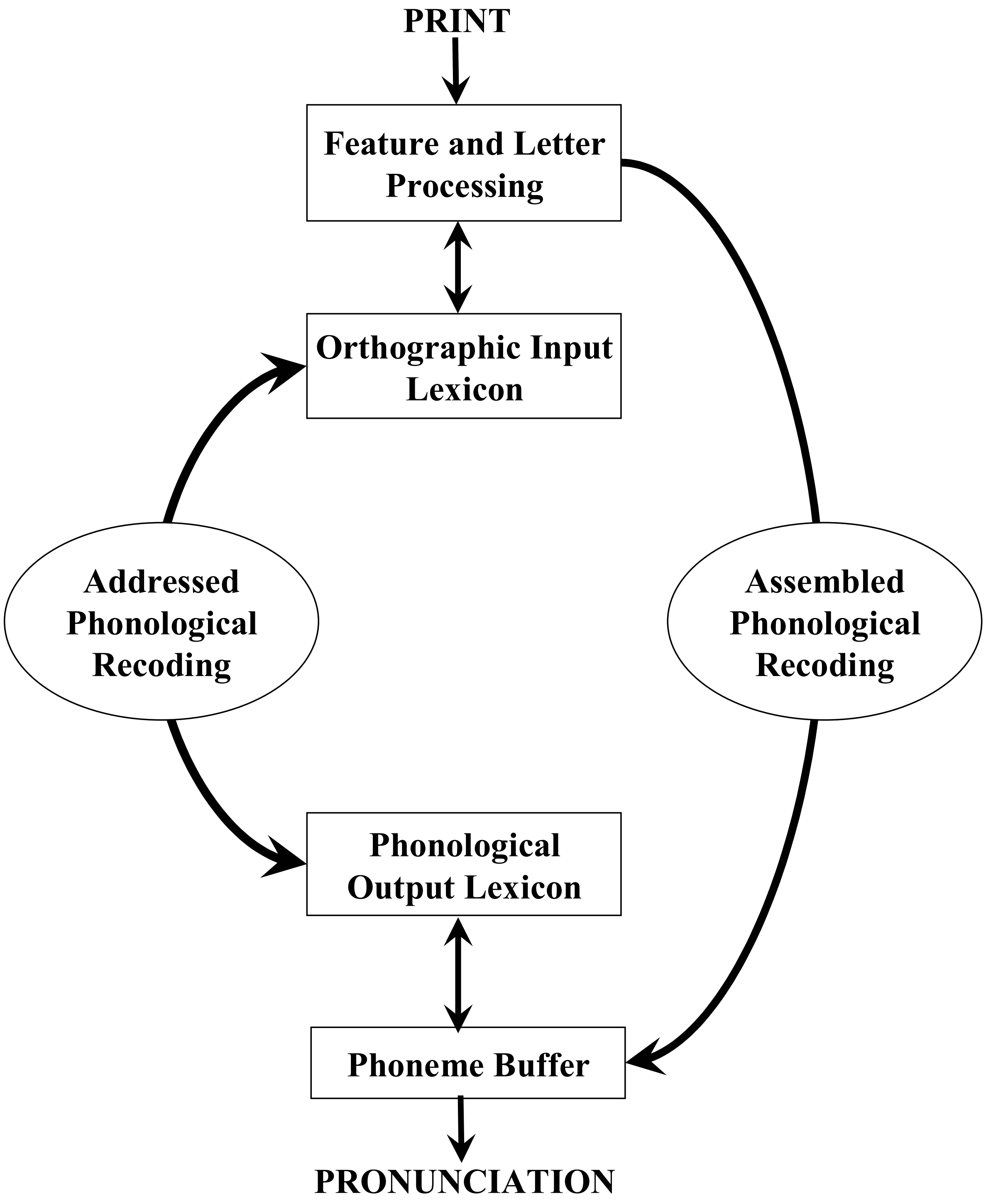
Chapter 1

Phonological Recoding

One objective of reading research is to assess how skilled readers generate a phonological code from print. Accounts of phonological recoding typically address two issues: (1) the *type(s)* of computations required and (2) *how* these computations unfold. With respect to the former issue, many researchers believe that skilled readers have two *types* of phonological recoding procedures. For example, Coltheart, Rastle, Perry, Langdon, and Ziegler's (2001) Dual Route Cascaded (DRC) model (see Figure 1) generates phonological codes using (1) sublexical spelling to sound correspondences (assembled phonology) and (2) whole word knowledge (addressed phonology). DRC assembles a phonological code sublexically, by translating graphemes into phonemes serially, letter by letter, left to right across a letter string. In contrast, DRC generates lexical phonology by addressing lexical-phonological representations directly from orthographic lexical representations.

With respect to *how* phonological recoding unfolds, many researchers belive that skilled readers generate phonological codes automatically. This claim is made by Perfetti and colleagues (e.g., Perfetti, Bell, & Delaney, 1988; Xu & Perfetti, 1999; Zhang, Perfetti, & Yang, 1999), Frost and colleagues (e.g., Gronau & Frost, 1997; Frost, 1998; 2003), Grainger and colleagues (e.g., Ferrand & Grainger, 1992; Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003), and Van Orden and colleagues (e.g., Van Orden, Pennington, & Stone, 1990; Ziegler, Van Orden, & Jacobs, 1997), among others (Brysbaert, 2001; Catena, Fuentes, & Tudela, 2002; Johnston & Castles, 2003; Lukatela

Figure 1: A Dual Route model of reading aloud



& Turvey, 1994; Luo, Johnson, & Gallo, 1998). For example, Xu and Perfetti (1999) argue for *"rapid automatic phonological activation, independent of stimulus based processing strategies"* (p. 26). Gronau and Frost (1997) claim their data are evidence for an *"automatic process of phonological computation"* (p. 111). Ferrand and Grainger (1992) argue their data supports *"the general hypothesis that phonological information is rapidly and automatically generated in the processing of pronounceable strings of letters"* (p. 369). Van Orden et al. (1990) state *that "through covariant learning, conscious rule application is replaced by the precise automatic phonologic coding that underlies skilled naming performance."* (p. 510).

Assessing Automaticity with the PRP paradigm

The goal of the present experiments is to test the widespread claim that phonological codes are generated automatically from print. In order to test whether phonological recoding is automatic I must first specify the characteristics exhibited by automatic processes. This enterprise is complicated because numerous definitions of automatic processing exist (see Table 1) and reading researchers often fail to specify the properties relevant to their account. Given the number of properties historically ascribed to automatic processes this renders these (underspecified) accounts difficult to assess and/or test[1]. Fortunately, many (but not all) of the characteristics traditionally ascribed to automatic processes fall out of the assumption that automatic processes either require minimal amounts of attention or do not require it at all (Logan, 1988; Posner & Snyder, 1975). For instance, if attention is required to control processing, then processes not affected by attention will unfold unintentionally and be obligatory (Logan, 1988).

Table 1: Characteristics often ascribed to automatic processes.

Characteristic	Authors (non-exhaustive)
1. Processing is stimulus driven	Posner & Snyder (1975); Hasher & Zacks (1979); Brown, Gore, & Carr (2002)
2. Processing cannot be intentionally controlled	Posner & Snyder (1975), Cohen, Servan-Schreiber, & McClelland, (1992); Hasher & Zacks (1979)
3. Processing does not require central capacity	McCann, Johnston, & VanSelst, 2000; Pashler, 1994; Hasher & Zacks (1979); Brown, Gore, & Carr (2002)
4. Processing occurs independently of other processes	Posner & Snyder (1975); Hasher & Zacks (1979); Logan (1988); Brown, Gore, & Carr (2002)
5. Ballistic (once launched cannot be stopped)	Hasher & Zacks (1979); Besner, (2001); Brown, Gore, & Carr (2002)
6. Processing is unconscious	Atkinson & Shiffrin, 1968; Laberge & Samuels, 1974; McCann, Folk, & Johnston, 1992; McCann, Johnston, & VanSelst, 2000; Pashler, 1994; Posner, 1978; Schneider & Shiffrin, 1977; Stolz & McCann, 2000
7. Processing is independent of attention	Shiffrin & Schneider (1977); Laberge & Samuels (1974); Logan (1988)
8. Attentional demands are reduced	Cohen, Servan-Schreiber, & McClelland, (1992)
9. Processing occurs in parallel	Treisman, Vieira, & Hayes (1992); James (1890)
10. Fast	Neely (1977); Logan (1988)
11. The stimulus captures attention	Treisman, Vieira, & Hayes (1992)
12. Processing occurs Independent of expectancies	Treisman, Vieira, & Hayes (1992); Neely (1977)
13. Processing is not affected by practice	Hasher & Zacks (1979)

Therefore, assessing whether a process is affected by "attention" is *one* reasonable test of automaticity.

The present experiments assess whether phonological recoding uses attention by examining whether performing a second unrelated task affects the time to pronounce a letter string. The availability of "central" attention is controlled using the Psychological Refractory Period (PRP) paradigm (see Pashler, 1994; Johnston, McCann, & Remington, 1995). In this paradigm subjects complete two speeded tasks in response to two stimuli (S1 and S2) that are presented at different Stimulus Onset Asynchronies (SOA). Subjects are typically instructed to respond to S1 (Task 1) first. The standard PRP effect is that as SOA decreases, the time to respond to the second task increases. Many theorists ascribe this slowing to both tasks needing (or using) the same limited capacity attention mechanism or processing bottleneck responsible for response selection (e.g., Welford, 1952; Pashler, 1984)[2].

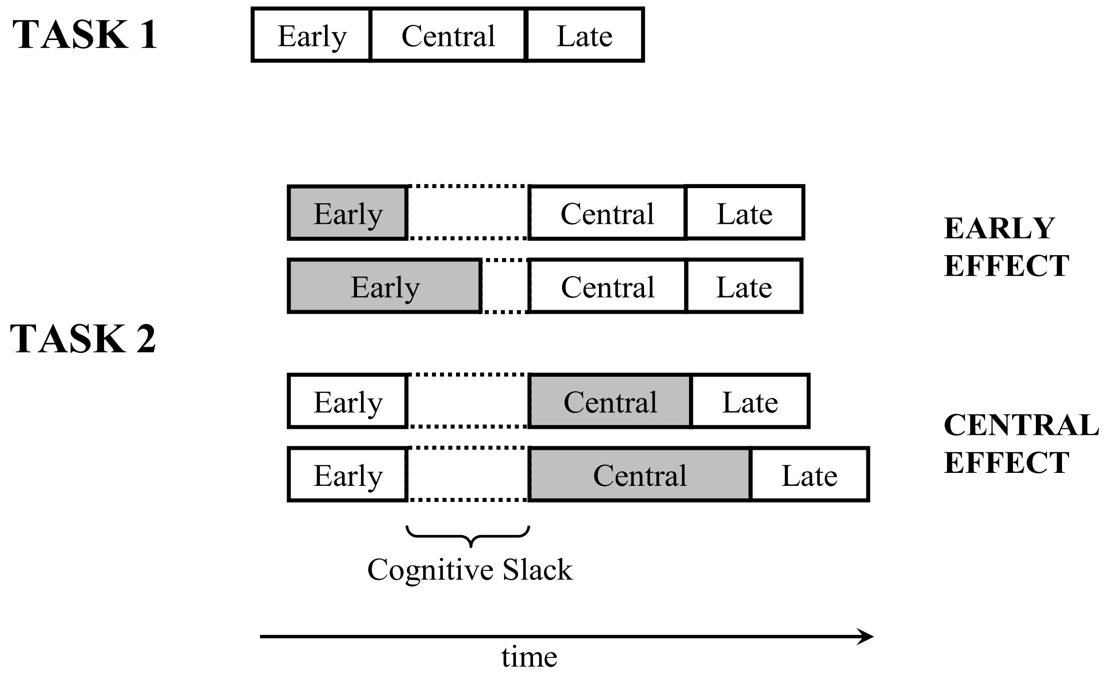
This limited capacity bottleneck is believed to operate as either an all-or-none (e.g., Pashler, 1984; 2000) or capacity sharing mechanism (Navon & Miller, 2002; Tombu & Jolicoeur, 2003). These accounts make many of the same predictions with respect to how automatic processes should affect Task 2 performance. Here I discuss these predictions using cognitive slack logic derived from the all-or-none bottleneck account. I return to these accounts of the central bottleneck in Part 2 where I examine them in more detail.

According to cognitive slack logic, the use of the same limited capacity attention system (hereafter referred to as central attention) by both tasks has straightforward consequences for Task 2 processes that occur before, during, or after the bottleneck. For example, when Task 1 and Task 2 overlap and participants are instructed to respond to Task 1 before Task 2, Task 1 gains access to central attention before Task 2. Task 2 processes that require central attention are functionally postponed until central attention becomes available (see Figure 2). If a factor manipulated in Task 2 occurs *prior* to the processing bottleneck, the effect of this factor will be absorbed into the slack created by Task 2 processes waiting for central attention to become available. A factor that affects processing prior to central attention will therefore produce no reaction time (RT) cost at the short SOA. Thus, if the effect of a factor goes completely underadditive with decreasing SOA this is *consistent* with the processes associated with this factor occurring "automatically".

If a factor manipulated in Task 2 has *additive* effects with SOA, then this factor affects a process that either (1) uses central attention or (2) occurs *after* central attention (Pashler, 1984; McCann et al., 2000; Navon & Miller, 2002; Tombu & Jolicoeur, 2003). Additive effects of SOA and a factor in Task 2 are therefore *inconsistent* with the process associated with this factor *occurring* automatically.

Partial underadditivity occurs when a factor has a smaller, but still significant, effect at the short SOA than at the long SOA. This outcome is consistent with the hypothesis that there are two or more components to the process (or processes) indexed by a factor. One component, indexed by the underadditivity, does not require central attention and a second component, indexed by the remaining effect, requires central attention (or occurs after central attention has been used).

Figure 2: An illustration of how Task 2 manipulations that occur prior to the processing bottleneck are absorbed into the cognitive slack created when central processes in Task 2 are postponed by central processes in Task 1 and how manipulations that affect central processes in Task 2 produce an effect on RTs at short SOAs."



Is Assembled Phonological Recoding Automatic?

Experiments 1 and 2 use the PRP paradigm to assess whether *assembled* phonological recoding (as opposed to addressed phonological recoding) uses central attention. If sublexical phonological recoding is automatic and therefore does not require attention, then factors indexing this process should produce completely underadditive effects with decreasing SOA.

According to a major dual route model (DRC; Coltheart et al., 2001) assembled phonology is necessary to read aloud a nonword correctly (note: this does not mean that there is no lexical contribution to nonword naming; e.g., Coltheart et al., 2001; Rastle & Coltheart, 1999; Reynolds & Besner, 2004). In the Dual Route model depicted in Figure 1, letter processing occurs in parallel across a letter string and the subsequent activation of multiple representations in the orthographic input lexicon also occurs in parallel. In contrast, sublexical spelling to sound translation (assembled phonology) occurs serially, left-to-right across the letter string. Therefore, the time to name a nonword letter string should increase with the number of letters (Besner & Roberts, 2003; Coltheart et al., 2001; Weekes, 1997). Consistent with the Dual Route account, the letter length effect is larger for nonwords than for words (Buchanan & Besner, 1993; Mason, 1978; Weekes, 1997). Indeed, Weekes (1997) reported that the time to name a *nonword* increases linearly with the number of letters, but that there is no effect of letter length for *words* when the effect of neighbors is partialled out.

Experiment 1

Experiment 1 assesses whether assembled phonological recoding uses central attention in the context of Task 2 of the PRP paradigm. If assembling a phonological code is automatic, then the letter length effect in nonword naming should go completely underadditive with decreasing SOA. In contrast, if assembled phonological recoding uses central attention then the effect of letter length in nonword naming will be additive with SOA.

Method

Subjects

Sixty undergraduate students from the University of Waterloo were each paid $4.00 to participate in the Experiment. All individuals had normal or corrected-to-normal vision and were native English speakers.

Stimuli

The stimuli were taken from Besner and Roberts (2003) and consisted of 28 short nonwords and 28 long nonwords matched for onsets and neighborhood density. The stimuli along with reaction time and error data can be seen in Appendix B.

Procedure

The short and long nonword stimuli were split into two sub-lists each that were counterbalanced across SOA using a latin-square design. Subjects were randomly assigned to a counterbalance condition based on the order in which they arrived in the laboratory. Subjects were tested individually and were seated approximately 50 cm from the computer monitor.

Stimulus presentation was controlled by a Pentium II 300 mHz computer running Micro Experimental Laboratory 2 (MEL 2) software (Schneider, 1988). Key press responses for the tone task were collected via keyboard. Vocal responses for Task 2 were collected using a Platronics LS1 microphone headset and a voice key assembly. Stimuli were displayed on a 17 inch ADI Microscan monitor.

The experiment was split into 2 blocks. Practice consisted of blocks of 16 trials with a separate set of stimuli that repeated until the subjects performed perfectly to ensure ample practice with the task. The experimental block consisted of 56 trials. Each trial began with a cross (+) displayed at the center of the screen. Subjects were instructed to fixate on the cross and press the spacebar to initiate the trial. When the spacebar was pressed a blank screen replaced the fixation screen. After 500 msec either a high (600Hz) or low (300Hz) tone sounded for 100 msec. Either 50 or 750 ms after the onset of the tone a nonword was presented on the computer screen, centered at fixation. Subjects responded to the tone task by pressing "V" to indicate that they heard a high tone or they pressed "N" to indicate that they heard a low tone. Subjects then named the nonwords into a headset microphone. Subjects were instructed to perform both tasks as quickly and accurately as possible, but to respond to the tone task first.

Results

The RT data from Experiment 1 can be seen in Figure 3 and the error data can be seen in Table 2. Trials on which there was an incorrect response in Task 1, or an incorrect pronunciation or voice key failure in Task 2, were removed prior to the RT analysis. That is, if an error was made on a given trial in Task 2, the RT data from both Task 1 and Task 2 were discarded. This resulted in the removal of 7.3% of the data. A pronunciation error was defined as an utterance that represented a clear mispronunciation of the nonword (i.e., an extra or deleted phoneme, or lexicalization).

RTs to correct responses were subjected to a recursive trimming procedure in which the criterion cutoff for outlier removal was established independently, for each subject in each condition, by reference to the sample size in that cell (VanSelst & Jolicoeur, 1994). This resulted in the removal of 2.8% of the remaining RT data due to outliers in Task 1 and an additional 1.4% of the RT data due to outliers in Task 2.

Task 1: Tone Discrimination

Reaction times and errors from the tone discrimination task were analyzed across subjects and items (used in Task 2) using a repeated measures ANOVA with stimulus onset asynchrony (SOA) and nonword letter length in Task 2 as factors. As SOA decreased, RT decreased, $F_1(1, 59) = 15.2$, $p < .001$, $MSE = 5877$, $F_2(1, 27) = 49.2$, $p < .001$, $MSE = 800$. No other effects approached significance (Fs < 1).

Analysis of the error data revealed that as SOA decreased, errors increased, $F_1(1, 59) = 5.2$, $p < .05$, $MSE = 14.8$, $F_2(1, 27) = 4.7$, $p < .05$, $MSE = 7.4$. There was no effect of nonword letter length, $F_1(1, 59) = 2.1$, $p > .10$, $MSE = 19.6$, $F_2\ (1, 27) = 3.3$, $p < .10$, $MSE = 6.1$. There was no interaction between SOA and length (Fs < 1).

In order to better understand the SOA effect on Task 1 performance, the subject data were corrected using Townsend and Ashby's (1983) efficiency score procedure. According to Townsend and Ashby the impact of speed accuracy trade-offs on RT data can be approximated by dividing the mean correct RT for each subject in each condition by the corresponding proportion correct to create an efficiency score. When this was

Figure 3: Mean Reaction Time (ms) in Experiment 1 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of nonword letter length and SOA.

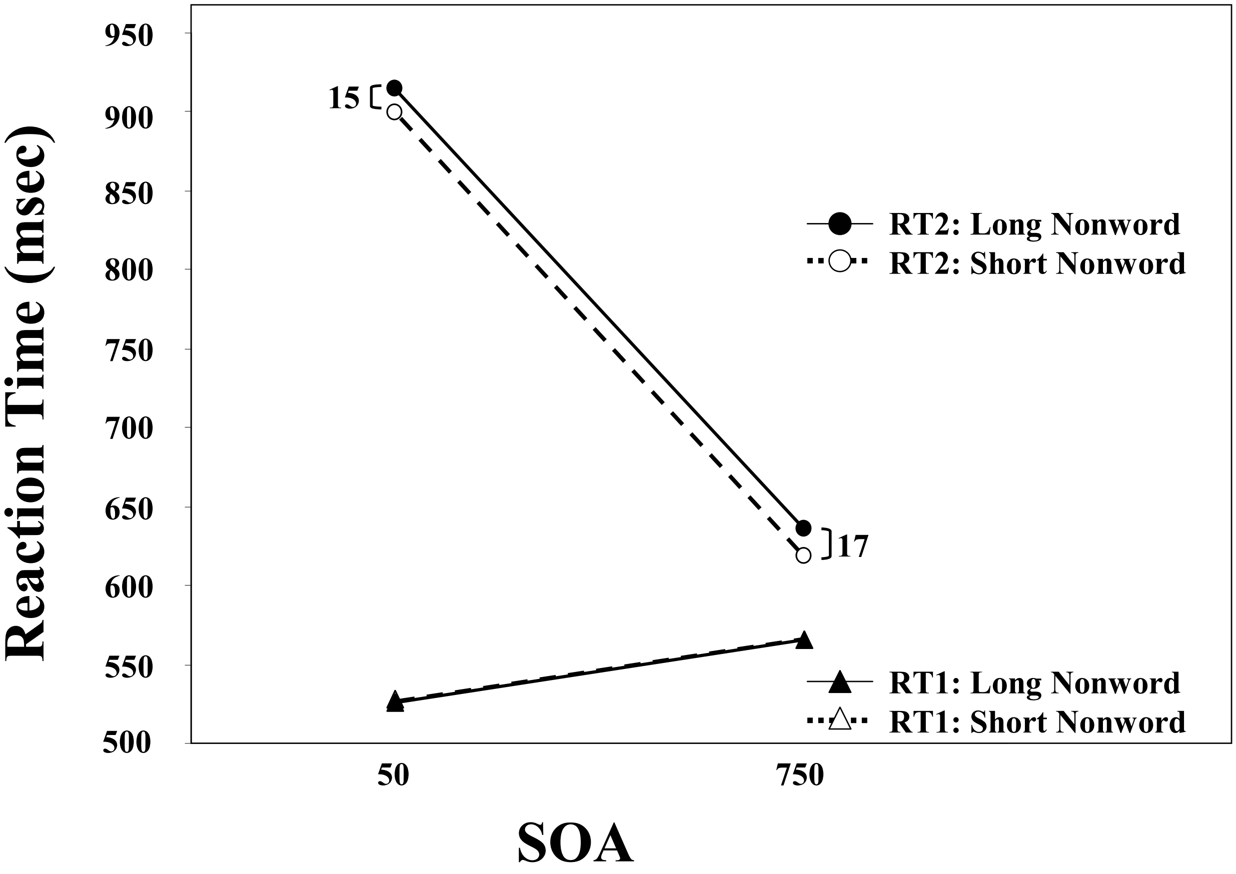


Table 2: Percent Error (%E) in Experiment 1 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of nonword letter length and SOA.

	SOA	
	50	**750**
Task 1: Tone Identification	%E	%E
Long Nonwords	4.0	2.4
Short Nonwords	3.1	2.0
Task 2: Nonword Naming		
Long Nonwords	3.4	3.1
Short Nonwords	1.4	1.5

done, correct RTs decreased as SOA decreased, $F(1, 59) = 10.6$, $p < .01$, $MSE = 6611$. For present purposes, this pattern does not compromise the interpretation of the Task 2 data. I examine the issue of Task 1 performance as a function of SOA in more detail in Part 2.

Task 2: Naming

The data from Task 2 were analyzed using a repeated measures ANOVA with SOA and nonword letter length as factors. As SOA decreased, RT increased, $F_1(1, 59) = 394.5$, $p < .001$, $MSE = 11963$, $F_2(1, 27) = 3450.6$, $p < .001$, $MSE = 657.1$. As nonword letter length increased, RT increased, $F_1(1, 59) = 8.6$, $p < .01$, $MSE = 1865.8$, $F_2(1, 27) = 7.2$, $p < .01$, $MSE = 1575.1$. Critically, there was no interaction between SOA and nonword letter length (Fs < 1).

Analysis of the error data revealed no effect of SOA (Fs < 1). As nonword letter length increased, errors increased, $F_1(1, 59) = 9.4$, $p < .01$, $MSE = 20.4$, $F_2(1, 27) = 3.6$, $p < .10$, $MSE = 4.7$. There was no interaction between SOA and nonword letter length (Fs < 1).

Discussion

Experiment 1 was designed to assess whether sublexical spelling to sound translation (assembled phonology) uses central attention by factorially manipulating SOA and nonword letter length in Task 2 of the PRP paradigm. Accounts that suppose assembled phonology is automatic predict an underadditive interaction between nonword letter length and SOA in which there is no effect of letter length at the short SOA and an effect of letter length at the long SOA. In contrast, an account in which assembled phonology uses central attention predicts additive effects of nonword letter length and

SOA. Inconsistent with such processing being automatic, additive effects of SOA and nonword letter length were observed.

Experiment 2

The size of the nonword letter length effect in Experiment 1 is consistent with that reported by Besner and Roberts (2003), but at ≈20 ms it is not very large. This makes it difficult to detect the underadditive interaction necessary to support the inference that phonological recoding is automatic (the power to find a 20 ms interaction between SOA and nonword letter length was .67). Two steps were taken to increase power in Experiment 2. First, the number of stimuli was increased from 56 to 88. Second, nonword letter length was deliberately confounded with grapheme-phoneme complexity, a second factor believed to affect assembled phonology. According to Rastle and Coltheart (1998), grapheme-phoneme complexity increases how long it takes to assemble a phonological code when subsequent letters in a stimulus modify the pronunciation given to an earlier letter (e.g., “th” in “steth”). Here I define a *basic* nonword as one in which each phoneme corresponds to a single letter grapheme and a *complex* nonword as one in which at least one phoneme corresponds to a multi-letter grapheme.

Method

Subjects

Thirty-two undergraduate students from the University of Waterloo were each paid $4.00 to participate in the Experiment. All individuals had normal or corrected-to-normal vision and were native English speakers.

Stimuli

The stimuli consist of 44 short *basic* nonwords (4 letters long) and 44 long *complex* nonwords (6 letters long) matched for onsets and neighborhood density. The stimuli along with RT and error data can be seen in Appendix D.

Procedure

The procedure was identical to that of Experiment 1.

Results

The RT data can be seen in Figure 4 and the error data can be seen in Table 3. Trials on which there was an incorrect response in Task 1, or an incorrect pronunciation or voice key failure in Task 2 were removed before the RT analysis. This resulted in the removal of 9.2% of the data. 2.4% of the remaining RT data was excluded due to outliers in Task 1 and an additional 1.5% of the remaining RT data was excluded due to outliers in Task 2.

Task 1: Tone Discrimination

As SOA decreased, RT decreased, $F_1(1, 31) = 11.2$, $p < .01$, $MSE = 4579$, $F_2(1, 43) = 20.2$, $p < .001$, $MSE = 3430$. No other effects approached significance (Fs < 2).

As SOA decreased, errors increased, $F_1(1, 31) = 4.7$, $p < .05$, $MSE = 15.9$, F_2 $(1, 43) = 6.7$, $p < .05$, $MSE = 15.8$. No other effects were significant (Fs < 1).

Once again, the main effects of SOA go in different directions for RT and errors. Subject RTs were therefore corrected using Townsend and Ashby’s (1983) method. When this was done, RT still decreased as SOA decreased, $F(1, 31) = 6.1$, $p < .05$, $MSE = 5622$.

Figure 4: Mean Reaction Time (ms) in Experiment 2 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of nonword letter length/graphemic complexity and SOA.

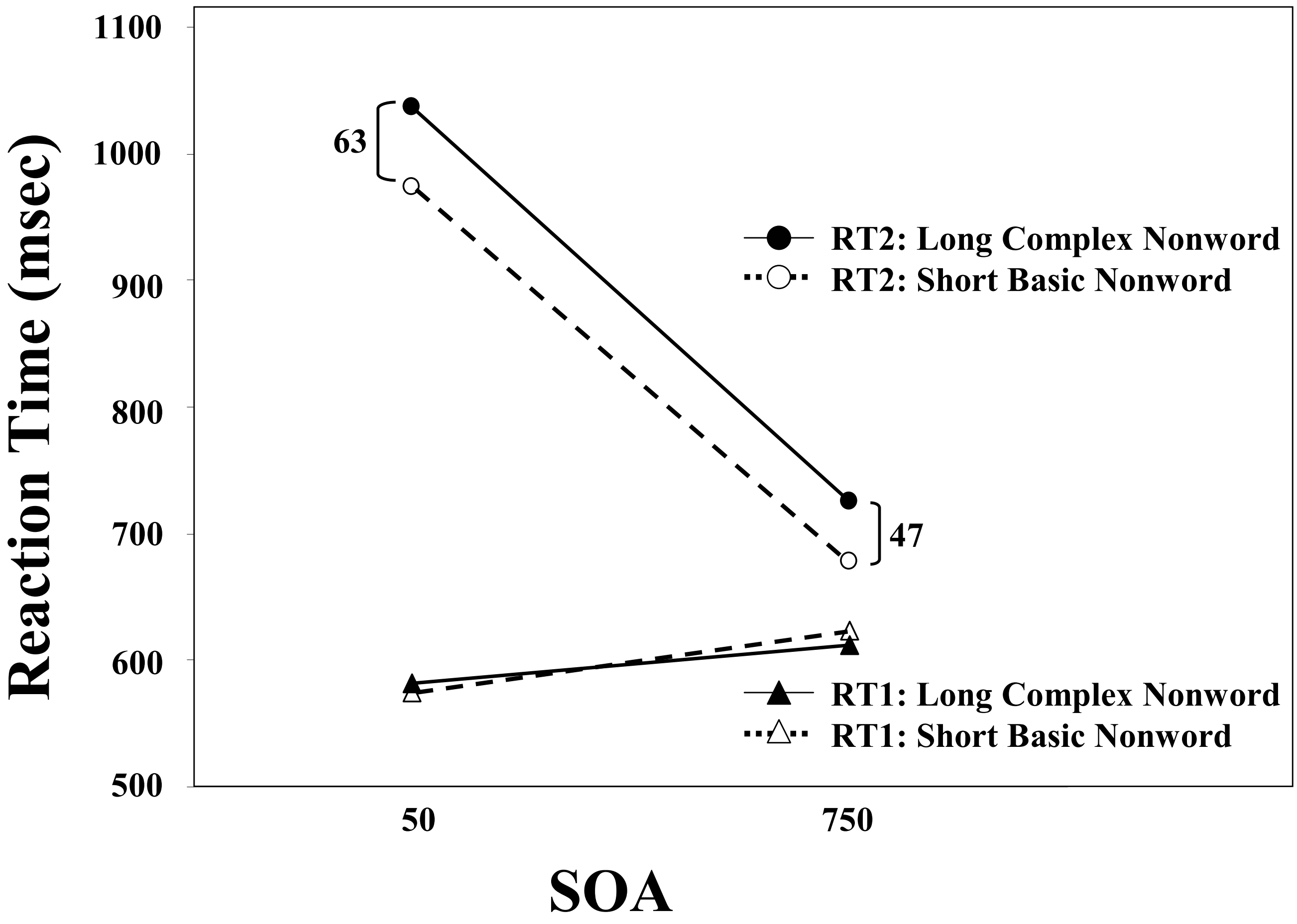


Table 3: Percent Error (%E) in Experiment 2 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of nonword letter length/complexity and SOA.

	SOA	
	50	**750**
Task 1: Tone Identification	%E	%E
Long Complex Nonwords	2.7	1.6
Short Basic Nonwords	3.6	1.6
Task 2: Nonword Naming		
Long Complex Nonwords	3.7	2.8
Short Basic Nonwords	1.7	2.1

Task 2: Naming

As SOA decreased, RT increased, $F_1(1, 31) = 232.9$, $p < .001$, *MSE* = 12655, $F_2(1, 43) = 1936.1$, $p < .001$, *MSE* = 2161. The long complex nonwords took longer to name than the short basic nonwords, $F_1(1, 31) = 31.1$, $p < .001$, *MSE* = 3159, $F_2(1, 43) = 43.6$, $p < .001$, *MSE* = 3124. There was no interaction between these factors (Fs < 1).

Analysis of the error data revealed no effect of SOA (Fs < 1). More errors were made naming the long complex nonwords than the short basic nonwords, $F_1(1, 31) = 9.0$, $p < .01$, *MSE* = 6.8, $F_2(1, 43) = 4.3$, $p < .05$, *MSE* = 17.5. There was no interaction between SOA and nonword difficulty as indexed by letter length and complexity (Fs < 1).

Discussion

Inconsistent with the claim that assembled phonological recoding occurs automatically, additive effects of SOA and nonword letter length/complexity were observed. The power to find the completely underadditive interaction predicted by the automatic account of assembled phonological recoding is .92.

Summary

Experiments 1 and 2 demonstrate that assembled phonological recoding uses central attention in the context of the PRP paradigm. As such, these experiments are inconsistent with the claim that assembled phonology occurs automatically.

Do Lexical Representations Automatically Contribute to the Computation of a Phonological Code?

There are numerous demonstrations that lexical knowledge contributes to the computation of assembled phonology. One factor that indexes such lexical knowledge is Neighborhood Density (N), which refers to the number of words created by changing each letter in a stimulus, one at a time (Coltheart, Davelaar, Jonasson, & Besner, 1977). As neighborhood size increases, naming times for words and nonwords decreases (Andrews, 1992; McCann & Besner, 1987; Reynolds & Besner, 2004; Peereman & Content, 1995). The central assumption here is that the effect of N arises from activation within the lexical system (Andrews, 1997; Coltheart et al., 1977; 2001). Consistent with this assumption, Reynolds and Besner (2002) showed that no N effect is observed when the lexical system in DRC is lesioned and the model names nonwords. In contrast, an N effect is observed when nonwords are named and the lexical route is intact.

Experiment 3

Here I examine neighborhood density effects in the context of the PRP paradigm in order to assess whether the lexical contribution to assembled phonology occurs automatically. If so then the neighborhood density effect should go underadditive with decreasing SOA. If the lexical contribution to phonological recoding is not automatic and uses central attention then N should produce additive effects with SOA in Task 2 of the PRP paradigm. Experiment 3 tested these contrasting predictions using nonword naming as Task 2.

Method

Subjects

Forty-eight undergraduate students from the University of Waterloo were each paid $4.00 to participate in the experiment. All individuals reported normal or corrected-to-normal vision and were native English speakers.

Stimuli

The stimuli were taken from Reynolds and Besner (2004) and consist of 42 low N nonwords and 42 high N nonwords matched for onsets, length and grapheme-phoneme complexity. The stimuli along with RT and error data can be seen in Appendix F.

Procedure

The procedure is identical to the one used in Experiment 1.

Results

The RT data from Experiment 2 can be seen in Figure 5 and the error data can be seen in Table 4. Trials on which there was an incorrect response in Task 1 or an incorrect pronunciation or voice key failure in Task 2 were removed prior to the RT analysis. This resulted in the removal of 11% of the data. Outlier analysis resulted in the removal of 2.3% of the remaining RT data in Task 1 and an additional 1.2% of the remaining RT data in Task 2.

Task 1: Tone Discrimination

Reaction times and errors from the tone discrimination task were analyzed across subjects and items (used in Task 2) using a repeated measures ANOVA with stimulus onset asynchrony (SOA) and neighborhood density (from Task 2) as factors. As SOA decreased RT decreased, $F_1(1, 47) = 5.9$, $p < .05$, $MSE = 6039$, $\mathrm{F}_2(1, 41) = 24.5$, $p < .001$, $MSE = 1285$. No other effects approached significance (Fs < 1.3).

Analysis of the error data revealed that as SOA decreased, errors increased, $F_1(1, 47) = 18.5$, $p < .001$, $MSE = 16.4$, $F_2(1, 41) = 19.4$, $p < .001$, $MSE = 14.4$. No other effects approached significance (Fs < 1).

Figure 5: Mean Reaction Time (ms) in Experiment 3 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of neighborhood density and SOA.

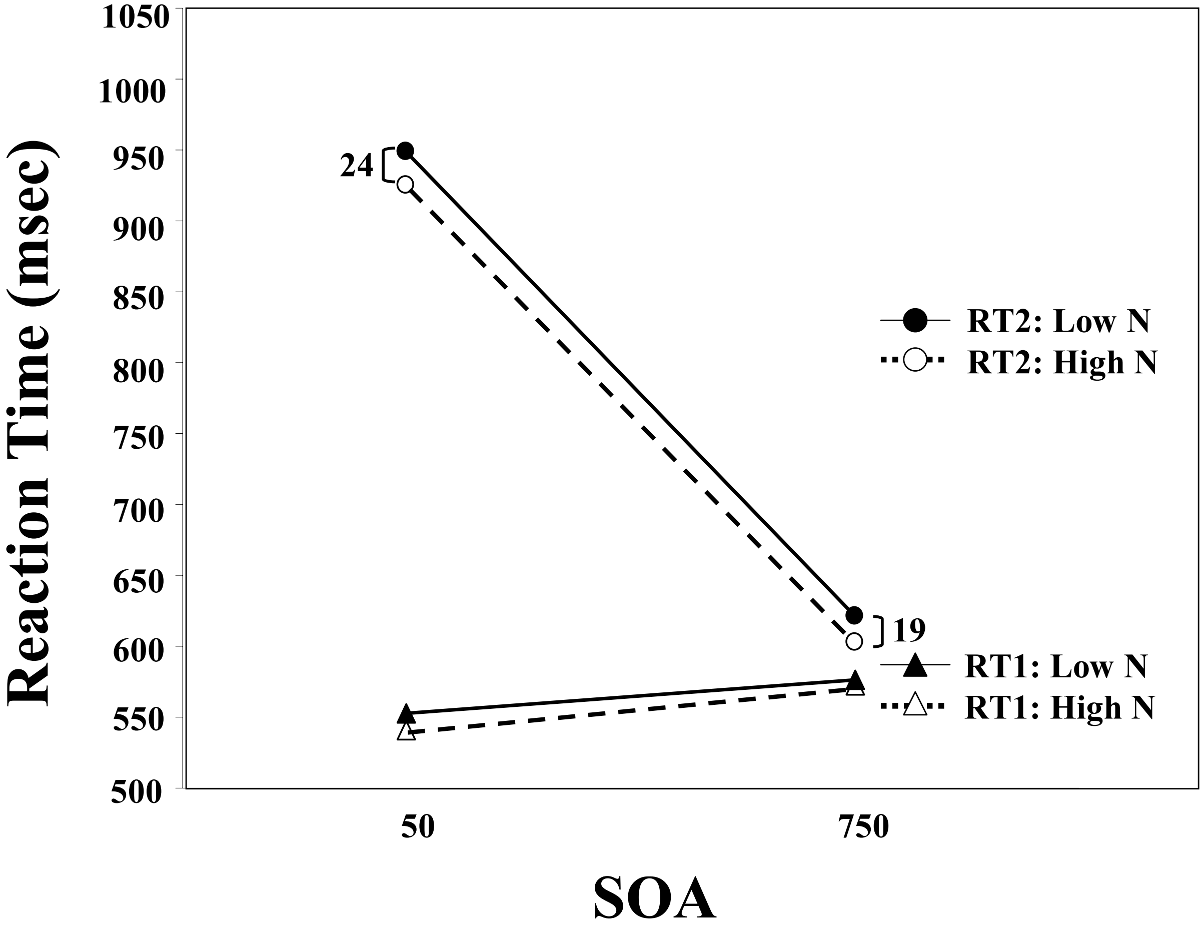


Table 4: Percent Error (%E) in Experiment 3 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of Neighbourhood Density and SOA.

	SOA	
	50	**750**
Task 1: Tone Identification	%E	%E
Sparse Neighbourhood	4.9	2.4
Dense Neighbourhood	4.9	2.4
Task 2: Nonword Naming		
Sparse Neighbourhood	3.7	2.7
Dense Neighbourhood	1.5	1.2

The main effect of SOA is difficult to interpret here because there is a speed accuracy trade off. Therefore, correct RTs from the subject analysis were calculated using Townsend and Ashby's (1983) correction. When this was done, there was no effect of SOA ($F < 1$).

Task 2: Naming

The RT data from Task 2 were analyzed using a repeated measures ANOVA with SOA and N as factors. As SOA decreased, RT increased, $F_1(1, 47) = 628$, $p < .001$, $MSE = 8068$, $F_2(1, 41) = 1500$, $p < .001$, $MSE = 2927$. The time to name the nonwords decreased as N increased, $F_1(1, 47) = 7.1$, $p < .05$, $MSE = 3095$, $F_2(1, 41) = 4.3$, $p < .05$, $MSE = 2207$. Critically, there was no interaction between SOA and N ($Fs < 1$).

Analysis of the error data revealed no effect of SOA ($Fs < 1$). As N decreased, errors increased, $F_1(1, 47) = 7.1$, $p < .01$, $MSE = 24.1$, $F_2(1, 41) = 12.5$, $p < .01$, $MSE = 11.4$. There was no interaction between SOA and N ($Fs < 1$).

Discussion

The purpose of Experiment 3 was to investigate whether lexical representations automatically contribute to phonological recoding in the context of the PRP paradigm. Neighborhood density was used to index the lexical contribution to phonology. Inconsistent with such an account, additive effects of N and SOA were observed. The observation that N and SOA have additive effects has implications for the locus of the N effect. I will return to this issue in the general discussion.

Experiment 4

In Experiment 3, I assessed whether neighborhood density and SOA would yield complete underadditivity as predicted by an account in which lexical knowledge automatically affects the computation of phonology. The power to find a completely underadditive interaction between N and SOA in Experiment 3 was .63 (Cohen, 1988). Given the strong implications of Experiment 3 for accounts of automatic phonological recoding, I chose to replicate the experiment using a different set of stimuli so as to increase my confidence in the observed additive effects of N and SOA.

Method

Subjects

Fifty-four undergraduate students from the University of Waterloo were each paid $4.00 to participate in the Experiment. All individuals reported normal or corrected-to-normal vision and were native English speakers.

Stimuli

The stimuli consisted of 40 low N nonwords and 40 high N nonwords matched for onsets and length. The stimuli along with RT and error data can be seen in Appendix H.

Procedure

The procedure is identical to Experiment 1.

Results

The RT data can be seen in Figure 6 and the error data can be seen in Table 5. Trials on which there was an incorrect response in Task 1 or an incorrect pronunciation or voice key failure in Task 2 were removed prior to the RT analysis. This resulted in the removal of 8.3% of the reaction time data. Outlier analysis resulted in the removal of 2.4% of the remaining RT data due to outliers in Task 1 and an additional 1.5% of the remaining RT data due to outliers in Task 2.

Figure 6: Mean Reaction Time (ms) in Experiment 4 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of neighborhood density and SOA.

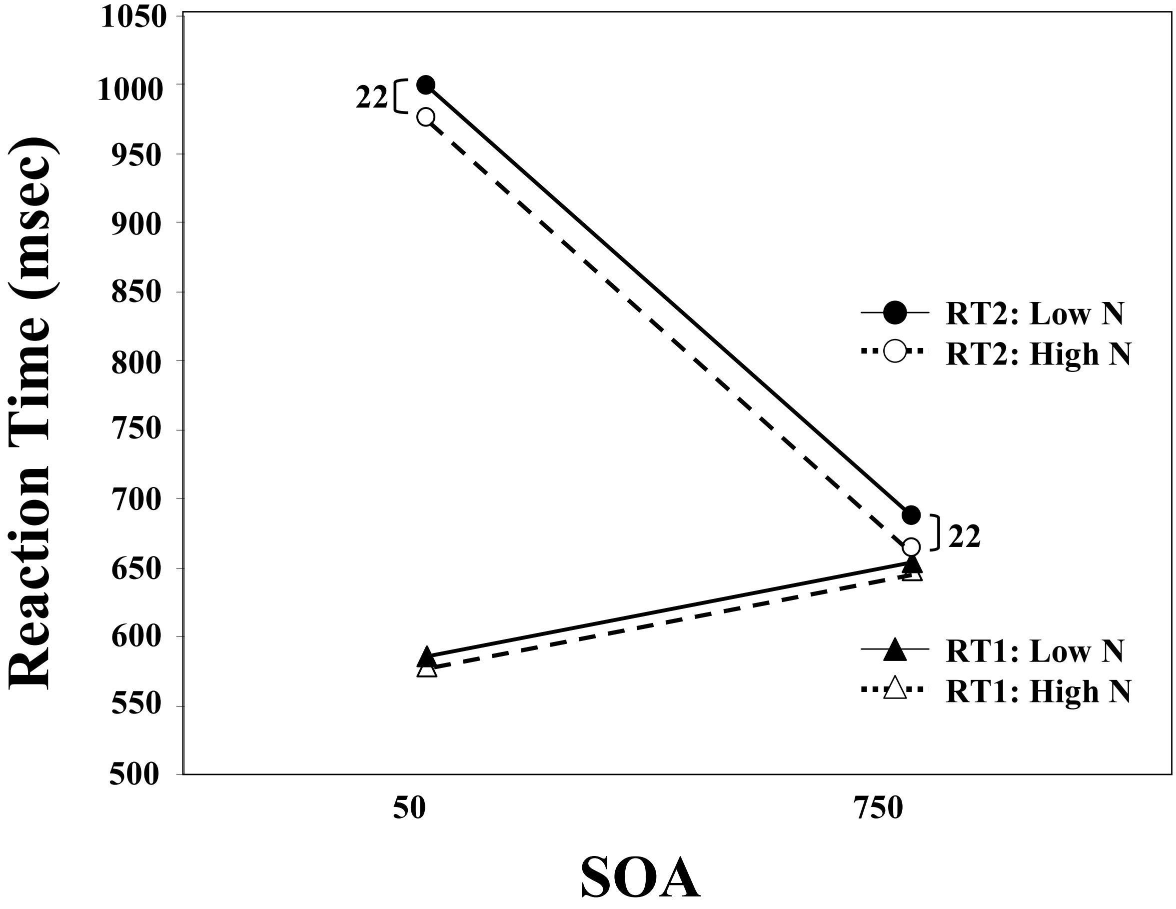


Table 5: Percent Error (%E) in Experiment 4 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of Neighbourhood Density and SOA.

	SOA	
	50	**750**
Task 1: Tone Identification	%E	%E
Sparse Neighbourhood	4.3	3.6
Dense Neighbourhood	5.4	3.7
Task 2: Nonword Naming		
Sparse Neighbourhood	7.1	7.6
Dense Neighbourhood	4.8	6.1

Task 1: Tone Discrimination

As SOA decreased, RT decreased, $F_1(1, 53) = 21.2$, $p < .001$, $MSE = 12254$, $F_2(1, 39) = 46.7$, $p < .001$, $MSE = 4195$. No other effects approached significance (Fs < 1).

Analysis of the error data revealed that as SOA decreased, errors increased, $F_1(1, 53) = 5.8$, $p < .05$, $MSE = 14.1$, $F_2(1, 39) = 12.8$, $p < .001$, $MSE = 6.8$. No other effects approached significance (Fs < 1.5).

Once again, the main effects of SOA are different for the RT and error data. RTs were therefore converted to efficiency scores to correct for this speed accuracy tradeoff (Townsend & Ashby, 1983). When this was done, the corrected subject RTs still decreased as SOA decreased, $F(1, 53) = 12.8$, $p < .001$, $MSE = 13367$.

Task 2: Naming

The RT data from Task 2 were analyzed using a repeated measures ANOVA with SOA and N as factors. As SOA decreased, the time to name a nonword increased, $F_1(1, 53) = 669$, $p < .001$, $MSE = 7833$, $F_2(1, 39) = 277$, $p < .001$, $MSE = 13724$. As N decreased, RT increased, $F_1(1, 53) = 9.7$, $p < .001$, $MSE = 2802$, $F_2(1, 39) = 8.0$, $p < .01$, $MSE = 3132$. As in Experiment 1, there was no interaction between SOA and N (Fs < 1).

Analysis of the error data revealed no effect of SOA, $F_1 < 1$, $F_2(1, 39) = 1.7$, $p > .10$, $MSE = 30.1$. As N decreased, errors increased, $F_1(1, 53) = 7.8$, $p < .01$, $MSE = 25.9$, $F_2(1, 39) = 4.0$, $p < .10$, $MSE = 77.7$. There was no interaction between SOA and N for either subjects or items (Fs < 1).

Discussion

Experiment 4 yielded additive effects of N and SOA. As discussed following Experiment 3, this outcome is *inconsistent* with the claim that lexical representations automatically contribute to the computation of phonology. Unlike Experiment 3, the power to find an underadditive interaction between N and SOA in the present experiment was .81, indicating that there was sufficient power to find an interaction if one existed (combining Experiments 3 and 4 the power to detect a completely underadditive interaction between SOA and N was .99).

Summary

Experiments 3 and 4 demonstrate that the lexical contribution to phonological recoding uses central attention in the context of the PRP paradigm. As such, these experiments are inconsistent with the claim that lexical representations automatically contribute to the generation of a phonological code.

Conclusions

There are numerous claims in the reading literature that skilled readers generate a phonological code from print automatically. The purpose of Experiments 1 – 4 was to test this claim. Many of the characteristics ascribed to automatic processes fall out of the assumption that they do not require attention. I therefore examined whether phonological recoding occurs automatically by assessing whether the processes involved in the generation of a phonological code use central attention. The availability of central attention was manipulated by varying the SOA between Task 1 and Task 2 in the context of the PRP paradigm.

Experiments 1 and 2 assessed whether *assembled* phonological recoding occurs automatically. Nonword letter length (Weekes, 1997) and graphemic complexity (Rastle & Coltheart, 1998) indexed assembled phonological recoding. Inconsistent with an account of automatic assembled phonology, nonword letter length and graphemic complexity produced additive effects with SOA in these experiments.

Experiments 3 and 4 assessed whether lexical representations automatically contribute to the generation of a phonological code. The lexical contribution to phonological recoding was indexed using neighborhood density (Andrews, 1992; Coltheart et al., 1977; McCann & Besner, 1987; Reynolds & Besner, 2004). Inconsistent with the claim that the lexical contribution to phonology occurs automatically, additive effects of N and SOA were observed.

Chapter 2

Many papers in the reading literature begin with the assumption that automatic processes exist and that specific paradigms can be used to examine them. For example, Markus (2002) begins by stating "It is a matter of debate whether the N400 component of the event-related brain potential (ERP) is sensitive to unconscious *automatic* priming mechanisms or to strategic mechanisms only" (p. 27). Frost (2003) refers to backward and forward masking as paradigms that are "used to examine fast *automatic* phonological computation" (p. 173) and as "experimental paradigms that focus on very early and *automatic* processing of print" (p. 175). Relatedly, Johnston and Castles (2003) state that "the masked priming technique has been employed to measure a variety of *automatic* information processes contributing to word recognition performance" (p. 193) and that they "describe work using a masked priming paradigm… to dissociate *automatic* orthographic and phonological mechanisms in word recognition" (p. 193) and by Perea and Rosa (2002) who "examine the presence of semantic priming effects with another technique that also taps *automatic* processes" (p. 187).

It is unclear, at least to me, how a procedure can be used to confidently examine automatic processes given that the reality of automatic processing is itself an issue of considerable debate. Indeed, the results of the Experiments 1 – 4 are the proverbial black swans for the hypothesis that all swans are white (phonological recoding is an automatic process).

Not surprisingly, proponents of automaticity are typically unfazed by demonstrations that processing is not automatic. I am not the first to point this out (e.g., see Bargh, 1992), nor do I expect to be the last. The standard response to demonstrations that processing is not automatic is to argue that automaticity is “context dependent”. A problem with the assumption of context dependent automaticity is that without an *a priori* specification of the conditions that make a process automatic, the construct risks being entirely circular. A second problem is that if some (as yet unspecified) context serves to make processing automatic, what conditions serve to render a process “not automatic”? Again, in the absence of a specified context it does not help theoretical development to label something as automatic or not.

Further, it is not apparent (at least to me) what is gained by salvaging automaticity as an explanatory concept in this way. If conditional automaticity were the dominant account of cognitive processing then this would shift the emphasis of theory development and experimental investigation to the contexts that afford automatic processing. This is problematic in two ways. First, it does not allow for the refutation of the claim that a process (in some context) is automatic. This is because in order to refute this claim *all* possible contexts would need to be investigated. Second, conditionalizing automaticity does not resolve any of the ambiguities raised by the numerous characteristics ascribed to the concept by different authors (see Table 1). Indeed, given that most authors do not specify what they mean by automatic processing, creating further ambiguities by conditionalizing when the unspecified characteristics may or may not be observed only seems to create additional problems.

What should we be doing instead? One approach is to abandon the use of the term “automatic”. Our understanding of visual word recognition has advanced sufficiently that, arguably, we should be making more specific claims about, for example, the condition-action “rules” that allow behaviour to proceed. This is likely to be a difficult enterprise, but I doubt that much progress will be made without it. We might also profit from paying more attention to (1) how processes are affected by attention, (2) how they can be controlled (e.g., Reynolds & Besner, 2005; and what this control would look like), (3) whether a process can be postponed or interrupted once it has been initiated, and (4) how processing is affected by consciousness (e.g., see Brown & Besner, 2002; Cheesman & Merikle, 1986; Neely, 1977).

In this part of the thesis I move beyond automaticity as an account of phonological recoding and attempt to make more specific observations. Experiment 5 examines whether *all* lexical processing requires central attention. Experiments 6 and 7 examine *how* central attention affects phonological recoding.

Are all lexical processes created equal?

The additive effects observed in Experiments 3 and 4 suggest that (at least) some of the lexical contribution to the generation of a phonological code uses central attention. The same conclusion was reached by McCann et al. (2000) who examined the effects of printed word frequency in Task 2 of the PRP paradigm. Consistent with the data from Experiments 3 and 4 they reported additive effects of word frequency and SOA in six experiments, irrespective of whether Task 2 was lexical decision or naming.

Although the results of McCann et al., and Experiments 3 and 4 here, are consistent with the claim that lexical processing uses central attention there are two reasons why it is premature to infer from them that *all* lexical processing uses central attention. First, the additive effects of N and word frequency with SOA do not discriminate between an account where “lexical processing” *uses* central attention and an account where lexical processing occurs *after* central attention is used. Therefore, other evidence is needed to distinguish between them. If preliminary feature and letter identification use central processing capacity then additive effects of a lexical factor and SOA by themselves will not tell us if lexical processing *per se* uses central attention.

A second problem is that N and word frequency do not necessarily index all lexical processes. For instance, N may only index *the activation of* phonological-lexical representations by orthographic-lexical representations (e.g., Coltheart et al., 2001; Peereman & Content, 1995; Reynolds & Besner, 2004). A similar possibility exists for word frequency. It is certainly true that many accounts assume that *lexical representations* themselves are sensitive to how frequently words are encountered (e.g., Coltheart et al., 2001; McClelland & Rumelhart, 1981; Morton, 1969). However, this assumption is not universal. For example, Besner and colleagues argue that word frequency does not affect lexical processing per se, but rather the *connections* between lexical-lexical and lexical-semantic representations (Besner & Smith, 1992; Borowsky & Besner, 1993; McCann & Besner, 1987; Reynolds & Besner, 2004). If the effect of word frequency in lexical decision and naming arises after input lexical representations are activated (i.e., the orthographic input lexicon), then additive effects of word frequency and SOA do not speak to the issue of whether *all* lexical processing uses central attention.

There is some evidence that processing up to and including letter representations does not require central attention. Johnston, Remington, and McCann (1995) had subjects classify whether a normal or distorted letter was either an ‘A’ or an ‘H’ in Task 2 of the PRP paradigm. Consistent with letter identification taking place before the processing bottleneck, Johnston et al. (1995) report that letter distortion was underadditive with decreasing SOA. That is, subjects took longer to correctly classify distorted letters than normal letters at the long SOA, but there was no difference at the short SOA. Although this is consistent with letter identification occurring prior to central attention, another interpretation is that letter distortion is cleaned up prior to letter identification. If this is the case, then it is still possible that letter identification uses central attention (see also Paap & Ogden, 1981).

Given the existing evidence, the extent to which lexical processes use central attention is still an open question. However, if a factor that indexes lexical processing yields an underadditive interaction with SOA, then this would provide evidence that processing up to and including some lexical processing occurs prior to central attention. One factor that is believed to index lexical processing in the orthographic lexicon is long-lag repetition priming. Scarborough, Cortese, and Scarborough (1977) reported that faster responses are made to repeated, relative to novel words, in the lexical decision task. They concluded that long-lag repetition priming affects lexical representations because priming for words (but not nonwords) persisted over many intervening items, was not affected by changes in case, and interacted with word frequency, facilitating low frequency words more than high frequency words. Scarborough et al. (1977) reported similar results in the naming task.

Experiment 5

The empirical question addressed by Experiment 5 is straightforward: Do long-lag repetition priming and SOA have additive effects in the context of the PRP paradigm or is there at least a partially underadditive interaction in which repeated items are less affected by a short SOA than a long one? If long-lag repetition priming and SOA yield at least a partially underadditive interaction, then this is consistent with (1) some lexical processing occurring prior to central attention and, therefore, (2) pre-lexical processes (feature and letter level) in the present context do *not* use central attention.

Method

Subjects

40 undergraduate students from the University of Waterloo were each paid $4.00 to participate in the Experiment. All individuals had normal or corrected-to-normal vision and were native English speakers.

Stimuli

It is widely believed that the generation of a correct phonological code for low frequency exception words is dependent on the activation of representations in the orthographic input lexicon (Coltheart et al., 2001). Thus, 100 low frequency exception words were used in the present experiment to force orthographic lexical processing. The stimuli along with RT and error data can be seen in Appendix J.

Procedure

Items were rotated through SOA and priming conditions across subjects. Subjects were randomly assigned to one of the counterbalance conditions based on the order in which they came to the laboratory. Subjects were tested individually and were seated approximately 50 cm from the computer monitor.

In Part 1, subjects read aloud words that appeared at fixation. They received 10 practice trials to familiarize themselves with the procedure before moving on to the experimental session. Block 1 consisted of 50 trials. Block 2 consisted of the same 50 trials presented in Block 1, but in a different randomized order.

Each trial began with a cross (+) displayed at the center of the screen. Subjects were instructed to fixate on the cross and press the spacebar to initiate the trial. When the spacebar was pressed a blank screen replaced the fixation screen. After 500 msec a word was presented on the computer screen, centered at fixation. The word remained on the screen until it was read aloud into the headset microphone. Subjects were instructed to read aloud the items quickly while maintaining a high degree of accuracy.

In Part 2, subjects performed both tone identification and reading aloud on each trial. They received 20 practice trials to familiarize themselves with the procedure before moving on to the experimental trials. The experimental block consisted of the 50 items from Part 1 randomly intermixed with 50 new words that had not been presented before.

Each trial began with a cross (+) displayed at the center of the screen. Subjects were instructed to fixate on the cross and press the spacebar to initiate the trial. When the spacebar was pressed a blank screen replaced the fixation screen. After 500 msec either a high (600Hz) or low (300Hz) tone sounded for 100 msec. Either 50 or 750 ms after the onset of the tone a word was presented on the computer screen, centered at fixation. Subjects responded to the tone task by pressing "V" to indicate that they heard a high tone or they pressed "N" to indicate that they heard a low tone. Subjects then named the word into a headset microphone. Subjects were instructed to perform both tasks as quickly and accurately as possible, but to respond to the tone task first.

Stimulus presentation was controlled by a Pentium II 300 mHz computer running Micro Experimental Laboratory 2 (MEL 2) software (Schneider, 1988). Key press responses for the tone task were collected via keyboard. Vocal responses for Task 2 were collected using a Platronics LS1 microphone headset and a voice key assembly. Stimuli were displayed on a 17 inch ADI Microscan monitor.

Results

Only the data from Part 2 were analyzed. Trials on which there was an incorrect response in Task 1 or Task 2 were removed prior to the RT analysis. This resulted in the removal of 9.8% of the RT data. An additional 4.6% were removed due to voice key failures. The remaining correct RTs were submitted to a recursive data trimming procedure in which the criterion for outlier removal was established based on the sample size in that cell (VanSelst & Joliceour, 1994). This resulted in the removal of 2.9% of the remaining RT data in Task 1 and an additional 1.7% of the remaining RT data in Task 2.

Task 1: Tone Discrimination

See Figure 7 for the reaction time data and Table 6 for the error data. Reaction times and errors for the tone discrimination task were analyzed across subjects and items (used in Task 2) using an ANOVA with SOA and repetition (from Task 2) as repeated factors.

Analysis of the RT data revealed that there was a main effect of SOA, $F_1(1, 39) = 10.3$, $p < .01$, $MSE = 13265$, $F_2(1, 99) = 34.4$, $p < .001$, $MSE = 8038$). No other effects approached significance (Fs < 1).

Analysis of the error data revealed that more errors were made as SOA decreased, $F_1(1, 39) = 21.7$, $p < .001$, $MSE = 13.4$, $F_2(1, 99) = 18.4$, $p < .001$, $MSE = 39.5$. There was a marginal effect of repetition, $F_1<1.5$, $F_2(1, 99) = 3.2$, $p < .10$, $MSE = 37.2$. No other effects approached significance (Fs < 1).

Once again, the main effects of SOA were different for the RT and error data. RTs were therefore converted to efficiency scores to correct for this speed accuracy tradeoff (Townsend & Ashby, 1983). When this was done, the corrected subject RTs still decreased as SOA decreased, $F(1, 39) = 4.8$, $p < .05$, $MSE = 15210$.

Task 2: Reading Aloud

The RT data for the words from Task 2 were analyzed using a repeated measures ANOVA with SOA and repetition as factors. These data can also be seen in Figure 7. As SOA decreased, RT increased, $F_1(1, 39) = 387.6$, $p < .001$, $MSE = 9031$, $F_2(1, 98) = 932.6$, $p < .001$, $MSE = 9209$. Faster responses were made to repeated words than to novel words, $F_1(1, 39) = 9.9$, $p < .01$, $MSE = 4194$, $F_2(1, 99) = 18.0$, $p < .001$, $MSE = 6020$. Critically, there was an underadditive interaction between SOA and repetition, $F_1(1, 39) = 5.0$, $p < .05$, $MSE = 3469$, $F_2(1, 99) = 9.1$, $p < .01$, $MSE = 7853$. The remaining effect of repetition at the short SOA was not significant, $F_1(1, 39) = 1.4$, $p > .05$, $MSE = 1830$, $F_2 < 1$.

Analysis of the error data revealed as SOA decreased, errors decreased, $F_1(1, 39) = 3.9$, $p < .10$, $MSE = 29.6$, $F_2(1, 99) = 5.3$, $p < .05$, $MSE = 65.7$. Fewer errors were made to repeated words than to novel words, $F_1(1, 39) = 10.5$, $p < .01$, $MSE = 31.3$, $F_2(1, 99) = 7.8$, $p < .01$, $MSE = 87.8$. There was an underadditive interaction between SOA and repetition, $F_1(1, 39) = 5.6$, $p < .05$, $MSE = 29.0$, $F_2(1, 99) = 4.4$, $p < .05$, $MSE = 73.9$. The remaining effect of repetition at the short SOA was not significant (Fs < 1).

Figure 7: Mean Reaction Time (ms) in Experiment 5 for Tone Identification (Task 1) and Word Naming (Task 2) as a function of Repetition and SOA.

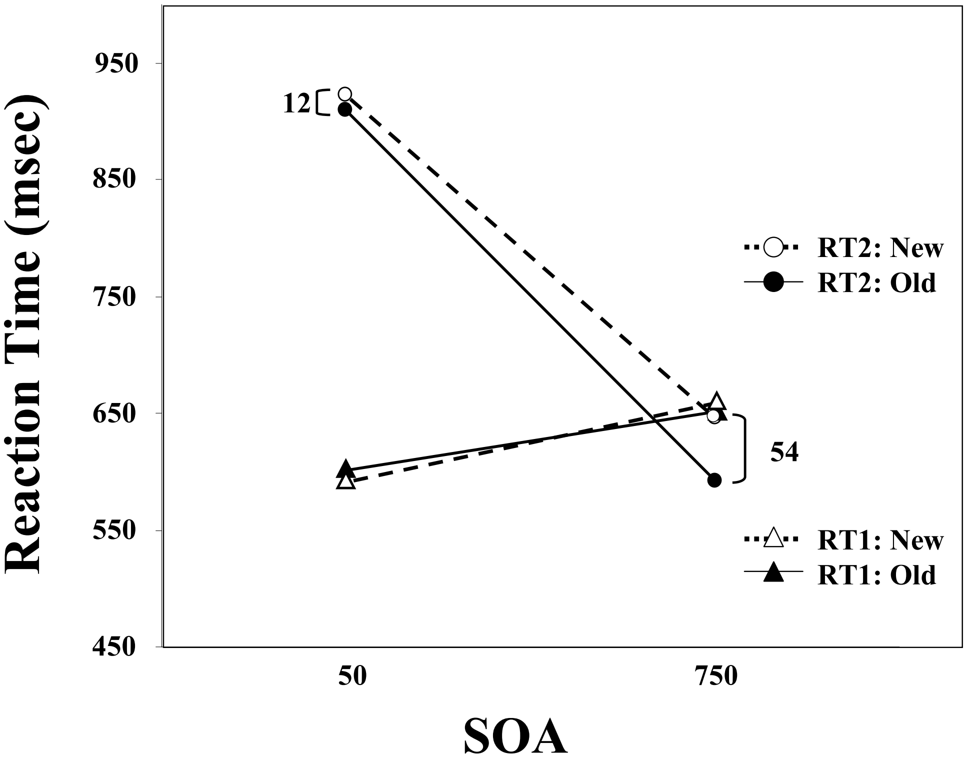


Table 6: Percent Error (%E) to Words in Experiment 5 for Tone Identification (Task 1) and Word Naming (Task 2) as a function of Repetition and SOA.

	SOA	
	50	**750**
Task 1: Tone Identification	%E	%E
Novel Items	5.9	3.1
Repeated Items	5.1	2.6
Task 2: Word Naming		
Novel Items	6.6	10.1
Repeated Items	5.7	5.5

Discussion

The purpose of Experiment 5 was to assess whether all lexical processes involved in the computation of phonology use central attention. The availability of central attention was manipulated by varying the SOA between Task 1 and Task 2 in the PRP paradigm. Task 2 was reading aloud and long-term repetition priming indexed lexical processing. The effect of repetition priming was underadditive with decreasing SOA, consistent with the hypothesis that there are (at least) two lexical processing components[3]; an early component of lexical processing that *does not* use central attention and a late component of lexical processing that *does* use central attention.

This outcome has several implications for accounts of phonological recoding. First, some lexical processing is able to contribute to the generation of a phonological code without requiring central attention. Second, feature and letter processing do not appear to need central attention in the context of reading aloud. As can be seen in Figure 2, according to cognitive-slack logic underadditivity with SOA is observed if no prior processes use central attention. Thus, the observation that some lexical processing (here, repetition priming for low-frequency exception words) occurs prior to central attention implies that prior processes (e.g., feature and letter processing) also do not use central attention in the present task.

Capacity Sharing vs. All-or-None Bottleneck

In experiments 1 – 5 the PRP paradigm was used to assess whether specific processes involved in the computation of a phonological code use central attention. The PRP paradigm can also be used to investigate *how* central attention is operating. One account of central attention is that it is only able to execute one process at a time (e.g., Pashler, 1994; McCann & Johnston, 1992). In the present context an all-or-none account implies that while Task 1 processing occupies central attention, lexical processing after the activation of representations in the orthographic input lexicon is postponed until central attention becomes available. Another account of central attention is that it is able to execute multiple processes concurrently by dividing processing capacity between them (Tombu & Jolicoeur, 2003; Navon & Miller, 2002). In the present context this account implies that representations in the orthographic lexicon are activated (Experiment 5) and then subsequent lexical processing is slowed until resources no longer need to be allocated to Task 1.

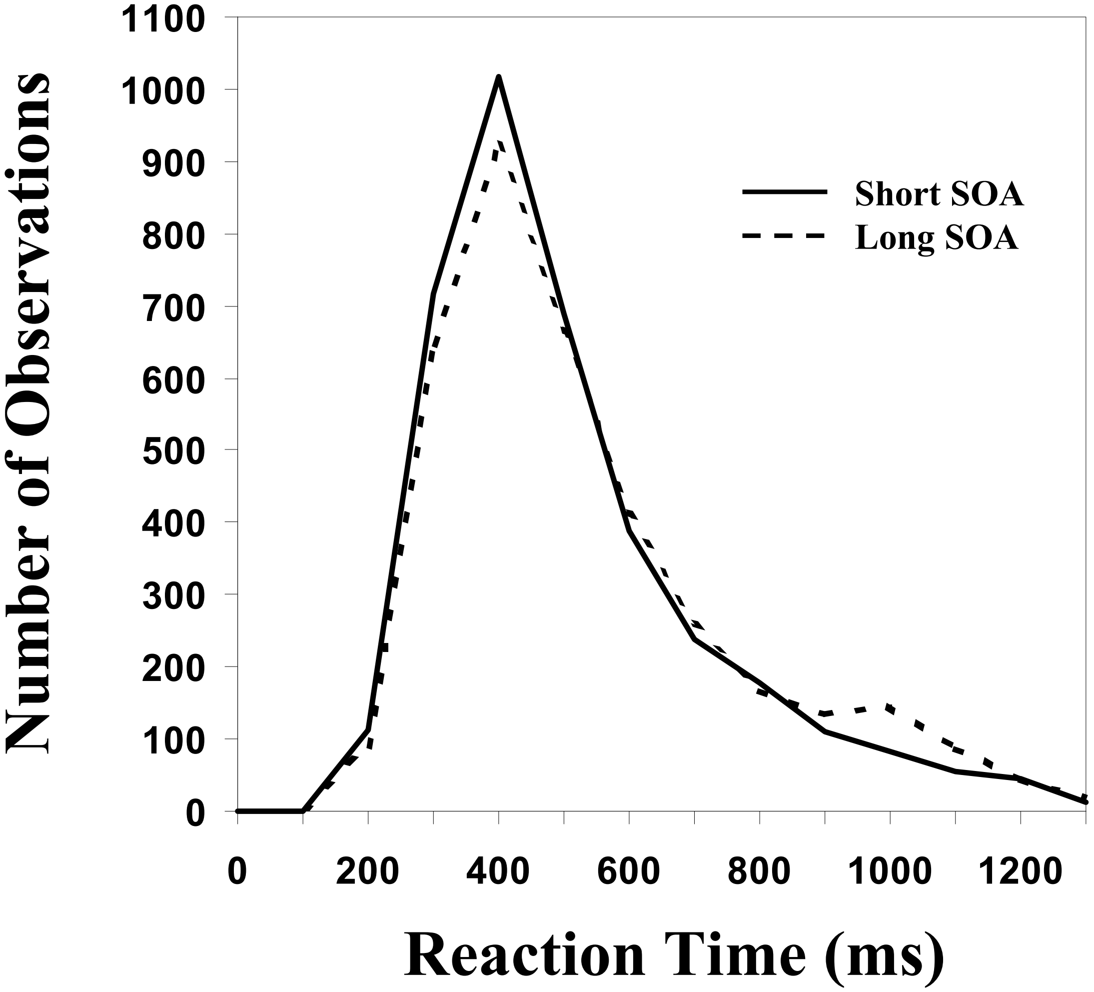
Additive effects of SOA and a factor in Task 2 of the PRP paradigm imply the use of central attention for both all-or-none and capacity sharing models. However, they do have different implications for how central attention affects processing. If central attention is best characterized by an all-or-none bottleneck model then this implies that processing is postponed and is therefore inconsistent with processing being ballistic. In contrast, one defining characteristic of a capacity sharing model is that resources can be flexibly allocated (e.g., Navon & Miller, 2002). Thus, if central attention is best characterized by a capacity sharing system, this implies that how processing is affected by attention could change under different contexts.

Evidence that central attention behaves as an all-or-none or capacity sharing model does not rule out that central attention can exhibit different characteristics in other contexts. Thus, if processing is postponed in the present context, it may only be slowed in another. This is because an all-or-none bottleneck is only a special case of a capacity sharing model in which processing is assigned entirely to one process and then to another. However, evidence that a process *can be postponed* is inconsistent with that process being ballistic because the defining characteristic of a ballistic process is that it *cannot* be stopped or postponed.

Examining Task 1 performance can discriminate between all-or-none and capacity sharing accounts of the processing bottleneck. One prediction made by capacity sharing models is that reaction times to Task 1 should *increase* as the SOA between tasks decreases. This increase arises because when Task 2 begins using central attention, less processing capacity is available for Task 1. All-or-none models of the processing bottleneck do not predict this RT1 increase (Navon & Miller, 2002; Tombu & Jolicoeur, 2003).

Although reaction times decreased with decreasing SOA in each of Experiments 1 - 4, inconsistent with capacity sharing, interpretation of these data is hindered by speed accuracy trade-offs. One possible interpretation is that subjects were either grouping their responses at the long SOA or waiting until the Task 2 stimulus appeared before responding. If this were the case, then the Task 1 data does not discriminate between these accounts. If Task 1 responses are being grouped with Task 2 at the long SOA then the distribution of Task 1 RTs in this condition should be either bi-modal or positively skewed. As can be seen in Figure 8, there is some evidence that the distributions of RTs are different at the short and long SOAs. The next experiment more closely examines whether the processing bottleneck is acting as an all-or-none or capacity sharing system.

Figure 8: The Frequency Distribution of Task 1 RTs from Experiments 3 and 4 at the short and long SOAs



Experiment 6

The purpose of Experiment 6 was to assess whether the process(es) that underlie assembled phonology share central attention with Task 1, or are functionally postponed until central attention become available. This is assessed by examining Task 1 RTs. An increase in Task 1 RT with decreasing SOA is consistent with assembled phonological recoding sharing central attention with Task 1 (Navon & Miller, 2002; Tombu & Jolicoeur, 2003).

In Experiments 1 - 5, reaction time estimates at the long SOA for Task 1 appeared to be affected by participants grouping Task 1 responses with the onset of the Task 2 stimulus. This renders it difficult to assess whether central attention is being shared between Task 1 and Task 2, or behaving like an all-or none bottleneck. To avoid this problem, a third SOA (250 ms) was added. By hypothesis, grouping Task 1 responses with Task 2 should be less likely at such a short SOA. A new set of stimuli are used to increase the generalizability of the additive effects of length/graphemic complexity with SOA as seen in Experiment 2.

Method

Subjects

Thirty-nine undergraduate students from the University of Waterloo were each paid $4.00 to participate in the Experiment. All individuals reported normal or corrected-to-normal vision and were native English speakers.

Stimuli

The stimuli consist of 63 short *basic* nonwords (4 letters long) and 63 long *complex* nonwords (6 letters long) matched for onsets and neighborhood density. The stimuli can be seen in Appendix 5.

Procedure

The procedure was identical to Experiments 1 – 5 except that the present experiment uses 3 SOAs (50, 250, and 750 ms).

Results

The RT data from Experiment 6 can be seen in Figure 9 and the error data can be seen in Table 7. As in previous experiments, trials in which there was an incorrect response in Task 1, or an incorrect pronunciation or voice key failure were removed prior to the RT analysis. This resulted in the removal of 12.7% of the data. Outlier analysis resulted in the removal of 2.7% of the remaining RT data due to outliers in Task 1 and an additional 2.1% of the remaining RT data due to outliers in Task 2.

Task 1: Tone Discrimination

Analysis of the RT data revealed that as SOA decreased, RT decreased, $F_1(2, 76) = 17.5$, $p < .001$, $MSE = 12634$, $F_2(2, 124) = 15.5$, $p < .001$, $MSE = 26241$. Slower responses were made to the tone when long complex nonwords relative to short basic nonwords were named in Task 2, $F_1(2, 76) = 4.3$, $p < .05$, $MSE = 4748$, $F_2(2, 124) = 15.3$, $p < .001$, $MSE = 4899$. There was no interaction between SOA and letter length/ complexity ($Fs < 1.2$).

Figure 9: Mean Reaction Time (ms) in Experiment 6 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of nonword letter length/graphemic complexity and SOA.

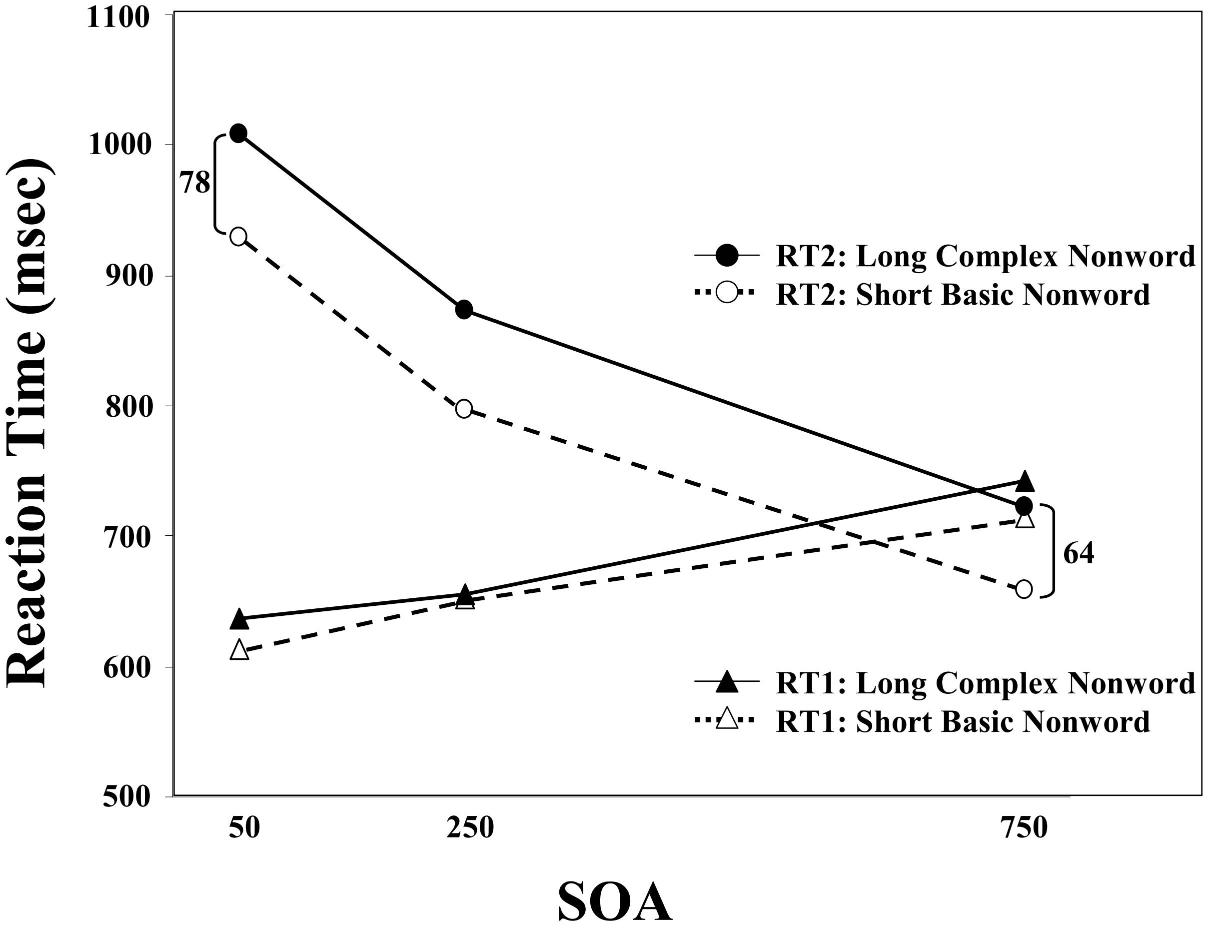


Table 7: Percent Error (%E) in Experiment 6 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of nonword letter length/ complexity and SOA.

	SOA		
	50	**250**	**750**
Task 1: Tone Identification	%E	%E	%E
Long Complex Nonwords	3.8	3.1	2.2
Short Basic Nonwords	4.0	3.1	1.9
Task 2: Nonword Naming			
Long Complex Nonwords	10.2	8.1	7.3
Short Basic Nonwords	6.5	7.6	7.1

Analysis of the error data revealed that as SOA decreased, errors increased, $F_1(2, 76) = 4.8$, $p < .05$, $MSE = 14.9$, $F_2(2, 124) = 6.0$, $p < .01$, $MSE = 208$. No other effects were significant (Fs < 1).

Planned comparisons of Task 1 performance at the 50 and 250 msec SOAs were conducted to discriminate between capacity sharing and postponement accounts of assembled phonology. Contrary to the predictions of the capacity sharing account, RT decreased as SOA decreased, $F_1(1, 38) = 5.7$, $p < .05$, $MSE = 5418$, $F_2(1, 62) = 3.2$, $p < .10$, $MSE = 19867$. There was no effect of SOA on errors, $\underline{F}_1(1, 38) = 1.4$, $p > .10$, $MSE = 18.5$, $F_2(1, 62) = 1.7$, $p > .10$, $MSE = 23.2$. These results are *inconsistent* with phonological recoding *sharing* central attention with Task 1.

Task 2: Naming

Analysis of the RT data revealed that as SOA decreased, RT increased, $F_1(2, 76) = 276.9$, $p < .001$, $MSE = 5467$, $F_2(2, 124) = 219.5$, $p < .001$, $MSE = 10793$. Long complex nonwords took longer to name than short basic nonwords, $F_1(2, 76) = 44.6$, $p < .001$, $MSE = 7074$, $F_2(2, 124) = 66.5$, $p < .001$, $MSE = 8665$. Critically, and as seen in both Experiments 1 and 2, there was no interaction between SOA and letter length/graphemic complexity in Experiment 6 (Fs < 1).

Analysis of the error data revealed no effect of SOA (Fs < 1). There was no difference in the number of errors made to long complex nonwords and short basic nonwords, $F_1(2, 76) = 2.0$, $p > .10$, $MSE = 66.2$, $F_2(2, 124) = 1.2$, $p > .10$, $MSE = 163.2$. There was no interaction between SOA and nonword letter length/complexity, $F_1(2, 76) = 1.7$, $p > .10$, $MSE = 43.2.4$, $F_2(2, 124) = 2.2$, $p > .10$, $MSE = 55.0$.

Discussion

Once again, SOA and factors affecting assembled phonological recoding yielded additive effects in Task 2. This is consistent with the claim that assembled phonological recoding uses central attention. Further, the observation that Task 1 RTs did not increase with decreasing SOA is inconsistent with phonological recoding sharing capacity with Task 1 processes. This suggests that in the present context assembled phonological recoding is functionally postponed until central attention becomes available.

Experiment 7

Here I assess whether the lexical contribution to phonological recoding indexed by the Neighborhood density effect shares central processing capacity with Task 1 or is postponed by an all-or-none bottleneck. If central processing capacity is shared then Task 1 RTs should increase with decreasing SOA.

A new set of stimuli were used in order to increase the generalizability of the additive effects of N and SOA observed in Experiments 3 and 4. As in Experiment 6 a third SOA (250 ms) was added to examine whether Task 1 RTs slow as a function of decreasing SOA. By hypothesis, grouping Task 1 responses with Task 2 should be less likely at such a short SOA.

Method

Subjects

39 undergraduate students from the University of Waterloo were each paid $5.00 to participate in the Experiment. All individuals had normal or corrected-to-normal vision and were native English speakers.

Stimuli

The stimuli consisted of 81 Low N nonwords and 81 high N nonwords matched for onsets and length. The stimuli can be seen in Appendix 6.

Procedure

The procedure was identical to Experiments 6.

Results

The RT data from Experiment 7 can be seen in Figure 10 and the error data can be seen in Table 8. As in the previous experiments, trials in which there was an incorrect response in Task 1, or an incorrect pronunciation or voice key failure were removed prior to the RT analysis. This resulted in the removal of 12.2% of the data. Outlier analysis resulted in the removal of 2.9% of the remaining RT data due to outliers in Task 1 and an additional 1.6% of the remaining RT data due to outliers in Task 2.

Task 1: Tone Discrimination

Analysis of the RT data revealed that as SOA decreased, RT decreased, $F_1(2, 76) = 18.6$, $p < .001$, $MSE = 7633$, $F_2(2, 320) = 53.6$, $p < .001$, $MSE = 963$. There was no effect of N, $F_1 < 1$, $F_2(1, 160) = 2.4$, $p > .10$, $MSE = 4521$. There was no interaction between SOA and N (Fs < 1).

Analysis of the error data revealed that as SOA decreased, errors increased, $F_1(2, 76) = 3.8$, $p < .05$, $MSE = 9.0$, $F_2(2, 320) = 4.8$, $p < .01$, $MSE = 17.6$. There was no effect of N, $F_1(1, 38) = 1.8$, $p > .10$, $MSE = 6.3$, $F_2 < 1$. No other effects were significant (Fs < 1).

Figure 10: Mean Reaction Time (ms) in Experiment 6 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of neighborhood density and SOA.

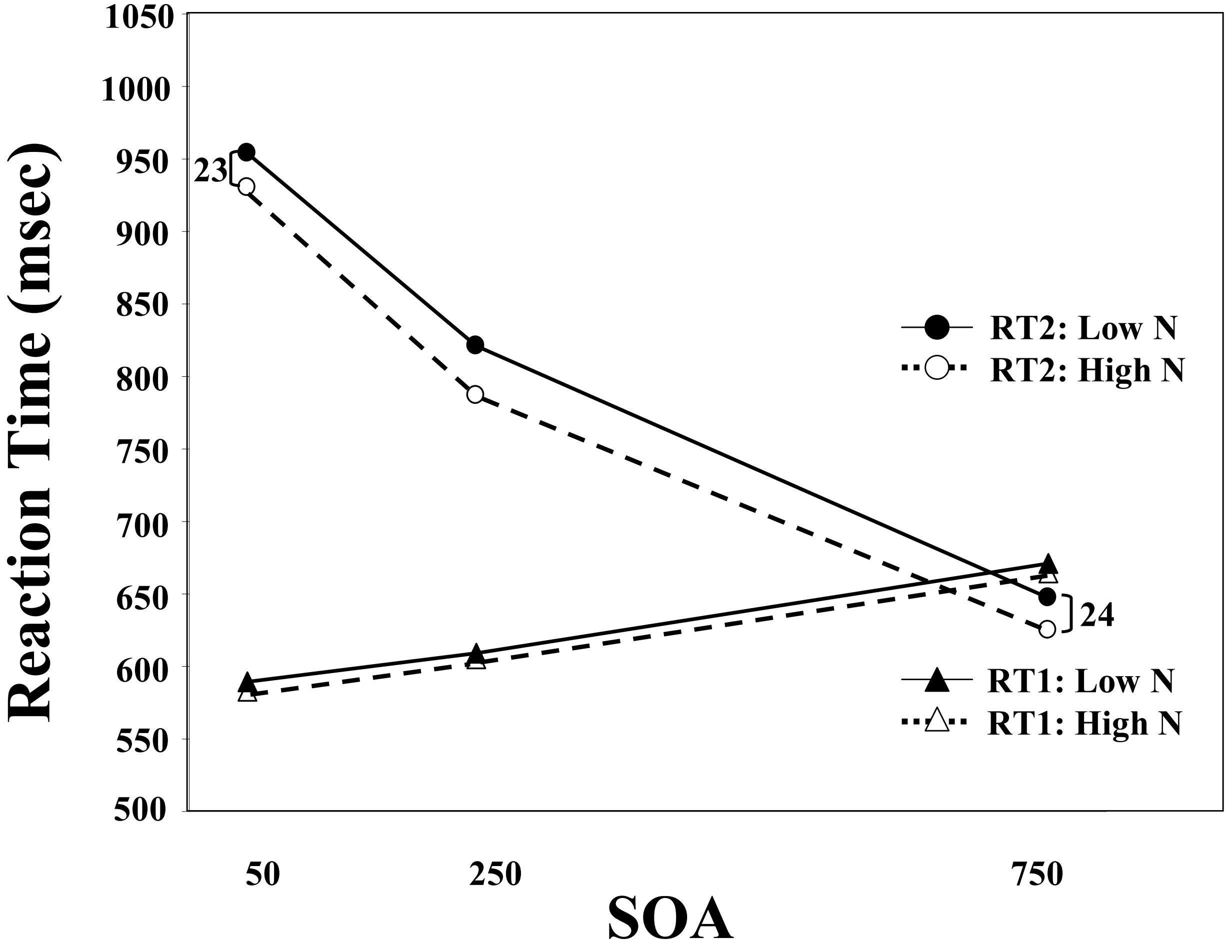


Table 8: Percent Error (%E) in Experiment 7 for Tone Identification (Task 1) and Nonword Naming (Task 2) as a function of Neighbourhood Density and SOA.

	SOA		
	50	**250**	**750**
Task 1: Tone Identification	%E	%E	%E
Sparse Neighbourhood	3.7	2.1	2.6
Dense Neighbourhood	3.0	2.1	2.0
Task 2: Nonword Naming			
Sparse Neighbourhood	6.1	5.5	4.8
Dense Neighbourhood	2.7	4.2	3.3

Task 1 performance was further examined at the 50 and 250 msec SOAs in order to assess whether central attention was functioning as either an all-or-none or capacity sharing system. These SOAs were used to avoid possible response grouping at the long SOA. As SOA decreased, RT decreased, $F_1(1, 38) = 5.5$, $p < .05$ $MSE = 3020$, $F_2(1, 160) = 12.9$, $p < .05$ $MSE = 5921$. However, as SOA decreased, errors increased, $F_1(1, 38) = 9.1$, $p < .05$ $MSE = 6.43$, $F_2(1, 160) = 7.1$, $p < .05$ $MSE = 20.7$.

Once again there was a speed accuracy tradeoff. Efficiency scores were therefore calculated by dividing correct mean RTs for each subject by their percent correct in each cell (Townsend & Ashby, 1983). Inconsistent with subjects sharing central processing capacity, there was no effect of SOA, $F(1, 38) = 1.8$, $p > .10$ $MSE = 3452$.

Task 2: Naming

Analysis of the RT data revealed that as SOA decreased, RT increased, $F_1(2, 76) = 189$, $p < .001$, $MSE = 9663$, $F_2(2, 320) = 496$, $p < .001$, $MSE = 3927$. As N decreased, RT increased, $F_1(1, 38) = 7.6$, $p < .01$, $MSE = 5474$, $F_2(1, 160) = 9.9$, $p < .01$, $MSE = 10404$. Critically, as was also observed in both Experiments 3 and 4, there was no interaction between SOA and neighborhood density (Fs < 1).

Analysis of the error data revealed no effect of SOA (Fs < 1). As N decreased, errors increased, $F_1(1, 38) = 7.8$, $p < .01$, $MSE = 31.8$, $F_2(1, 160) = 7.2$, $p <.01$, $MSE = 74.7$. Critically, there was no interaction between SOA and N, $F_1(2, 76) = 2.1$, $p > .10$, $MSE = 11.7$, $F_2(2, 320) = 1.1$, $p > .10$, $MSE = 39.2$.

Discussion

The purpose of Experiment 7 was to assess whether the lexical contribution to the generation of a phonological code indexed by neighborhood density shares capacity with Task 1 or is postponed by an all-or-none bottleneck. One prediction made by capacity sharing accounts of the processing bottleneck is that it should take longer to respond to Task 1 at the short SOA relative to the long SOA. This increase in Task 1 RTs occurs because reallocating a portion of the processing capacity to Task 2 increases the duration of the anonymous processes in Task 1 that use central attention. Inconsistent with the lexical processes indexed by neighborhood density sharing processing sharing capacity with Task 1, the SOA effect in Task 1 did not increase as SOA decreased. In the present context this suggests that processing in Task 2 was postponed until some anonymous process in Task 1 was finished.

In addition, Task 2 data yielded additive effects of neighborhood density and SOA, consistent with lexical phonological processing using central attention. This extends the generalizability of this effect.

Conclusions

The purpose of Part 2 was to move beyond asking whether processing is or is not automatic by asking more specific questions about how processing unfolds. Experiment 5 assessed whether *some* lexical processing occurs prior to central attention. Long-term repetition priming, which affects processing in (at least) the Orthographic Input Lexicon (e.g., Scarborough et al., 1977; Clarke & Morton, 1983; Visser & Besner, 2001), yielded partially underadditive effects with decreasing SOA. This suggests that representations in the orthographic lexicon and prior processes (such as feature and letter level processes) are activated without central attention. The fact that long-term repetition priming produces such an interaction with SOA is inconsistent with the claim that *all* lexical processing uses attention.

Experiments 6 and 7 assessed whether the sublexical and lexical contributions to phonology examined in Experiments 1 – 4 share capacity with Task 1 or are postponed until resources become available. Inconsistent with resources being shared between the two tasks, Task 1 RTs did not increase with decreasing SOA. This suggests that these processes were postponed until central attention became available, inconsistent with these processes being ballistic.

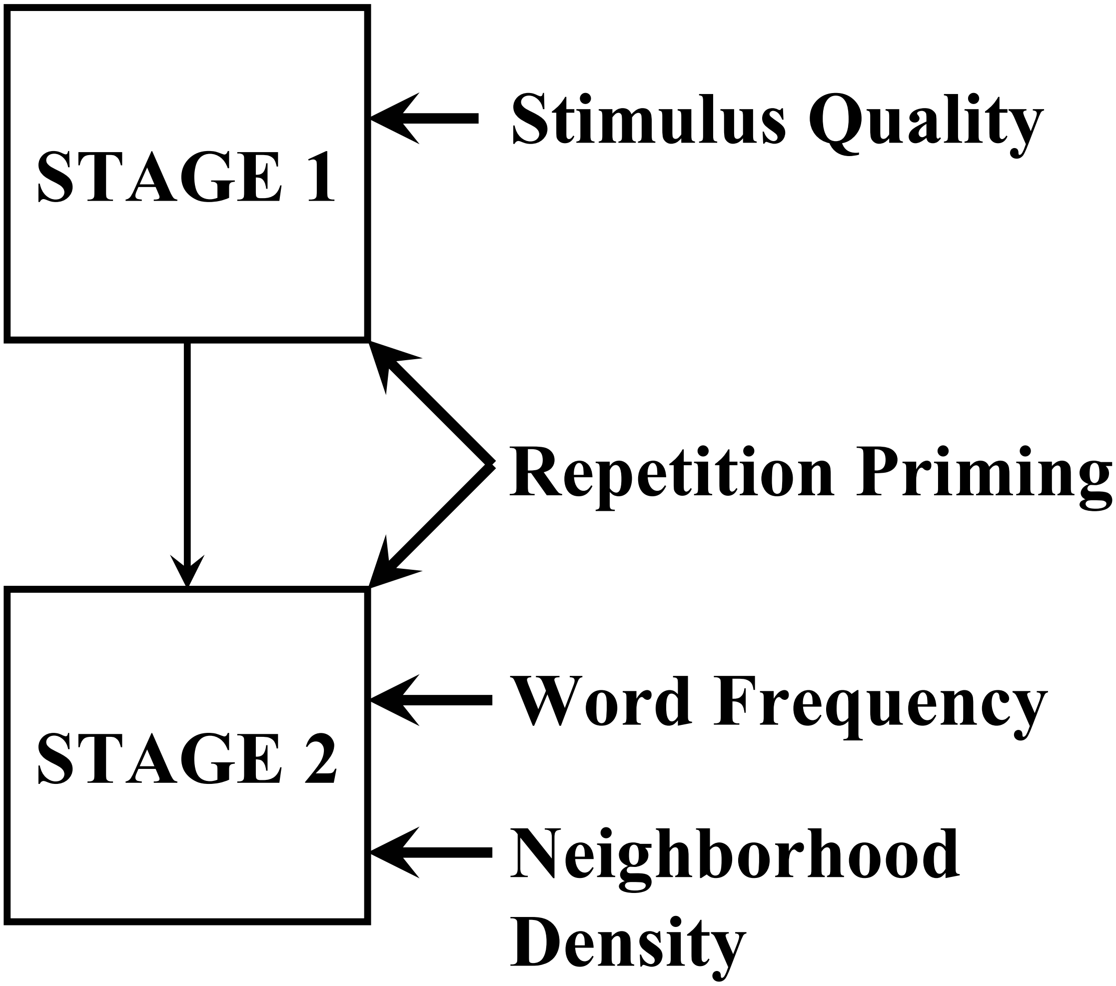
General Discussion

The focus of the experiments in Part 1 was on assessing whether phonological recoding occurs automatically. Inconsistent with such an account, all four experiments indicated that at least some components of the sublexical and lexical contributions to phonology use central attention. The focus of the experiments in Part 2 was on more specific investigations of the nature of these processes. For instance, Experiment 5 demonstrated that at least some lexical processing does not require central attention. And Experiments 6 and 7 suggested that in the present context, some sublexical and lexical contributions to phonological recoding were postponed by an all-or-none bottleneck.

So far, the outcomes of Experiments 1 – 7 have been interpreted in terms of whether processing uses central attention. However, these data can also be understood in terms of a multi-stage model of lexical processing that is supported by other high order interactions reported in the literature; namely, the joint effects of stimulus quality, word frequency, and repetition (see Figure 11). Repetition priming interacts with word frequency in naming and lexical decision (Forster & Davis, 1984; Norris, 1984; Scarborough et al., 1977; Visser & Besner, 2001) and repetition priming interacts with stimulus quality (Besner & Swan, 1982; Norris, 1984). However, stimulus quality and word frequency produce additive effects in lexical decision and naming (e.g., Balota & Abrams, 1995; Borowsky & Besner, 1993; Plourde & Besner, 1997; Herdman, Chernecki, & Norris, 1999; Stanners, Jastrzembski & Westbrook, 1975). This suggests that repetition priming affects processing at (at least) two distinct loci; one affected by stimulus quality and one affected by word frequency. The additive effects of neighborhood density and stimulus quality (Reynolds & Besner, 2004) and the interaction between neighborhood density and word frequency (Andrews, 1992) are consistent with neighbors affecting only the late(r) stage of processing indexed by word frequency (Reynolds & Besner, 2004).

A similar pattern is observed in the PRP paradigm. The observation that stimulus quality effects in Task 2 are underadditive with SOA (e.g., Pashler & Johnston, 1989), whereas the word frequency effect is additive with SOA (McCann et al., 2000)[4], is consistent with the claim that stimulus quality and word frequency index separate processes. Further, the observation that repetition priming which is known to interact with stimulus quality goes at least partially underadditive with decreasing SOA is consistent with stimulus quality and repetition both affecting the same early stage of processing. Similarly, the additive effects of neighborhood density with both stimulus quality and SOA are consistent with neighborhood density affecting a late stage of processing.

Figure 11: Two-Stage model of processing illustrating the joint effects of repetition priming, stimulus quality, word frequency and neighborhood density. (I have no commitment as to whether processing is discrete or cascaded).



One response to McCann et al.'s claim that central attention is necessary for visual word recognition has been to argue that attention is necessary for lexical activation when a linguistic stimulus is being attended (e.g., Brown et al., 2002). The observation that long term repetition priming goes underadditive with SOA is inconsistent with this claim. because it suggests that some lexical processing occurs without being affected by central attention – even when the task encourages attending to a linguistic stimulus.

It is possible to map this two-stage model onto the Dual Route architecture (see Figures 1, 11 and 12). In these terms, processing up to and including the Orthographic Input Lexicon would constitute an 'early' stage of processing that does not require central attention (though it has been argued that such processing requires *spatial* attention – see Besner, Risko, & Sklair, 2005; Lachter, Forster, & Ruthruff, 2004; McCann, Folk, & Johnston, 1992; Stolz & McCann, 2000; Stolz & Stevanovski, 2004). Processes that occur after the activation of representations in the Orthographic Input Lexicon including the activation of semantics and representations in the phonological output lexicon constitute (at least) a late stage of processing that uses central attention [though there are no experiments (yet) that have examined whether a semantic factor (e.g., imageability) is additive with SOA in the context of the PRP paradigm].

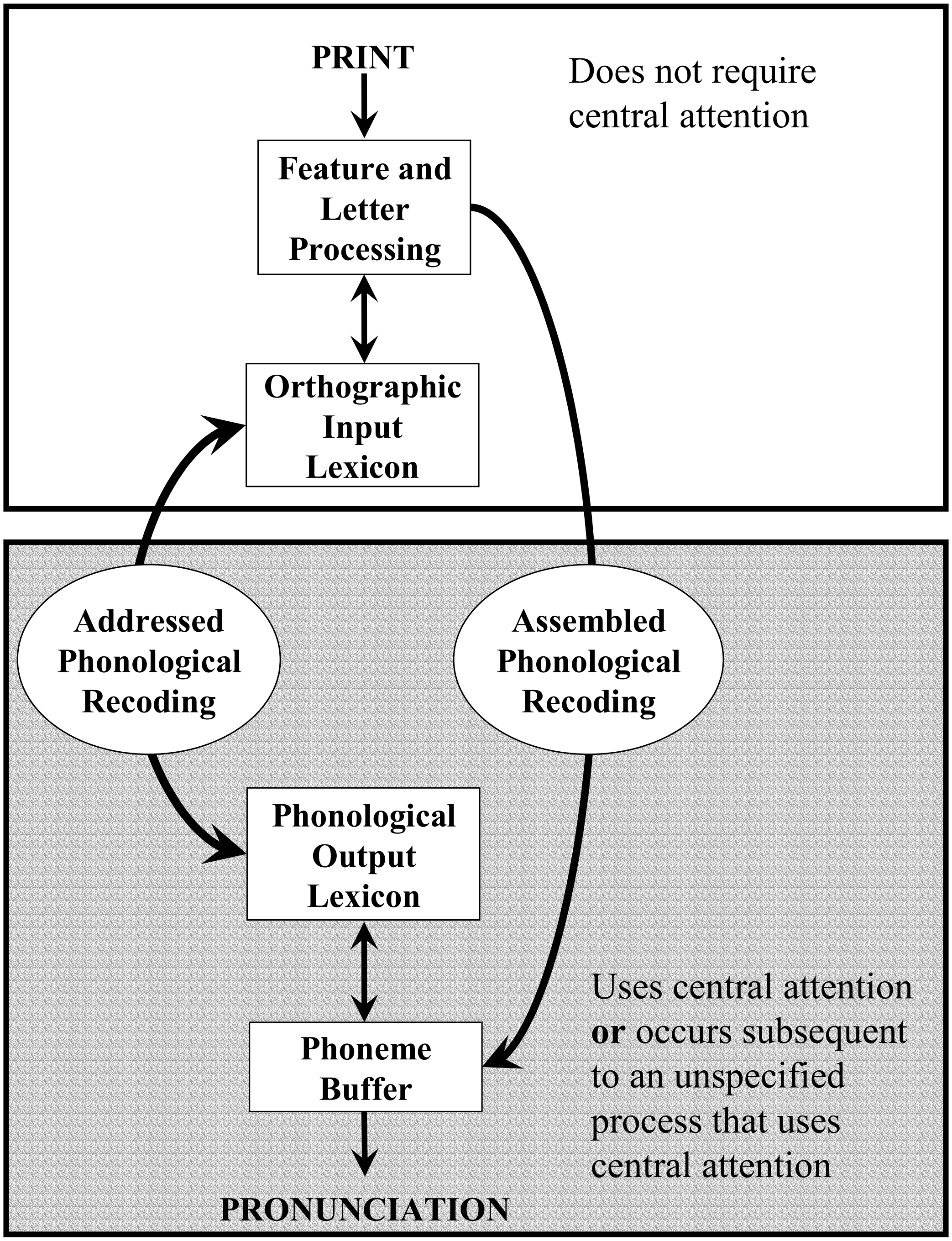
The Locus of the Word Frequency Effect

The observation that SOA and long-term repetition priming yielded underadditive effects in Experiment 1 suggests that processing up to and including the Orthographic Input Lexicon does not require central attention. Given this, if word frequency affects processing in the orthographic lexicon, then word frequency should also yield underadditive effects with decreasing SOA. McCann et al.'s observation that word frequency has additive (rather than underadditive) effects with SOA is consistent with word frequency indexing some post input-lexical process that uses central attention (provided no unspecified prior stage uses central attention). This is consistent with Besner and colleagues' hypothesis that word frequency does not affect processing within the orthographic and phonological lexicons themselves, but instead affects the mapping between representations in the orthographic and phonological lexicons and between these lexicons and semantics (Besner, 1999; Besner & Smith, 1992; Borowsky & Besner, 1993; McCann & Besner, 1987; Reynolds & Besner, 2004).

The Locus of the Neighborhood Density Effect

The results of the present experiments also address how neighborhood density affects reading aloud. For instance, one account of neighborhood density effects in lexical decision and reading aloud is that they arise through interactive activation between the orthographic input lexicon and letter level processing (Andrews, 1992; Sears et al., 1995). The outcomes of the present studies are hard to reconcile with such an account. The underadditive interaction between long-term repetition priming and SOA observed in Experiment 5 suggest that representations in the orthographic lexicon are activated prior to the effect of central attention. In contrast, the additive effects of neighborhood density and SOA observed in Experiments 2, 3, and 7 suggest that neighborhood density affects performance has its effects at or after the central attention. This implies that neighborhood density has its effects late in processing. This is consistent with claim that the neighborhood density effect arises via the activation of entries in the phonological output lexicon directly from representations in the

Figure 12: A Dual Route model of reading aloud illustrating the influence of central attention.



orthographic lexicon (Coltheart et al., 2001; Peereman & Content, 1995; Reynolds & Besner, 2004).

Single vs. Dual Route models of Phonological Computation

One major issue in visual word recognition is how lexical representations are activated. In Dual Route models, lexical representations can be activated either directly from an orthographic code, or indirectly after a phonological code is assembled by the sublexical route (e.g., Coltheart et al., 2001). Another possibility is that phonology is computed *before* lexical activation (e.g., Frost, 1998; Gronau & Frost, 1997; Frost & Yogev, 2001; Lukatela & Turvey, 1990; 1994a, 1994b; Perfetti, Bell, &Delaney, 1988). The latter account is inconsistent with the results of the present experiments. As noted above, the underadditive interaction between long-term repetition priming (which affects the time to respond to words but not nonwords; cf., Scarborough et al., 1977) and SOA suggests at least some lexical representations are activated prior to central attention. In contrast, the additive effects of nonword length and graphemic complexity with SOA suggest that the sublexical computation of a phonological code occurs at or after a stage of processing affected by central attention. Thus the results of the present experiments suggest that at least orthographic lexical representations are activated prior to the computation of phonology.

Attention and Control

A concern raised in the introduction was that models of visual word recognition and reading aloud are encapsulated, autonomous systems that do not specify a role for attention. The present findings, understood in the context of a simple structural bottleneck model (e.g., Pashler, 1984; 1994), add to a growing number of studies demonstrating a critical role for attention in reading. The present research contributes to this literature by identifying a locus at which central attention has its effects and by demonstrating that one role attention may play is functionally postponing processes until resources become available.

Yet, recent theories of multi-task performance suggest that central attention plays a far greater role than simple bottleneck models suppose. For instance, it has been argued that central attention coordinates Task 1 and Task 2 performance by creating and implementing task sets (Logan & Gordon, 2001; Meyer & Kieras, 1997). Task sets are conceptualized as the set of processes required to perform a task. For instance, Logan and Gordon (2001) implement task sets by changing parameters associated with importance of selecting a stimulus, the relevance of different response categories, the number of stimulus features that are captured, and resetting evidence collectors.

Logan and Gordon (2001) do not include perceptual processing prior to stimulus categorization (e.g., the similarity between a stimulus [e.g., the word "cat"] and a category in long term memory [e.g., that something is a word] as part of the task set. Here I argue that, at least in the context of visual word recognition, an additional role for central attention is creating and maintaining this similarity by creating and maintaining the functional architecture of the reading system.

Consistent with this idea is the correlation between the locus of the central attention bottleneck and the locus at which a number of contextual factors affect reading performance. As discussed above, the pattern of underadditive and additive effects of psycholinguistic factors and SOA in Task 2 of the PRP paradigm suggest that central attention affects performance after letter processing, but prior to (or during) the translation of an orthographic code into phonology or semantics.

Similarly, a number of contextual factors that modulate performance in visual word recognition and reading aloud have been interpreted has having a similar locus (e.g., Brown & Besner, 2002; Reynolds & Besner, 2004; 2005; Smith & Besner, 2001; Stolz & Neely, 1995). For instance, Stolz and Neely (1995) argued that in semantic priming the ratio of related (e.g., doctor preceded by nurse) and unrelated (e.g., doctor preceded by cat) trials determines whether semantic information feeds backwards through the system to facilitate word identification. They based this account on the observation that the when prime relatedness and stimulus quality are factorially manipulated, the effect of stimulus quality was smaller on related trials than on unrelated trials when the ratio of related to unrelated trials was high. In contrast, when the ratio of related to unrelated trials was low, the effect of stimulus quality was the additive with relatedness. Additional evidence comes from studies that have examined the impact of searching the prime word for a letter. Consistent with central attention modulating the functional architecture of the reading system after letter identification but prior to the activation of phonology or semantics, performing letter search on the prime eliminates semantic and phonological priming, but not morphological priming (Ferguson & Besner, submitted; Stolz & Besner, 1998).

This evidence for control suggests that the reading system is modular in nature. Additional evidence for this claim comes from the double dissociation between phonological (Funnel, 1983) and surface dyslexia (Coltheart, Byng, Masterson, Prior, & Riddoch, 1983). Phonological dyslexics are able to read aloud exception words correctly (e.g., pint) but not nonwords (e.g., zint), whereas surface dyslexics are able to read aloud nonwords correctly but have difficulty with low frequency exception words. This suggests that there are separate sublexical and lexical systems (modules) for computing phonological codes (e.g., Coltheart et al., 2001; Morton & Patterson, 1980).

A question that frequently arises with respect to modular systems is how they are bound together; a concern that is punctuated in the present context by the observation that how these modules are bound together is mediated by contextual factors. Given the correlation between the locus of contextual and central attention effects on reading performance, I propose that one role of attention (for lack of a better word) is to bind modular subsystems so as to allow (seemingly) seamless performance (see Logan, 1978 for a related claim).

Conclusions

The idea that phonological recoding in reading reflects a set of automatic processes which are ballistic and do not use central attention (as defined here) has a long and deep history. In contrast, the results of the present experiments suggest that many (but not all) aspects of phonological recoding use central attention, are affected by other ongoing mental events, and can be functionally postponed. It is my contention that theoretical development in this field (and others) will likely be facilitated by recognizing and abandoning our obsession with the idea that skilled performance inevitably means that all the underlying processes are automatic.

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Footnotes

1. Assuming 11 different characteristics there are 2047 different possible definitions of "automatic".
2. One issue concerns whether the processing bottleneck is strategic (Meyers & Kieras, 1997), structural (Pashler, 1994; McCann & Johnston, 1995), or some combination of both (Logan & Gordon, 2001). This is an important issue, but does not affect the interpretability of the present experiments with respect to automaticity. In both cases, demonstrating that Task 1 affects phonological recoding is inconsistent with the claim that generating a phonological code occurs without interference from other processes. I return to this issue in more detail in the general discussion.
3. An interesting contrast to the results from Experiment 5 can be found in Carrier and Pashler (1995) who investigated whether retrieval from episodic memory uses central capacity. Participants were exposed to a list of words auditorially and then made explicit old/new judgments to visually presented words in the context of the PRP paradigm. Carrier and Pashler (1995) reported additive effects of old/new and SOA. It is unclear at present why the two procedures produce qualitatively different results, but my conjecture is that the explicitness of old/new judgments bottlenecks performance.
4. McCann et al. (2000) report that word frequency and SOA are additive factors in 6 experiments. However, there has been one recent report of a partially underadditive interaction between SOA and word frequency with visually presented stimuli (Cleland, Gaskell, Quinlan, & Tamminen, 2005). That said, there are a number of odd aspects to their work: (1) there is an abnormally large frequency effect at the long

SOA (127 msec), (2) there was an unusually large number of errors (15%) for the low frequency words, (3) participants took longer classifying the low frequency words than nonwords, and (4) it appears as though lexicality had additive effects with decreasing SOA (28, 18, & 26 msec at the 100, 200, & 800 msec SOAs respectively). It may be that the underadditive interaction these authors report is a consequence of their use of a box procedure for removing outliers (observations were excluded if the time to respond was less than 150 msec or greater than 3000 msec). This could result in the exclusion of proportionately more responses for low frequency words at the short SOA (the slowest condition) than at the long SOA. An additional possibility is that at the long SOA the errors reflect slow guessing, but at the short SOA they reflect fast guessing. In this scenario there are as many correct guesses as errors at the short SOA and hence enough fast correct guesses to produce the small underadditive interaction of word frequency and SOA.

Appendices

Appendix A

Participant Data from Experiment 1

	Task 1: Tone Identification							
	Short SOA (50 msec)				Long SOA (750 msec)			
	Short		Long		Short		Long	
Subject	RT	%E	RT	%E	RT	%E	RT	%E
1	370	8	387	0	443	8	418	8
2	802	7	690	21	1031	14	1158	21
3	473	0	455	8	506	0	434	0
4	386	7	370	0	422	0	409	7
5	407	0	468	8	459	0	540	7
6	362	14	398	0	502	0	459	0
7	669	0	701	0	735	0	820	0
8	525	0	658	0	554	0	534	0
9	514	0	465	0	490	0	474	0
10	498	0	557	0	578	0	555	0
11	663	0	615	0	624	0	652	0
12	613	0	589	7	794	0	848	0
13	930	8	851	0	1020	0	994	0
14	745	7	598	0	646	0	660	0
15	481	0	526	7	631	0	577	0
16	630	0	670	0	595	0	541	0
17	345	8	308	7	386	0	375	7
18	565	0	490	14	626	0	560	7
19	692	0	704	0	724	0	640	0
20	386	0	425	21	419	0	484	0
21	846	8	741	0	827	0	785	0
22	372	0	368	0	403	0	419	0
23	501	0	502	0	519	0	472	0
24	563	0	589	0	604	0	607	0
25	517	0	512	0	568	0	606	0
26	483	0	522	0	480	7	486	7
27	711	0	597	0	653	0	740	0
28	521	0	611	0	647	0	613	0
29	468	14	509	23	725	0	710	8
30	850	0	873	0	892	0	846	0
31	491	0	482	0	555	0	475	0

Appendix A (continued)

Participant Data from Experiment 1

	Task 1: Tone Identification							
	Short SOA (50 msec)				Long SOA (750 msec)			
	Short		Long		Short		Long	
Subject	RT	%E	RT	%E	RT	%E	RT	%E
32	356	0	356	15	376	0	398	0
33	491	8	398	14	570	0	527	14
34	523	0	562	0	533	0	537	0
35	620	7	518	0	657	7	627	0
36	546	0	619	0	763	0	717	0
37	572	0	620	0	452	0	538	0
38	440	0	473	0	428	0	463	15
39	456	0	475	7	455	0	429	0
40	569	15	644	0	534	0	582	7
41	531	8	615	8	761	7	742	0
42	578	0	565	0	549	0	598	0
43	506	0	430	0	598	0	507	0
44	549	0	514	0	524	0	514	0
45	735	0	666	0	662	0	653	8
46	385	0	410	7	397	0	421	0
47	388	0	389	8	415	0	364	0
48	510	0	555	0	548	0	575	0
49	457	14	549	7	447	14	436	7
50	327	0	336	0	354	0	366	0
51	387	7	379	0	390	0	424	0
52	417	0	406	0	402	0	447	0
53	515	0	503	0	548	0	533	0
54	551	0	586	0	616	0	658	0
55	401	0	374	7	473	0	381	7
56	583	7	574	0	530	7	573	0
57	590	0	543	8	502	15	579	14
58	619	0	530	0	697	0	680	0
59	539	0	462	0	442	0	459	7
60	395	7	359	0	433	0	421	0
61	416	0	434	0	483	0	456	0
62	509	7	579	0	508	0	529	0

Appendix A (continued)

Participant Data from Experiment 1

	Task 2: Nonword Naming							
	Short SOA (50 msec)				Long SOA (750 msec)			
	Short		Long		Short		Long	
Subject	RT	%E	RT	%E	RT	%E	RT	%E
1	832	0	837	8	627	8	636	8
2	1033	0	954	0	679	0	714	7
3	803	0	776	8	468	0	520	7
4	755	0	826	0	553	0	561	7
5	863	0	953	8	630	0	624	7
6	646	0	678	14	484	0	475	0
7	1268	0	1263	0	875	0	872	0
8	850	0	1026	0	619	0	590	8
9	764	0	704	7	527	0	462	8
10	843	0	905	0	672	0	663	0
11	961	0	1069	7	649	0	725	0
12	1006	14	945	0	692	7	754	0
13	1267	0	1271	7	694	0	723	0
14	1015	14	932	14	709	0	668	8
15	944	0	1067	0	543	0	597	7
16	903	0	998	0	597	7	647	0
17	752	0	712	7	565	0	586	0
18	984	0	930	7	708	14	724	0
19	1235	0	1250	0	884	0	863	0
20	593	0	632	7	457	0	471	0
21	1151	0	1103	8	666	0	650	0
22	751	7	802	0	485	0	486	0
23	899	0	861	14	640	0	643	0
24	961	0	988	0	510	0	531	7
25	1054	0	1050	0	785	0	834	0
26	700	0	794	7	470	0	485	0
27	983	8	922	0	598	0	716	14
28	999	0	1139	0	736	0	813	0
29	650	7	632	23	521	0	562	23
30	1135	0	1224	14	699	0	829	7
31	828	0	861	0	660	0	608	0

Appendix A (continued)

Participant Data from Experiment 1

	Task 2: Nonword Naming							
	Short SOA (50 msec)				Long SOA (750 msec)			
	Short		Long		Short		Long	
Subject	RT	%E	RT	%E	RT	%E	RT	%E
32	646	0	632	0	557	0	544	0
33	855	0	724	0	703	0	652	7
34	1291	0	1373	0	877	0	835	7
35	892	0	808	7	533	0	543	0
36	898	0	964	0	544	8	564	0
37	929	15	861	7	595	0	654	0
38	872	0	896	0	558	0	531	0
39	764	0	795	0	605	7	697	7
40	989	0	1121	0	568	0	556	0
41	885	8	898	0	659	0	656	0
42	1005	0	1027	0	759	7	801	0
43	734	0	709	15	532	0	553	0
44	1116	0	1120	0	540	0	595	0
45	1315	8	1189	0	772	0	777	0
46	839	0	880	0	578	0	588	0
47	912	0	901	0	696	0	710	0
48	920	0	1029	7	742	0	801	0
49	845	0	903	7	524	0	510	0
50	608	0	621	0	452	0	438	0
51	801	0	777	0	598	14	591	0
52	822	0	838	0	590	0	562	0
53	899	0	896	0	585	0	594	8
54	988	0	981	0	618	0	606	0
55	716	0	716	0	568	0	541	0
56	1124	0	1108	0	683	7	722	0
57	940	0	922	0	621	0	668	0
58	830	0	763	0	590	0	655	0
59	977	0	925	0	644	0	713	7
60	633	0	573	0	452	0	421	0
61	837	0	863	0	520	0	512	0
62	835	0	1024	0	708	8	811	15

Appendix B

Item Data from Experiment 1

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	letter length	RT	%E	RT	%E	RT	%E	RT	%E
dra	short	579	3	568	0	907	0	602	0
fla	short	516	3	578	0	933	0	585	0
kal	short	506	0	602	0	910	0	640	3
plu	short	474	3	568	0	841	0	592	0
pru	short	558	3	545	3	923	0	575	0
sko	short	520	3	503	0	864	0	570	0
sma	short	547	6	579	0	861	0	580	0
spo	short	545	4	550	3	865	0	599	0
twa	short	551	3	567	0	911	0	607	0
zof	short	528	6	566	0	919	0	623	0
bleg	short	575	3	563	3	913	3	595	0
blic	short	546	3	596	3	932	3	631	0
cril	short	527	0	620	9	954	0	667	0
drek	short	504	7	570	3	870	0	575	0
drob	short	529	0	543	3	939	0	587	3
flif	short	529	3	528	0	914	3	652	3
flis	short	564	0	515	0	1016	3	709	3
frev	short	541	0	564	0	947	0	647	6
frin	short	536	3	535	0	933	0	621	0
grys	short	540	3	548	0	1043	7	700	10
kolf	short	521	3	577	3	938	3	662	0
preb	short	514	9	589	0	911	0	633	0
sneb	short	564	0	601	6	913	0	626	0
stiv	short	522	3	589	0	839	3	633	3
stol	short	520	3	576	0	829	0	561	9
twag	short	513	0	568	7	852	0	571	0
twon	short	519	3	638	6	912	9	650	0
zics	short	511	3	576	3	927	3	654	0

Appendix B (continued)

Item Data from Experiment 1

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	letter length	RT	%E	RT	%E	RT	%E	RT	%E
dralf	long	535	9	573	0	986	13	703	3
fleft	long	541	6	521	0	980	3	652	6
kacts	long	525	0	549	0	915	0	674	3
plept	long	496	0	584	0	881	3	654	3
practs	long	532	7	577	3	905	0	617	0
scost	long	520	3	563	0	909	6	675	3
smast	long	544	3	583	0	919	0	576	0
spolts	long	537	3	538	6	974	7	609	18
twept	long	580	6	605	0	943	3	633	6
zolks	long	529	3	558	0	910	0	619	3
bleds	long	496	6	553	3	906	6	602	0
blemps	long	582	3	605	9	991	0	635	0
crask	long	536	6	578	3	933	0	621	0
drapt	long	515	0	604	6	892	0	585	0
drists	long	559	3	497	3	936	3	630	0
flents	long	522	6	559	0	926	0	668	0
flist	long	477	10	618	6	956	3	651	0
frast	long	497	3	584	3	895	0	614	0
frolts	long	547	3	563	0	965	0	667	6
gropts	long	561	0	567	0	958	13	676	3
kolfs	long	536	9	610	3	943	3	719	10
pramps	long	554	0	537	3	950	0	615	0
snept	long	524	3	567	3	871	6	578	3
stasks	long	480	0	587	6	926	26	626	15
stonds	long	507	3	576	0	869	0	588	0
twilt	long	544	6	530	0	910	0	576	0
twumps	long	536	0	536	3	963	0	728	0
zimps	long	550	7	570	3	926	0	636	0

Appendix C

Participant Data from Experiment 2

	Task 1: Tone Identification							
	Short SOA (50 msec)				Long SOA (750 msec)			
	Short/Basic		Long/Complex		Short/Basic		Long/Complex	
Subject	RT	%E	RT	%E	RT	%E	RT	%E
1	930	0	995	0	1129	0	1146	0
2	941	0	849	5	1135	5	950	6
3	587	5	638	0	630	0	615	0
4	887	0	1038	0	1017	0	986	0
5	489	0	523	5	561	0	567	0
6	429	9	419	0	504	5	535	5
7	852	0	794	5	826	0	767	0
8	1131	0	959	0	1120	0	956	5
9	476	0	628	5	588	0	611	0
10	463	32	382	24	445	14	429	5
11	929	0	1051	0	1019	0	1077	0
12	389	14	413	5	526	0	419	0
13	444	14	467	0	477	0	472	14
14	516	5	582	0	503	0	558	0
15	443	0	430	9	551	0	580	0
16	405	0	412	0	422	0	423	0
17	430	10	485	5	422	5	394	5
18	462	0	569	0	598	0	654	0
19	388	5	405	0	412	0	395	0
20	428	5	393	0	423	0	405	0
21	362	9	431	0	439	5	486	10
22	458	0	550	0	618	5	546	0
23	594	0	552	5	539	0	560	0
24	531	0	553	5	701	0	693	0
25	446	5	491	5	664	0	681	5
26	533	0	446	0	453	5	460	0
27	678	0	551	0	566	0	560	0
28	462	0	487	0	456	5	468	0
29	801	0	701	5	779	5	794	0
30	449	0	462	0	469	0	458	0
31	419	5	425	5	407	0	404	0
32	624	0	539	0	555	0	551	0

Appendix C (continued)

Participant Data from Experiment 2

	Task 2: Nonword Naming							
	Short SOA (50 msec)				Long SOA (750 msec)			
	Short/Basic		Long/Complex		Short/Basic		Long/Complex	
Subject	RT	%E	RT	%E	RT	%E	RT	%E
1	1377	0	1427	0	804	0	924	0
2	1218	14	1352	14	1021	10	963	17
3	1005	0	1059	0	676	0	747	0
4	1501	5	1660	0	1013	10	1175	5
5	895	0	1116	5	712	0	848	0
6	673	0	706	0	542	0	553	5
7	1270	0	1247	5	803	0	790	0
8	1581	10	1522	10	1082	5	1092	5
9	836	0	1081	5	505	0	601	0
10	716	5	760	5	650	10	644	14
11	1428	0	1550	0	1016	0	1030	0
12	871	0	1018	0	602	5	595	11
13	825	0	898	5	562	0	572	0
14	962	0	1014	5	669	0	771	5
15	682	0	660	0	496	0	507	0
16	602	0	635	0	461	0	447	0
17	900	0	1021	0	571	0	609	0
18	902	5	1086	0	658	0	717	5
19	782	0	873	5	592	0	624	0
20	827	0	880	0	637	0	622	0
21	859	0	1005	0	633	0	757	0
22	885	0	983	0	578	0	680	0
23	877	5	975	19	660	14	716	0
24	999	0	1067	0	671	0	712	0
25	815	5	852	5	528	10	636	9
26	1037	0	981	5	709	0	856	5
27	1137	0	1059	0	614	0	647	0
28	875	0	928	5	672	0	699	0
29	1270	0	1141	0	764	0	819	0
30	816	0	916	5	596	0	631	0
31	835	9	849	25	645	5	649	12
32	893	0	847	0	544	0	579	0

Appendix D

Item Data from Experiment 2

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	graphemic complexity	RT	%E	RT	%E	RT	%E	RT	%E
blaf	short-basic	547	0	688	6	980	0	729	0
clil	short-basic	608	7	626	6	1051	7	857	0
crem	short-basic	670	13	703	0	1115	0	711	0
glak	short-basic	571	0	539	6	952	0	665	0
grud	short-basic	568	0	632	0	1044	0	696	0
klen	short-basic	498	0	585	6	1008	0	705	0
kred	short-basic	557	0	649	0	1051	0	726	0
plib	short-basic	602	0	529	0	992	0	687	0
plis	short-basic	610	0	602	0	1016	0	698	0
prul	short-basic	581	7	705	0	1000	0	782	6
scuk	short-basic	557	0	589	12	940	0	686	6
slez	short-basic	552	15	739	0	930	8	689	18
smik	short-basic	614	0	615	0	960	0	646	0
spiv	short-basic	623	7	539	0	976	0	607	7
spom	short-basic	585	0	499	0	972	0	652	12
srep	short-basic	583	0	702	6	953	8	694	6
stob	short-basic	591	0	575	0	977	0	645	0
stec	short-basic	562	0	569	0	993	0	641	0
trif	short-basic	607	13	695	0	937	0	718	6
trel	short-basic	572	7	622	6	1039	0	635	0
plic	short-basic	587	0	577	0	1043	0	657	6
snis	short-basic	573	7	554	0	987	0	606	0
bleece	long-complex	542	0	559	12	983	0	719	0
clouse	long-complex	657	7	557	0	1120	0	687	6
creeph	long-complex	594	7	591	0	1111	7	747	7
glough	long-complex	642	0	653	0	1127	0	851	0
groose	long-complex	544	0	605	0	967	8	759	0
klough	long-complex	565	0	624	0	1107	0	779	0
krieve	long-complex	620	8	522	0	1117	0	764	0
plawce	long-complex	587	0	609	0	1066	0	786	18
ploice	long-complex	684	7	622	0	1117	7	793	6
praele	long-complex	584	0	555	0	1029	7	788	0

Appendix D (continued)

Item Data from Experiment 2

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	graphemic complexity	RT	%E	RT	%E	RT	%E	RT	%E
sceeve	long-complex	697	0	474	0	1149	0	611	8
slouse	long-complex	511	7	625	6	992	7	659	0
smawsh	long-complex	643	0	562	0	1145	0	806	12
sprate	long-complex	564	0	561	0	945	0	686	12
sprush	long-complex	676	0	610	0	1060	0	724	13
sreeze	long-complex	676	8	589	0	1055	15	710	0
stribe	long-complex	583	0	576	0	958	0	602	0
stroge	long-complex	591	14	561	0	1021	7	681	0
trouse	long-complex	562	7	630	0	1001	7	690	0
trouge	long-complex	554	0	609	0	1098	0	710	6
plaesh	long-complex	611	0	543	6	1040	14	835	0
snooge	long-complex	533	0	647	0	1025	0	669	0
blif	short-basic	533	0	598	0	886	6	656	0
clek	short-basic	565	0	541	0	1041	6	639	0
cren	short-basic	580	6	695	0	967	0	694	0
pliv	short-basic	541	0	674	0	966	0	722	0
grus	short-basic	545	0	594	0	925	0	650	0
klel	short-basic	623	0	662	0	1059	0	701	7
krum	short-basic	599	6	707	0	1006	0	758	7
plil	short-basic	543	0	597	0	1049	14	721	0
prub	short-basic	620	13	654	0	1009	0	690	0
scib	short-basic	698	6	587	7	1114	0	617	0
slel	short-basic	558	12	694	0	978	0	641	0
smib	short-basic	555	6	623	0	867	0	637	0
spad	short-basic	550	0	565	0	947	0	592	0
spuk	short-basic	578	12	660	0	918	6	654	0
srec	short-basic	538	0	645	0	941	6	662	7
stum	short-basic	595	0	613	0	903	0	633	0
staz	short-basic	552	7	636	0	900	0	645	0
stet	short-basic	540	0	655	7	863	6	632	0
pliz	short-basic	605	6	647	0	1004	0	696	0
trub	short-basic	605	6	706	7	1003	0	642	0

Appendix D (continued)

Item Data from Experiment 2

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	graphemic complexity	RT	%E	RT	%E	RT	%E	RT	%E
plif	short-basic	464	6	579	0	855	13	639	0
snel	short-basic	588	0	620	0	952	0	629	0
bloide	long-complex	644	0	629	0	1058	0	731	7
claete	long-complex	632	0	735	0	1154	0	820	0
creeze	long-complex	534	0	669	8	1104	0	739	0
plawle	long-complex	565	6	655	7	1065	0	783	0
grouge	long-complex	608	0	626	0	1071	0	713	7
kleigh	long-complex	634	6	604	0	1202	0	736	0
kroupe	long-complex	560	0	638	7	1013	0	803	0
pleege	long-complex	552	0	638	0	1054	0	728	0
priesh	long-complex	518	6	673	7	1058	6	760	0
scawce	long-complex	495	0	673	0	937	6	712	0
sleege	long-complex	559	8	611	8	933	8	699	0
smaefe	long-complex	595	0	584	0	994	0	723	0
sprine	long-complex	595	6	635	0	990	0	609	0
sprune	long-complex	499	6	620	0	868	6	662	0
sreeve	long-complex	572	6	758	0	956	24	682	7
strine	long-complex	498	13	678	7	896	0	672	0
strofe	long-complex	550	0	663	0	924	6	644	0
strone	long-complex	581	0	607	0	966	0	644	0
pleeph	long-complex	566	0	693	0	1085	18	797	9
trouph	long-complex	557	0	580	7	1067	0	734	0
plawgh	long-complex	596	0	660	0	1099	0	765	0
snaeph	long-complex	548	0	568	0	976	13	732	0

Appendix E

Participant Data from Experiment 3

	Task 1: Tone Identification								Task 2: Nonword Naming							
	Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
	Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	509	0	457	0	420	5	427	5	1056	30	932	20	645	5	571	0
2	370	20	329	33	399	6	428	16	793	10	703	0	583	6	562	0
3	593	0	637	0	671	0	543	0	1073	5	1096	0	713	0	620	0
4	357	5	358	0	342	0	364	0	761	0	756	0	459	0	431	5
5	995	0	834	0	1173	0	1269	0	1236	5	1134	0	893	5	898	0
6	617	0	492	5	623	0	551	0	1170	0	1174	0	879	0	868	0
7	338	24	336	5	346	0	325	10	709	0	684	0	524	0	503	0
8	417	0	437	5	491	0	469	0	631	5	722	5	521	0	532	0
9	410	0	390	0	402	0	373	0	836	0	843	0	525	0	535	0
10	596	5	566	0	611	14	579	5	1020	0	976	5	601	0	611	0
11	483	0	472	0	490	0	460	0	970	0	952	0	614	5	538	0
12	425	10	457	0	473	6	442	5	722	0	754	0	476	6	444	5
13	420	5	400	0	448	0	427	0	851	0	758	0	576	0	525	0
14	569	0	501	0	521	0	467	0	880	0	778	0	518	0	494	0
15	386	0	425	5	407	0	380	5	802	0	821	0	540	0	551	5
16	605	0	831	0	829	0	983	0	1075	0	1245	0	888	0	905	0
17	536	5	535	0	522	0	531	0	1059	5	1104	0	771	0	749	0
18	595	5	602	5	593	0	591	0	958	0	932	0	575	0	568	0
19	472	5	446	0	472	0	472	0	744	0	706	0	410	0	431	0
20	467	0	454	0	400	0	550	0	775	0	811	0	431	5	494	0
21	474	5	450	0	489	0	477	0	766	0	743	0	556	0	530	0
22	410	0	329	5	388	5	408	0	1003	0	890	0	598	0	569	0
23	475	15	475	19	498	0	472	21	978	0	970	0	601	0	510	5

Appendix E (continued)

Participant Data from Experiment 3

	Task 1: Tone Identification								Task 2: Nonword Naming							
	Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
	Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
24	546	0	565	0	530	0	581	0	794	0	775	0	474	0	464	0
25	600	5	600	10	725	0	712	0	1101	15	1100	0	681	14	749	0
26	494	10	644	0	533	5	570	0	793	10	953	0	610	0	582	0
27	489	5	468	0	447	0	450	0	959	5	934	0	450	0	500	0
28	485	7	518	0	451	0	494	6	687	13	734	0	618	9	536	0
29	811	0	711	15	803	5	755	5	1420	5	1215	5	954	26	750	0
30	676	13	610	13	653	8	618	6	1015	0	933	0	701	0	633	6
31	384	0	411	0	444	0	438	0	924	0	972	0	668	6	708	0
32	881	17	806	5	1010	22	1007	5	1063	6	974	0	801	0	780	0
33	624	6	591	20	864	11	834	0	826	6	777	5	522	0	604	0
34	466	0	409	0	468	0	430	0	870	0	802	0	540	0	511	0
35	537	5	644	0	670	0	564	0	1125	0	1196	0	717	0	686	0
36	812	12	599	12	737	0	706	0	1131	0	896	6	585	0	587	0
37	463	0	587	0	729	5	585	0	802	5	966	5	620	0	585	0
38	650	0	666	10	578	0	605	0	938	0	910	0	551	0	573	0
39	643	5	593	20	765	5	703	0	936	0	912	0	623	0	639	0
40	586	0	566	0	590	0	577	0	893	0	813	0	590	0	502	6
41	505	5	502	0	476	0	501	0	932	0	905	0	401	0	410	0
42	406	5	407	5	417	0	415	5	759	0	814	0	504	0	483	0
43	567	0	629	10	689	0	611	0	1015	5	981	0	699	10	684	5
44	724	10	699	15	688	11	852	5	1131	0	1036	5	670	5	681	0
45	439	5	396	0	392	0	409	0	708	5	685	0	474	0	477	0
46	388	10	391	5	416	5	373	5	818	0	870	0	465	0	459	0
47	882	10	715	10	746	0	857	10	1547	40	1276	10	1011	29	967	15
48	973	6	1026	6	836	6	837	0	1491	6	1479	6	996	0	939	6

Appendix F

Item data from Experiment 3

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E
bant	high	476	13	515	4	885	8	593	13
dast	high	581	4	539	10	1008	4	639	5
dend	high	536	0	544	4	890	4	592	0
dest	high	532	4	587	0	938	0	634	0
dind	high	467	5	528	9	843	20	580	5
dunt	high	517	14	536	0	839	5	548	5
fant	high	593	9	618	0	916	0	677	9
fent	high	577	4	506	0	988	0	595	10
fest	high	498	0	529	0	920	8	635	0
fint	high	479	4	561	5	962	13	645	0
fost	high	541	4	504	5	959	4	619	0
fust	high	533	13	534	0	958	17	665	0
hant	high	632	5	656	5	1011	0	695	0
hend	high	590	4	603	0	1020	9	601	5
hest	high	530	0	598	9	915	0	635	17
hust	high	597	10	588	0	1018	0	554	4
kest	high	576	0	603	0	1017	4	765	9
kint	high	545	0	582	0	911	0	594	0
lant	high	590	9	557	0	976	0	562	0
lind	high	576	5	591	0	942	0	613	0
lond	high	534	13	623	0	947	0	604	0
lont	high	572	10	564	0	1013	5	648	0
mant	high	530	0	503	0	1023	4	603	0
nast	high	570	4	590	4	967	4	621	0
nent	high	544	5	553	0	923	0	631	4
pont	high	551	5	638	0	938	0	655	4
pust	high	613	0	599	4	951	13	625	0
rast	high	555	0	571	0	935	0	592	0
rint	high	598	5	578	5	1058	9	594	5
sant	high	537	0	506	5	923	0	563	0
sast	high	502	4	528	0	840	4	563	5
sest	high	536	8	617	0	852	0	603	0

Appendix F (continued)

Item data from Experiment 3

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E
sint	high	496	0	545	9	888	5	635	0
sunt	high	536	0	584	5	911	4	592	0
sust	high	551	5	598	0	897	0	604	0
tant	high	522	5	578	4	889	0	640	0
tast	high	516	0	600	4	948	0	591	0
tind	high	528	9	637	0	931	0	615	0
tunt	high	589	9	495	4	1048	0	568	0
tust	high	590	5	560	0	973	5	595	13
wint	high	501	10	572	5	888	0	592	0
wust	high	479	5	551	0	880	5	634	0
bapt	low	599	8	519	4	943	0	593	0
dakt	low	561	13	551	0	964	0	574	0
demf	low	492	8	645	5	893	13	638	0
demk	low	489	9	552	0	880	0	562	0
dild	low	524	9	589	0	939	9	614	5
dund	low	602	9	554	0	963	0	548	0
fapt	low	586	5	514	4	941	0	608	9
femp	low	547	5	549	0	868	5	620	0
fenf	low	497	4	584	4	908	0	613	0
fimk	low	518	5	536	13	997	5	591	4
fomp	low	573	0	594	0	1014	0	649	0
fuld	low	474	0	591	0	894	0	610	0
hamf	low	591	4	577	0	973	0	635	5
hemk	low	457	8	514	0	919	4	521	0
hept	low	547	9	549	5	899	0	608	0
himp	low	515	4	508	10	877	0	574	0
kect	low	522	0	603	0	818	0	628	0
kimp	low	518	0	647	5	885	0	606	0
lamf	low	514	4	530	0	923	0	547	0
limf	low	525	4	559	0	855	4	605	0
lomk	low	600	0	672	0	1021	4	588	0
lonf	low	508	9	568	0	921	0	584	0

Appendix F (continued)

Item data from Experiment 3

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E
mamk	low	485	4	632	0	904	0	753	4
nald	low	531	0	588	0	940	0	612	0
nant	low	533	5	621	0	908	0	701	4
pomk	low	539	4	465	5	909	0	586	0
pumk	low	543	4	551	4	947	4	594	0
ramf	low	533	9	564	5	898	0	625	5
rild	low	554	0	533	0	1015	0	533	0
samf	low	601	4	613	4	1002	0	583	0
samk	low	609	0	596	0	924	0	608	0
semp	low	520	0	614	4	841	0	643	4
simk	low	527	0	543	0	913	0	581	0
suld	low	531	0	539	0	916	0	551	0
sumf	low	609	4	530	4	962	4	611	0
tamf	low	519	4	588	0	917	0	611	0
timp	low	574	4	582	8	995	0	583	4
timk	low	566	5	534	4	962	5	540	0
tuld	low	520	8	583	0	910	0	597	0
tunf	low	558	8	628	0	907	4	643	5
wimf	low	495	11	594	4	858	0	663	0
wund	low	511	14	563	4	843	0	595	0

Appendix G

Participant data from Experiment 4

	Task 1: Tone Identification								Task 2: Nonword Naming							
	Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
	Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	713	0	600	5	764	0	725	0	1086	0	937	0	686	15	650	5
2	558	0	565	5	554	5	589	0	1142	0	1108	0	684	0	814	0
3	399	5	430	5	350	0	384	0	705	10	756	0	521	0	487	0
4	471	11	652	0	525	0	579	0	865	0	1004	0	548	0	571	0
5	370	6	344	10	409	0	371	5	749	6	666	0	509	5	486	0
6	573	5	534	15	591	0	624	0	997	0	984	5	742	5	726	0
7	365	5	385	17	374	0	364	6	902	0	904	0	621	0	670	0
8	541	0	553	0	605	0	636	0	1069	0	1098	5	734	10	704	15
9	867	0	790	0	1022	0	961	0	1608	5	1467	0	1124	0	1052	0
10	384	5	370	10	358	0	410	10	798	0	844	0	531	5	534	5
11	687	0	610	0	723	0	642	0	1280	0	1200	0	746	0	748	0
12	947	5	1008	0	1055	0	1022	0	1168	0	1233	0	806	0	726	6
13	405	12	507	0	516	0	436	0	871	6	944	6	636	0	621	0
14	461	10	445	5	473	5	395	0	789	0	764	0	492	0	433	0
15	397	0	433	0	397	0	405	0	729	0	745	0	558	15	530	0
16	472	0	638	0	522	6	491	0	940	6	1124	5	785	0	733	6
17	709	0	658	0	824	0	638	0	1145	10	1104	5	885	6	733	6
18	493	0	517	0	504	5	512	5	827	0	819	5	493	0	512	0
19	319	0	349	0	370	0	386	0	601	0	662	0	490	15	493	6
20	481	0	529	0	516	0	667	0	808	5	896	5	526	0	562	5
21	460	0	504	5	553	11	581	5	649	0	695	0	480	0	477	11
22	358	5	341	10	333	0	352	0	639	11	598	10	421	30	421	32
23	770	0	729	10	1101	0	844	0	1218	15	1126	10	866	5	674	0
24	743	0	792	5	819	0	747	0	1235	10	1200	11	928	20	824	5
25	455	5	492	5	496	0	478	0	756	5	853	0	444	25	422	22
26	865	11	830	6	1220	15	1247	0	1220	0	1287	0	990	20	947	0
27	776	0	614	0	950	0	678	0	1279	53	955	27	867	16	673	16

Appendix G (continued)

Participant data from Experiment 4

	Task 1: Tone Identification								Task 2: Nonword Naming							
	Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
	Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
28	546	0	617	0	565	0	715	6	843	13	903	0	562	20	595	0
29	808	0	619	0	586	0	561	0	1456	28	1117	11	821	21	781	10
30	672	0	679	0	687	0	671	5	1021	0	1008	11	602	11	587	0
31	833	6	701	5	899	0	966	0	1210	18	1073	11	707	10	717	6
32	760	0	621	0	613	0	549	0	1238	10	1022	10	706	11	614	10
33	473	0	473	0	487	10	536	6	862	15	875	18	588	10	600	22
34	402	0	433	0	436	0	449	0	758	0	809	0	547	5	528	5
35	471	0	563	6	564	0	602	0	1178	6	1223	6	775	5	849	0
36	439	0	452	0	530	0	496	0	826	0	864	0	539	0	512	5
37	444	0	442	0	464	0	567	0	749	6	728	5	491	5	508	0
38	631	5	570	11	575	5	624	5	905	16	835	22	608	25	552	15
39	677	0	717	0	955	0	773	0	1085	11	1118	0	846	0	639	5
40	599	0	476	0	494	0	528	0	937	5	817	11	521	0	534	5
41	1104	0	1089	6	1385	5	1485	0	1728	11	1727	0	1397	5	1573	0
42	485	5	450	5	467	0	450	5	751	0	704	0	485	0	477	0
43	490	11	445	0	498	0	493	0	883	0	809	6	653	11	579	0
44	665	0	614	0	843	0	940	0	1016	0	968	0	734	0	788	11
45	784	5	641	11	1074	0	882	6	1123	16	966	11	786	6	691	18
46	341	6	364	10	385	5	371	0	695	6	690	10	503	21	482	11
47	535	5	587	11	874	11	693	20	906	20	957	0	685	0	622	10
48	387	0	378	11	409	0	442	5	778	5	716	0	523	5	514	0
49	450	0	476	0	462	0	448	0	772	10	768	0	509	10	502	5
50	1050	6	991	0	1334	0	1439	0	1275	6	1150	0	878	5	930	5
51	760	0	706	0	863	0	788	0	1622	10	1597	10	1162	10	1065	5
52	478	0	684	10	523	0	440	0	988	0	1086	0	693	0	760	0
53	982	0	999	7	1161	0	889	0	1398	33	1444	21	1199	6	835	24
54	602	5	513	0	621	6	666	0	1024	0	1021	0	693	0	655	0

Appendix H

Item data from Experiment 4

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E
flink	high	622	4	756	0	1024	4	810	0
blick	high	578	0	710	3	963	0	697	3
cleck	high	576	4	586	0	932	0	636	3
spart	high	581	4	632	0	890	0	633	3
stant	high	548	12	787	3	890	8	784	10
brack	high	534	4	755	0	917	0	744	3
clask	high	525	4	713	0	858	0	774	7
spabs	high	662	4	703	3	1086	0	818	7
starm	high	608	0	695	3	913	4	664	3
steck	high	598	0	708	3	965	9	731	7
blunk	high	516	0	727	0	850	8	748	7
brend	high	514	8	618	0	895	4	714	3
crist	high	589	0	683	3	963	0	739	7
crunt	high	570	0	612	3	908	7	639	14
spant	high	550	4	672	0	888	4	741	0
drack	high	548	0	673	0	917	4	796	3
frust	high	562	4	689	4	952	0	712	7
grent	high	562	0	819	3	965	0	817	3
prond	high	536	0	644	0	877	4	711	10
sprap	high	543	9	670	7	860	0	667	10
flect	low	578	4	741	0	902	4	726	8
blust	low	590	0	604	8	907	8	649	19
drisk	low	635	0	630	0	1019	4	687	3
scrat	low	597	12	671	0	922	8	730	4
sturt	low	483	0	657	4	827	0	708	18
blect	low	582	0	640	3	960	0	675	7
crent	low	524	8	693	0	886	8	692	3
krand	low	527	0	601	3	895	4	733	7
scrun	low	570	0	666	0	911	0	655	14
trenk	low	612	8	661	7	922	8	738	3
blapt	low	563	8	717	0	900	0	738	0
clumf	low	542	4	752	3	902	0	820	0
frept	low	618	13	658	0	966	8	694	4
skerm	low	642	13	560	4	999	4	627	0
tresk	low	622	4	654	0	911	4	642	4
clarn	low	558	4	625	0	898	0	691	7
flurn	low	514	0	618	0	914	0	699	0
klent	low	568	4	633	3	933	0	670	0
ploct	low	584	0	665	0	943	0	668	0
strof	low	561	4	647	0	905	0	781	26

Appendix H (continued)

Item data from Experiment 4

		Task 1: Tone Identification				Task 2: Nonword Naming			
		50 msec SOA		750 msec SOA		50 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E
frick	high	674	3	725	0	1209	7	725	0
blund	high	598	0	624	0	1036	4	648	4
clonk	high	648	4	536	4	1103	7	569	13
spint	high	617	3	594	0	1067	14	595	8
stard	high	520	3	694	0	880	3	621	4
brint	high	611	0	595	0	1019	4	620	4
clant	high	618	0	605	0	1081	4	661	0
spink	high	553	3	641	0	1002	7	632	0
starn	high	584	4	536	4	977	32	621	33
stonk	high	648	7	600	4	1064	10	602	0
blask	high	613	3	640	4	1045	3	614	0
brast	high	589	0	572	0	1055	4	621	4
crant	high	701	3	606	8	1183	7	598	0
crost	high	523	0	716	0	993	7	725	27
spenk	high	647	0	606	4	1102	17	598	12
dronk	high	606	4	750	4	1091	0	698	15
frist	high	574	0	680	0	1143	32	783	35
grick	high	663	3	647	0	1201	23	747	12
pront	high	625	0	627	0	1143	8	632	8
sprut	high	555	3	548	4	977	17	588	8
flind	low	583	4	645	4	1027	4	638	0
blisk	low	608	0	666	4	1034	0	682	0
drind	low	614	4	672	4	1036	12	648	4
scren	low	574	0	653	0	981	3	623	24
strub	low	572	7	678	4	964	3	653	8
blesk	low	512	4	628	0	927	0	691	0
crind	low	525	7	707	0	976	0	625	0
krisk	low	558	4	728	0	929	7	610	20
scruk	low	580	11	576	4	936	7	612	0
tramf	low	549	3	609	0	961	14	569	4
blosk	low	595	4	656	0	1019	7	628	4
clurn	low	610	0	641	4	1038	4	651	0
fract	low	622	7	609	0	1089	7	603	0
skist	low	608	7	584	0	1076	0	575	0
tropt	low	577	4	637	0	977	12	565	4
clirm	low	660	4	660	4	1138	4	698	4
frarn	low	568	0	638	0	1060	4	626	0
klird	low	611	0	623	0	1101	10	614	0
plerm	low	648	0	606	0	1122	4	610	0
stect	low	586	0	608	4	1003	13	597	35

Appendix I

Participant data from Experiment 5

	Task 1: Tone Identification								Task 2: Word Naming							
	Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
	Old		New		Old		New		Old		New		Old		New	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	527	0	581	0	542	0	549	4	911	5	909	4	570	4	609	0
2	386	4	394	4	561	0	514	0	667	0	668	4	521	14	553	0
3	855	0	823	0	1137	0	1184	4	1063	4	1003	9	754	9	894	23
4	788	0	754	0	677	4	727	0	1113	8	1108	8	586	5	670	12
5	384	0	437	8	381	0	426	4	688	4	732	4	508	8	571	4
6	724	2	742	4	623	2	678	0	1054	7	1082	7	652	12	649	9
7	773	0	770	4	1076	0	1056	0	1013	0	1064	8	770	0	802	13
8	614	0	603	0	605	0	562	0	1158	0	1111	18	767	9	749	9
9	643	0	628	4	555	0	519	0	1108	0	1098	5	666	9	624	0
10	382	24	389	4	453	4	406	0	758	13	786	0	518	4	542	4
11	603	0	573	8	684	0	758	8	864	0	893	10	657	10	600	39
12	565	0	522	0	582	4	574	0	753	4	742	8	523	8	495	26
13	695	0	643	13	487	4	546	0	1117	17	1150	18	641	25	742	4
14	473	19	595	0	444	9	480	0	731	12	818	0	417	5	453	14
15	397	0	380	4	432	0	440	0	590	4	605	0	438	0	484	12
16	548	4	551	4	565	0	606	0	893	4	944	12	566	0	642	9
17	489	0	626	0	539	0	534	0	772	0	893	4	508	4	532	4
18	458	16	465	8	768	4	712	8	670	4	655	4	472	0	487	8
19	685	17	646	8	827	8	721	0	920	5	1001	10	721	0	707	14
20	689	12	712	0	878	4	749	8	1009	5	1117	4	730	9	766	21
21	713	0	674	0	644	0	811	8	1130	5	1064	5	586	0	742	10
22	422	4	488	8	436	4	440	0	660	5	748	0	478	4	474	9
23	414	8	444	17	504	0	489	8	649	0	665	0	474	0	495	9
24	587	4	532	8	586	8	491	8	811	8	762	0	565	0	590	12
25	621	8	575	8	765	4	729	4	873	0	848	0	507	0	517	4
26	554	4	511	4	562	0	635	0	997	8	1075	21	703	20	778	20
27	407	4	506	8	427	0	441	0	692	0	789	0	459	0	463	0
28	608	4	448	8	626	0	564	8	949	17	797	19	660	10	705	17
29	471	0	461	8	515	0	735	0	940	0	994	0	551	4	815	4
30	572	0	483	0	669	0	625	4	811	8	783	13	569	13	592	10
31	365	36	405	39	399	38	413	33	544	4	608	0	398	0	410	0
32	679	4	680	4	712	0	554	0	1218	9	1233	5	718	0	862	5
33	733	8	678	12	598	4	609	4	1005	0	1023	15	598	4	690	13
34	607	8	648	13	616	0	507	0	827	5	871	5	463	5	440	11
35	593	4	519	0	654	0	648	0	792	12	750	12	522	4	523	13
36	832	4	777	4	835	4	846	0	1058	25	1096	19	697	4	835	13
37	996	4	1001	9	1035	0	1461	8	1317	17	1352	5	720	19	1313	19
38	751	0	676	4	854	0	729	0	1102	0	1031	0	718	0	704	0
39	647	0	582	8	786	0	740	0	952	0	833	4	554	0	542	4
40	810	4	774	4	1001	0	1043	4	1229	11	1176	5	749	0	769	12

Appendix J

Item data for Experiment 5

		Task 1: Tone Identification								Task 2: Word Naming							
		Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)	
number	stimulus	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	wad	535	0	564	8	680	0	609	0	851	30	851	0	591	0	675	0
2	beau	618	10	573	0	708	0	510	0	903	20	913	8	649	10	604	13
3	bowl	546	0	635	0	726	0	605	0	866	0	935	0	563	11	553	0
4	chic	524	0	491	15	716	13	574	0	1011	10	839	38	648	25	682	57
5	coup	672	17	611	13	725	0	648	0	962	17	914	0	661	13	592	0
6	deaf	586	22	622	0	753	0	587	13	912	0	879	0	595	0	577	0
7	dove	551	0	604	0	711	0	573	0	902	0	862	0	585	0	479	0
8	dove	661	0	551	8	705	0	812	0	959	0	914	0	676	0	866	0
9	feud	532	0	574	18	658	0	616	0	850	0	866	0	559	0	559	0
10	glow	530	0	521	0	797	0	709	0	845	0	822	0	680	0	944	0
11	hood	624	0	563	8	963	0	791	0	929	0	839	0	724	0	880	0
12	isle	579	0	700	0	694	0	559	0	856	0	979	0	538	0	549	0
13	lamb	609	10	580	9	799	0	631	0	965	0	887	9	595	0	647	0
14	limb	541	0	589	8	721	0	602	17	856	0	847	0	572	0	574	0
15	monk	522	0	600	0	798	0	453	13	825	10	976	8	734	0	592	13
16	pear	484	0	638	15	872	0	454	14	791	11	927	8	748	0	541	29
17	pint	571	11	629	8	983	10	643	0	846	0	820	0	732	0	514	0
18	shoe	607	0	611	8	720	0	553	0	938	0	884	0	631	0	593	0
19	sown	482	0	513	17	770	0	601	0	852	0	747	0	619	0	642	0
20	swan	503	10	546	0	684	0	677	0	829	0	785	18	651	0	647	0
21	tomb	489	0	599	7	638	0	667	0	813	0	892	0	648	0	795	22
22	warp	620	0	530	0	624	0	405	0	871	0	781	8	492	0	558	13
23	wasp	509	0	600	0	869	0	692	0	803	0	878	0	734	0	633	0
24	womb	543	11	656	14	765	0	739	0	872	11	908	21	645	0	838	0
25	yolk	546	0	569	0	587	0	868	0	922	0	883	0	538	0	848	0
26	blown	588	0	647	0	467	0	654	15	904	0	966	0	550	0	550	0
27	broom	559	0	640	0	495	0	733	8	868	0	962	0	553	0	614	0
28	bind	481	0	671	0	571	0	584	0	848	0	959	0	537	10	562	0
29	chute	507	0	562	0	548	0	681	0	881	0	983	14	624	33	699	42
30	crepe	507	0	644	0	546	0	584	0	820	0	1025	0	597	0	623	0
31	dough	618	0	433	14	506	0	580	8	900	17	882	14	631	0	567	50
32	fiend	555	0	645	0	550	0	740	9	890	0	1046	0	564	0	620	0
33	flown	572	0	777	0	784	0	646	0	958	50	1282	38	720	0	600	42

Appendix J (continued)

Item data for Experiment 5

		Task 1: Tone Identification								Task 2: Word Naming							
		Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)	
number	stimulus	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
34	ghoul	567	0	489	10	540	0	757	15	862	0	812	0	574	0	692	0
35	grind	787	14	609	0	647	0	815	8	1009	0	939	13	655	20	691	33
36	guise	566	0	748	13	509	11	635	10	862	0	1042	0	572	0	617	0
37	mould	582	0	608	13	663	0	656	8	946	0	936	0	607	13	622	15
38	niche	535	0	644	0	680	10	737	0	864	14	1171	30	808	20	698	36
39	plaid	567	0	644	0	543	0	558	0	827	0	988	11	560	0	562	0
40	reign	562	13	564	0	593	0	667	0	867	0	915	0	571	0	561	0
41	scent	484	13	686	0	539	0	604	0	756	13	1142	10	583	44	602	0
42	stead	546	0	642	0	533	0	666	8	908	0	963	0	578	10	677	8
43	suede	760	0	565	0	579	0	643	9	1065	0	957	0	657	0	617	0
44	swarm	679	13	610	0	692	0	695	8	1017	0	964	0	572	0	588	0
45	thumb	612	0	706	10	560	0	642	0	968	0	1087	0	554	0	560	0
46	weird	508	0	717	0	621	0	575	0	881	0	1042	0	495	0	508	0
47	wolf	512	0	572	0	518	0	517	0	779	14	947	0	561	0	543	0
48	dreamt	461	13	613	0	460	0	631	8	729	38	846	14	628	11	635	15
49	hearth	681	0	664	20	556	9	597	0	928	0	1033	0	592	0	590	0
50	sponge	533	0	712	0	564	0	660	0	792	0	1131	11	603	17	640	14
51	drought	497	23	423	11	546	0	790	0	804	8	746	11	483	13	669	11
52	aunt	640	8	576	0	521	0	680	0	908	0	950	0	492	0	705	0
53	choir	684	0	586	0	678	0	783	10	935	0	873	10	536	0	772	0
54	chef	594	8	586	0	522	0	739	0	857	0	949	0	513	0	595	0
55	comb	537	0	616	9	516	0	817	13	810	0	939	0	545	0	617	0
56	crow	638	14	542	10	653	0	606	0	903	0	830	0	528	0	574	0
57	dual	591	0	521	11	553	0	733	0	853	0	936	0	591	0	640	0
58	gist	648	17	595	0	585	0	770	0	911	8	1008	50	560	29	682	56
59	heir	842	8	508	0	452	0	580	0	1069	25	878	55	560	50	686	33
60	hoof	529	0	508	0	500	0	700	0	808	0	810	0	526	0	643	0
61	knot	656	0	590	10	628	0	838	0	927	0	864	0	583	0	784	0
62	lieu	637	17	480	0	564	0	897	0	923	25	860	11	619	50	866	25
63	malt	593	8	469	0	509	0	831	0	829	0	791	0	502	0	686	0
64	sieve	592	17	460	0	458	0	702	0	995	42	893	38	533	25	585	75
65	pier	821	8	674	10	613	0	912	0	1089	0	1008	10	582	0	834	0
66	sewn	572	0	514	0	501	14	578	11	887	0	883	0	500	0	701	11

Appendix J (continued)

Item data for Experiment 5

		Task 1: Tone Identification								Task 2: Word Naming							
		Short SOA (50 msec)				Long SOA (750 msec)				Short SOA (50 msec)				Long SOA (750 msec)			
		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)		Repeated Stimuli (Old)		Novel Stimuli (New)	
number	stimulus	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
67	soot	573	0	513	0	407	0	577	0	840	23	825	10	501	43	731	20
68	steak	511	0	528	0	693	0	902	0	798	0	879	0	536	0	760	0
69	swap	560	23	670	0	754	0	760	0	839	0	1016	0	583	0	705	10
70	tsar	699	25	672	10	687	0	817	0	1041	8	1071	10	647	14	910	10
71	wart	693	8	567	0	661	0	874	10	974	0	842	0	522	0	728	0
72	brooch	577	8	490	40	568	0	781	10	869	33	861	40	609	0	826	60
73	worm	529	8	464	0	565	0	753	0	868	0	897	0	556	0	736	10
74	aisle	612	8	517	0	537	0	791	0	848	8	932	0	560	0	640	0
75	brook	616	15	617	0	457	0	760	0	954	0	973	10	489	14	662	11
76	chasm	480	0	412	29	731	0	531	0	828	30	689	43	797	36	657	60
77	chord	826	0	522	0	639	0	585	10	1130	0	826	13	599	8	666	20
78	cough	670	0	521	25	717	0	518	0	921	0	806	0	568	0	549	0
79	dealt	630	9	618	13	832	8	650	0	974	0	984	0	631	0	635	0
80	dwarf	740	0	518	13	740	7	612	0	1007	0	816	0	607	0	600	0
81	flood	609	0	606	13	568	0	590	0	908	0	968	0	503	0	598	0
82	geese	609	0	474	0	839	25	552	0	946	0	696	25	717	0	722	0
83	glove	542	0	566	0	685	0	540	0	911	0	1020	0	549	0	567	0
84	guild	619	0	776	13	685	0	445	0	964	20	1041	0	593	8	670	13
85	knoll	735	0	601	0	726	9	724	0	1050	0	1058	0	645	0	756	0
86	naive	619	0	472	0	589	0	528	0	896	0	792	17	509	8	661	11
87	pearl	764	0	780	0	661	0	592	0	1125	11	1086	0	519	0	544	10
88	realm	620	0	633	13	697	0	680	0	952	0	847	13	501	0	571	10
89	rogue	544	22	435	17	765	0	678	0	907	11	710	0	677	0	677	30
90	shove	630	0	626	0	745	15	502	0	973	0	1003	0	597	8	626	0
91	stow	712	0	628	0	760	8	531	0	1104	0	940	0	618	0	621	0
92	suite	633	0	708	14	517	9	697	0	970	0	1130	0	519	9	714	33
93	sword	648	0	630	14	834	8	546	20	993	0	920	0	730	0	592	0
94	tread	693	0	571	0	667	0	646	0	1080	20	905	0	550	8	668	10
95	yacht	695	0	652	0	642	0	504	10	952	0	911	0	602	0	590	0
96	douche	645	0	475	14	586	0	514	0	909	14	729	0	563	0	627	0
97	hearse	660	0	695	13	751	8	522	0	986	0	999	0	589	17	688	33
98	learnt	628	0	752	25	561	0	662	0	975	0	997	0	481	0	617	0
99	trough	619	0	556	0	698	8	480	0	1072	30	838	14	610	15	660	60
100	stealth	662	11	511	13	752	18	512	0	1085	11	858	13	658	0	673	9

Appendix K

Participant data from Experiment 6

	Task 1: Tone Identification											
	Short SOA (50 msec)				Intermediate SOA (250 msec)				Long SOA (750 msec)			
	Short / Basic		Long / Complex		Short / Basic		Long / Complex		Short / Basic		Long / Complex	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	603	0	594	0	525	0	566	0	395	0	586	0
2	339	5	388	5	412	0	398	9	420	0	432	0
3	442	10	475	5	430	0	484	0	478	0	416	0
4	443	0	500	0	464	0	410	0	470	0	460	0
5	438	10	462	0	466	0	485	15	461	5	501	0
6	651	5	622	5	637	0	677	5	676	0	620	0
7	612	0	567	0	591	0	626	0	650	0	688	0
8	657	0	644	5	573	0	647	0	633	0	773	0
9	465	0	624	5	595	5	575	5	577	5	531	10
10	486	24	622	24	670	14	634	0	792	10	768	10
11	616	5	678	5	763	9	728	15	958	5	922	15
12	704	0	777	0	705	0	732	0	847	0	900	0
13	747	11	788	5	651	5	776	5	864	0	790	5
14	624	0	575	0	511	5	513	0	524	0	522	0
15	532	0	546	0	607	0	466	5	608	0	668	0
16	488	0	585	5	552	5	510	0	531	0	522	0
17	605	5	581	0	675	0	579	0	616	0	640	0
18	567	0	539	0	488	0	459	0	443	0	478	5
19	710	0	705	0	816	0	882	0	1166	0	1322	0
20	436	0	440	0	488	0	471	0	521	0	512	0
21	1065	0	1117	0	1000	10	1451	0	1398	0	1512	0
22	403	0	491	0	449	0	443	5	511	0	533	5
23	672	0	774	10	940	0	796	5	1114	0	1096	0
24	461	14	505	10	536	5	539	10	487	5	568	5
25	679	15	640	14	594	5	572	5	853	0	636	0
26	534	5	406	15	449	10	430	5	552	11	401	6
27	516	10	517	0	609	0	570	0	450	0	530	0
28	744	5	784	0	843	5	802	0	929	0	1041	5
29	1000	0	971	5	1018	5	1273	0	1214	0	1414	0
30	489	19	616	0	641	14	696	19	635	5	660	5
31	845	0	840	5	1095	0	943	0	1104	5	1230	0
32	420	0	404	0	415	0	407	0	422	0	488	0
33	662	0	682	9	648	5	620	5	607	0	629	0
34	576	0	571	0	535	5	531	0	655	0	647	0
35	627	0	617	15	746	9	648	5	896	18	701	5
36	917	10	1015	5	1107	0	1068	0	1281	0	1403	5
37	943	0	991	0	917	0	835	0	941	0	1014	0
38	611	0	582	0	683	0	681	0	560	5	736	0
39	595	5	609	0	575	5	638	5	603	0	680	5

Appendix K (continued)

Participant data from Experiment 6

	Task 2: Nonword Naming											
	Short SOA (50 msec)				Intermediate SOA (250 msec)				Long SOA (750 msec)			
	Short / Basic		Long / Complex		Short / Basic		Long / Complex		Short / Basic		Long / Complex	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	783	5	815	0	587	5	660	6	471	0	535	15
2	599	0	667	0	491	5	638	5	448	0	516	10
3	860	0	943	15	538	0	800	33	594	5	545	10
4	803	10	906	38	673	0	818	25	581	0	632	0
5	683	0	883	10	583	5	667	5	519	5	633	9
6	1188	5	1325	40	1064	10	1365	5	992	27	1167	14
7	1030	0	1001	24	865	0	956	5	658	5	659	5
8	894	10	925	14	673	21	775	14	552	19	653	24
9	819	9	1043	15	787	10	764	10	541	18	565	15
10	759	0	945	14	771	0	761	15	611	0	670	5
11	888	32	1086	0	902	14	873	15	718	20	736	5
12	1031	15	1120	14	855	19	953	0	734	21	876	19
13	1081	0	1167	23	840	24	964	15	801	20	779	15
14	886	14	900	0	602	10	669	10	529	0	623	10
15	862	0	882	18	721	5	664	11	570	5	617	0
16	879	0	969	5	741	10	735	5	631	0	652	5
17	872	5	804	0	678	5	633	5	508	5	520	10
18	1047	10	1068	0	867	0	943	10	668	5	755	5
19	1005	0	899	14	861	0	859	14	704	0	883	5
20	643	5	684	0	539	0	572	5	511	5	550	0
21	1368	0	1385	5	1136	5	1605	0	1207	0	1204	11
22	739	0	858	0	689	0	846	0	584	0	644	0
23	956	0	1015	5	989	0	832	5	672	5	723	6
24	801	14	906	10	749	5	791	10	564	5	540	20
25	1079	35	1102	24	810	33	963	19	947	10	797	16
26	680	0	669	0	468	0	507	5	437	6	478	6
27	978	0	1174	0	912	0	1098	5	709	0	968	0
28	1021	0	1074	0	904	5	890	5	643	0	756	0
29	1306	15	1344	5	1193	20	1469	9	841	24	1065	0
30	705	10	807	15	638	10	707	5	490	5	466	0
31	907	18	887	24	948	30	828	25	599	25	646	19
32	757	5	806	6	590	0	646	0	505	9	522	14
33	1191	25	1312	18	1017	10	1219	10	793	14	967	15
34	917	0	894	10	741	14	723	5	692	10	687	0
35	1027	5	1025	5	875	0	857	0	793	0	679	0
36	1010	0	1171	5	1034	0	1050	0	729	0	976	0
37	1290	5	1440	10	1088	10	1153	0	880	5	986	0
38	1003	5	1393	16	945	15	1055	5	662	0	861	0
39	906	0	1009	0	688	0	774	0	574	0	641	0

Appendix L

Item data from Experiment 6

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	graphemic complexity	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
kulf	short-basic	583	13	729	0	789	0	1001	0	868	9	724	25
zalp	short-basic	518	0	636	0	782	0	810	0	712	0	653	0
drec	short-basic	509	14	638	8	812	0	853	7	721	0	718	0
dwab	short-basic	576	0	621	8	766	0	943	0	749	0	683	8
tulb	short-basic	485	7	658	8	818	0	797	0	678	8	732	8
smet	short-basic	563	0	643	8	938	9	868	0	709	0	683	9
kanc	short-basic	584	18	741	0	856	8	1015	27	823	8	784	0
kalp	short-basic	569	0	668	0	717	0	965	8	751	8	618	0
yalc	short-basic	526	14	614	0	853	0	945	7	728	0	722	0
plym	short-basic	497	8	597	0	752	0	939	23	754	9	782	58
falp	short-basic	541	0	769	8	911	0	880	7	996	15	711	25
dwep	short-basic	474	0	658	8	676	10	940	14	822	8	592	10
wumf	short-basic	461	0	856	11	662	15	921	8	938	0	781	8
glif	short-basic	469	15	742	0	875	0	883	8	826	0	757	0
dwak	short-basic	602	0	764	0	715	0	943	15	854	0	712	25
glof	short-basic	528	8	697	8	687	0	837	8	747	23	649	15
glyp	short-basic	670	8	611	8	987	8	1044	23	769	38	910	25
kesk	short-basic	661	0	581	0	871	0	983	0	656	0	780	0
skol	short-basic	506	0	671	0	839	0	806	0	741	23	655	9
smif	short-basic	558	7	690	0	763	0	814	0	712	0	536	0
drif	short-basic	555	8	707	0	708	0	926	8	808	0	566	8
jalp	short-basic	674	0	540	0	847	8	1053	0	756	7	605	0
brol	short-basic	714	0	543	0	676	0	1040	8	722	8	582	0
dreb	short-basic	696	8	527	0	836	0	969	0	731	0	679	0
smeb	short-basic	673	0	516	0	847	8	930	8	727	7	597	0
blem	short-basic	614	0	560	7	712	0	870	0	754	0	575	8
fliz	short-basic	582	9	519	7	834	0	992	0	810	7	679	8
prun	short-basic	590	0	541	7	904	0	890	18	782	7	756	25
prud	short-basic	650	17	606	0	1008	0	1028	17	843	21	838	8
blun	short-basic	754	8	559	8	682	0	1128	8	757	0	682	0
blif	short-basic	704	0	544	0	760	0	954	0	764	8	584	0
relk	short-basic	704	0	583	8	654	0	955	0	827	0	554	0
crut	short-basic	672	0	549	7	740	0	1051	0	737	13	558	15

Appendix L (continued)

Item data from Experiment 6

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	graphemic complexity	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
snet	short-basic	587	8	612	8	858	8	828	17	753	8	613	8
nalp	short-basic	649	10	573	0	734	0	1031	10	810	7	678	0
jalc	short-basic	709	0	580	0	785	0	1030	0	804	0	586	15
skeb	short-basic	704	0	525	0	895	7	911	15	691	8	646	7
lalp	short-basic	708	0	510	0	735	14	978	8	710	14	629	7
julb	short-basic	775	8	545	0	737	0	1118	8	791	0	676	8
cril	short-basic	759	0	521	8	660	0	1107	8	718	0	590	0
scig	short-basic	658	0	648	7	706	0	1074	9	832	14	616	14
zelk	short-basic	580	8	583	0	819	0	865	0	786	0	709	0
spof	short-basic	547	8	595	0	666	0	797	15	711	17	636	14
gelk	short-basic	620	0	937	0	539	0	887	8	997	18	731	14
velk	short-basic	663	0	719	0	486	0	941	0	839	8	610	0
fesk	short-basic	630	0	664	0	639	0	915	0	784	8	618	0
nusp	short-basic	588	0	768	8	520	0	939	0	962	8	685	7
frub	short-basic	603	14	640	0	578	0	905	7	748	0	677	0
dwiz	short-basic	728	0	835	0	584	0	1059	23	970	0	734	0
skos	short-basic	662	0	844	9	592	0	847	31	1011	9	606	21
snef	short-basic	586	0	794	0	579	0	757	0	886	17	581	0
frup	short-basic	686	15	688	0	563	0	1004	0	741	17	668	7
crel	short-basic	612	0	734	0	621	7	838	8	815	8	632	0
jelm	short-basic	680	0	585	0	648	7	966	8	720	0	689	0
clis	short-basic	512	0	804	8	557	7	751	0	872	0	603	0
frid	short-basic	644	0	775	0	654	0	947	0	934	0	726	0
snez	short-basic	596	0	644	8	517	0	835	8	856	33	588	7
flif	short-basic	601	0	758	8	679	0	919	8	901	0	711	7
visk	short-basic	695	8	653	0	534	0	942	0	765	0	536	0
pliv	short-basic	643	0	729	8	558	0	1029	0	909	17	658	14
grus	short-basic	628	8	707	0	554	0	868	0	802	0	624	0
clig	short-basic	610	0	828	0	504	0	833	0	954	17	609	0
brup	short-basic	619	0	695	8	631	0	921	0	819	25	740	0
kuiche	long-complex	576	0	753	0	1215	0	1266	40	1002	9	1167	18
zaitch	long-complex	584	0	753	0	731	0	1089	7	908	15	716	0
drelch	long-complex	632	0	734	7	752	0	1100	0	851	0	707	0

Appendix L (continued)

Item data from Experiment 6

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	graphemic complexity	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
dwitch	long-complex	522	0	641	7	1105	0	869	0	724	0	927	0
toathe	long-complex	568	0	688	0	891	0	914	15	836	8	939	9
smeigh	long-complex	570	14	640	23	841	0	949	21	634	23	703	8
kusque	long-complex	561	0	741	7	917	0	1092	7	906	14	785	8
kauche	long-complex	637	13	778	0	845	0	1049	13	919	0	649	8
yauche	long-complex	633	7	745	0	1057	0	868	14	909	18	1013	17
plaugh	long-complex	530	7	600	8	934	0	1061	36	784	15	845	15
fautch	long-complex	580	17	586	8	826	0	1066	0	747	0	750	0
dwudge	long-complex	584	0	666	0	846	0	992	0	796	0	773	9
worgue	long-complex	657	8	696	0	798	8	1085	0	864	0	731	8
gleigh	long-complex	507	14	681	0	742	0	997	36	867	15	707	8
dwache	long-complex	449	7	802	0	817	0	835	20	907	0	570	8
gleece	long-complex	524	0	691	0	803	8	927	0	800	0	703	0
gladge	long-complex	497	8	675	0	865	0	991	0	771	8	826	8
kautch	long-complex	566	8	795	15	753	0	1017	8	924	15	754	8
skinch	long-complex	632	0	711	0	910	0	1001	0	833	8	765	0
smeave	long-complex	541	0	657	9	812	0	833	0	683	0	730	0
drowth	long-complex	708	0	722	0	806	8	1008	14	886	8	724	0
jeathe	long-complex	672	0	562	7	872	0	959	18	824	21	737	0
browth	long-complex	693	8	548	7	777	0	1008	8	835	7	678	8
drodge	long-complex	673	8	595	0	746	8	980	0	801	0	590	25
smaice	long-complex	742	9	524	0	922	0	1096	0	911	8	716	15
blooch	long-complex	688	0	529	0	874	9	1077	33	866	0	786	9
fladge	long-complex	669	0	574	0	859	0	1055	0	929	7	770	0
preige	long-complex	615	0	575	0	870	8	902	33	1034	7	804	0
preece	long-complex	756	0	532	0	807	8	1129	0	802	0	668	0
blynch	long-complex	903	0	544	7	870	0	1377	36	879	14	841	15
rauche	long-complex	754	0	642	7	722	0	1110	0	1100	14	668	0
criege	long-complex	674	8	655	0	920	0	1046	0	973	0	746	9
snooth	long-complex	948	9	510	0	908	0	1282	18	920	0	834	8
nourge	long-complex	784	0	604	7	878	8	1091	9	770	0	624	0
jautch	long-complex	760	0	494	0	866	0	1075	0	845	0	743	0
skedge	long-complex	663	10	566	0	724	0	964	20	840	33	618	8

Appendix L (continued)

Item data from Experiment 6

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	graphemic complexity	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
lourth	long-complex	643	8	517	0	798	8	976	0	710	0	721	0
jorgue	long-complex	693	0	508	0	710	8	951	0	795	7	637	0
croche	long-complex	793	10	562	7	923	0	1101	30	846	0	828	9
scight	long-complex	670	0	599	0	712	0	1045	42	841	36	664	38
zeathe	long-complex	732	0	543	0	754	0	1158	33	728	33	654	31
speuce	long-complex	674	0	584	8	761	0	1029	9	929	0	642	0
gautch	long-complex	576	8	773	8	533	0	866	0	916	8	609	0
vautch	long-complex	673	0	783	0	698	0	1019	0	1009	0	848	0
feague	long-complex	677	0	884	0	651	7	1032	0	1075	8	740	7
nounge	long-complex	601	11	620	0	565	0	884	0	998	8	823	8
frouse	long-complex	655	0	651	0	531	0	976	15	946	8	711	8
dwirch	long-complex	697	0	760	0	508	7	983	8	1007	0	698	7
skeuth	long-complex	673	0	617	0	677	0	959	0	842	0	785	0
snauge	long-complex	687	0	733	18	585	7	966	8	870	27	605	0
fralph	long-complex	754	0	700	8	638	7	1002	8	866	8	716	0
craith	long-complex	592	0	651	0	553	0	965	8	815	8	717	21
jourth	long-complex	696	8	679	0	599	0	968	8	882	17	725	8
cleace	long-complex	649	8	605	0	589	7	912	0	791	0	645	7
freich	long-complex	688	8	907	8	502	0	1274	0	1173	0	652	0
sneave	long-complex	552	0	790	0	612	0	981	15	1078	8	785	8
sneave	long-complex	656	8	776	0	584	0	1068	0	816	9	637	0
flenge	long-complex	649	8	645	0	553	0	973	0	849	0	637	0
vounge	long-complex	637	0	832	9	621	8	994	8	1020	9	729	23
plault	long-complex	653	0	737	0	605	7	957	15	980	17	795	29
grodge	long-complex	560	0	649	10	675	0	903	8	705	10	611	7
clouch	long-complex	667	0	801	0	628	0	981	0	1000	0	720	0
brauce	long-complex	491	15	1013	0	531	0	816	23	1276	18	688	14

Appendix M

Participant data from Experiment 7

	Task 1: Tone Identification											
	Short SOA (50 msec)				Intermediate SOA (250 msec)				Long SOA (750 msec)			
	Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	632	3.7	545	0.0	728	0.0	594	0.0	721	0.0	618	0.0
2	520	3.5	510	0.0	692	0.0	560	0.0	611	0.0	553	4.2
3	669	0.0	679	3.5	672	0.0	705	3.5	781	6.9	826	10.7
4	501	3.5	510	0.0	461	3.7	439	0.0	472	6.9	472	3.6
5	710	3.6	808	3.6	928	0.0	1003	0.0	1198	3.5	1081	0.0
6	362	0.0	386	3.6	366	0.0	373	0.0	377	0.0	390	0.0
7	593	3.9	562	7.4	616	0.0	577	3.6	645	7.7	594	0.0
8	543	0.0	499	3.6	566	7.4	560	0.0	600	7.1	639	3.7
9	346	0.0	329	0.0	365	7.1	363	3.6	375	3.7	370	0.0
10	486	0.0	468	3.6	538	0.0	528	3.6	515	3.6	519	0.0
11	380	6.9	441	7.4	387	3.6	378	0.0	386	0.0	368	0.0
12	906	0.0	777	0.0	810	0.0	871	3.6	1123	0.0	1078	0.0
13	915	3.9	814	0.0	854	0.0	926	0.0	1037	0.0	966	0.0
14	625	7.1	587	0.0	550	0.0	633	3.7	636	0.0	723	0.0
15	883	7.4	758	7.1	764	0.0	654	7.1	833	3.7	803	3.6
16	511	3.6	491	7.1	502	3.6	482	0.0	565	3.9	504	0.0
17	925	3.7	903	3.7	954	4.4	872	3.7	1116	3.6	1052	0.0
18	478	17.9	455	14.3	497	14.3	511	0.0	549	10.7	464	3.6
19	569	3.6	553	0.0	624	0.0	610	3.6	576	3.6	577	0.0
20	1346	14.3	1353	7.1	1422	7.1	1328	10.7	1410	14.3	1534	10.7
21	582	12.0	638	7.7	636	7.4	706	11.1	928	3.9	921	0.0
22	476	10.7	586	7.1	542	3.6	559	3.6	607	0.0	653	0.0
23	386	0.0	462	3.7	527	0.0	531	3.7	502	3.6	484	0.0
24	557	0.0	503	3.6	527	0.0	521	3.6	624	0.0	599	0.0
25	476	0.0	458	0.0	481	0.0	453	0.0	480	0.0	484	6.7
26	445	3.9	500	0.0	448	0.0	445	0.0	496	0.0	488	0.0
27	506	0.0	488	0.0	472	2.0	521	0.0	479	0.0	488	0.0
28	637	0.0	689	0.0	780	0.0	738	3.6	1022	0.0	1093	0.0
29	426	3.5	455	3.5	434	10.3	399	0.0	441	3.9	479	10.7
30	464	0.0	420	7.4	424	3.7	451	3.7	458	3.6	481	3.6
31	563	0.0	606	0.0	559	0.0	631	0.0	784	0.0	767	3.5
32	667	7.4	697	3.6	643	0.0	622	0.0	691	0.0	725	0.0
33	735	0.0	651	0.0	753	0.0	721	0.0	906	0.0	924	0.0
34	673	3.6	679	0.0	676	0.0	714	0.0	640	0.0	659	0.0
35	443	3.5	392	0.0	432	0.0	446	0.0	497	0.0	435	3.9
36	556	0.0	630	0.0	542	0.0	550	0.0	570	0.0	564	0.0
37	440	3.9	476	0.0	550	0.0	551	0.0	493	3.6	487	6.9
38	539	3.7	512	0.0	481	0.0	559	0.0	443	3.5	473	3.3
39	507	7.4	471	6.7	541	3.6	495	7.4	599	0.0	593	0.0

Appendix M (continued)

Participant data from Experiment 7

	Task 2: Nonword Naming											
	Short SOA (50 msec)				Intermediate SOA (250 msec)				Long SOA (750 msec)			
	Sparse N		Dense N		Sparse N		Dense N		Sparse N		Dense N	
Subject	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
1	1013	0.0	937	0.0	935	0.0	773	3.9	659	3.9	544	0.0
2	854	0.0	837	0.0	829	3.5	704	3.6	518	0.0	432	0.0
3	878	0.0	897	3.5	659	0.0	730	0.0	570	0.0	560	0.0
4	684	0.0	633	0.0	561	0.0	562	0.0	451	0.0	450	0.0
5	1111	3.6	1234	3.6	1124	0.0	1213	0.0	946	0.0	815	0.0
6	719	3.6	733	0.0	622	0.0	607	0.0	556	11.5	547	3.7
7	946	11.5	952	3.7	847	3.6	729	7.1	707	11.5	594	0.0
8	883	7.7	767	0.0	761	14.8	687	7.1	651	10.7	564	7.4
9	774	7.1	720	0.0	733	10.7	669	0.0	576	0.0	527	3.7
10	997	25.0	993	10.7	822	25.9	870	3.6	542	14.3	508	10.7
11	731	3.5	733	0.0	514	3.6	573	3.5	497	0.0	480	3.6
12	1276	19.2	1092	0.0	968	11.1	1077	3.6	834	3.7	787	0.0
13	1258	3.9	1156	7.1	973	7.4	1042	3.7	860	3.6	748	14.3
14	886	14.3	868	0.0	801	0.0	806	0.0	632	7.1	660	0.0
15	1654	7.4	1296	3.6	1610	7.7	1086	10.7	1307	7.4	1252	3.6
16	711	21.4	672	14.3	526	17.9	509	7.1	503	11.5	452	7.4
17	1357	7.4	1289	3.7	1168	0.0	1091	3.7	819	3.6	831	0.0
18	774	17.9	765	3.6	661	14.3	681	7.1	576	21.4	547	3.6
19	877	0.0	802	3.9	717	3.6	723	0.0	635	0.0	523	7.1
20	1945	0.0	1831	0.0	1902	3.6	1585	0.0	1049	3.6	1248	0.0
21	847	4.0	833	3.9	657	7.4	723	22.2	650	3.9	650	0.0
22	916	14.3	974	10.7	800	14.3	773	3.6	622	10.7	616	14.3
23	704	3.6	779	0.0	691	0.0	663	0.0	511	0.0	486	0.0
24	947	17.9	849	14.3	777	3.7	703	21.4	692	7.1	625	18.5
25	1030	0.0	981	0.0	872	3.5	889	0.0	601	4.0	630	3.3
26	759	7.7	812	0.0	683	3.6	634	0.0	563	0.0	507	0.0
27	887	6.0	890	1.9	714	3.9	759	1.9	613	1.9	625	1.9
28	943	3.6	997	0.0	867	3.5	852	10.7	772	3.6	764	3.6
29	610	0.0	599	0.0	479	0.0	451	7.4	441	0.0	449	0.0
30	701	0.0	656	0.0	505	0.0	517	0.0	491	3.6	460	0.0
31	848	3.6	932	3.6	791	0.0	758	0.0	581	3.7	590	3.5
32	937	0.0	994	0.0	683	0.0	655	0.0	569	0.0	634	0.0
33	1170	3.7	1136	0.0	1045	3.7	951	3.5	751	0.0	773	0.0
34	1027	0.0	1042	3.5	847	0.0	860	3.6	519	0.0	572	0.0
35	668	0.0	652	3.6	539	4.0	531	0.0	445	4.4	446	3.9
36	993	7.1	1047	0.0	795	13.8	746	10.7	571	10.0	502	7.1
37	913	11.5	970	0.0	913	14.8	884	7.4	709	14.3	677	0.0
38	943	0.0	945	3.7	733	3.3	817	0.0	602	3.5	584	3.3
39	1019	0.0	997	3.3	876	7.1	822	7.4	682	3.6	696	3.3

Appendix N

Item data from Experiment 7

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
beve	low	506	6	643	8	907	9	882	13	1035	8	770	18
blebb	low	571	0	852	0	629	0	973	8	1046	17	668	0
clall	low	601	10	675	0	669	0	1052	10	922	13	824	0
clule	low	618	0	622	0	1047	0	994	0	827	0	659	0
cooge	low	585	0	691	0	591	0	1182	0	858	0	598	15
craun	low	624	0	578	0	640	0	989	0	832	0	672	0
deche	low	622	0	662	0	556	0	871	0	1110	0	558	0
dreff	low	663	6	570	0	753	0	983	0	790	0	663	0
drete	low	566	0	572	0	707	9	989	25	794	13	672	18
feuth	low	629	14	631	11	677	0	1261	7	1104	0	776	15
flalp	low	598	9	677	0	633	0	949	9	871	0	766	13
geche	low	630	0	591	0	806	0	993	0	828	31	790	17
gluce	low	700	8	577	0	698	9	1071	8	978	13	762	0
gowth	low	598	0	561	0	668	0	970	0	939	6	681	18
gruke	low	529	6	605	9	808	0	1061	18	807	9	783	8
gruse	low	539	8	508	0	770	20	1025	8	826	13	723	10
jowth	low	534	0	564	0	683	0	962	0	796	9	686	18
leuth	low	496	0	573	0	726	0	890	11	958	8	645	11
naice	low	538	0	629	6	668	0	1007	8	874	0	764	11
poosh	low	645	0	634	8	679	0	1057	18	837	25	714	0
prafe	low	584	0	507	0	614	9	945	29	732	6	631	27
praff	low	607	0	542	6	516	10	870	25	752	0	587	0
prewt	low	642	0	603	0	755	0	975	8	850	0	698	0
shebe	low	535	0	659	0	752	8	862	0	1015	40	583	17
shilm	low	559	0	630	0	678	0	909	9	776	17	671	12
sherv	low	763	0	650	0	594	0	997	8	786	6	557	9
shisp	low	510	0	509	0	644	0	881	12	640	9	661	17
skebe	low	616	0	734	0	579	0	1001	45	878	25	578	7
spalc	low	588	0	551	0	622	8	901	6	658	18	602	0
spaul	low	660	0	515	0	723	0	933	0	660	0	826	10
spebe	low	875	18	828	0	705	0	1219	27	987	23	640	0
spaub	low	573	0	485	0	684	0	866	0	837	0	620	0
staub	low	594	0	564	0	829	0	923	0	688	8	641	0

Appendix N (continued)

Item data from Experiment 7

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
stegg	low	557	0	445	7	744	8	841	0	614	0	617	0
sturb	low	511	0	707	0	692	7	825	9	755	25	648	0
teece	low	402	0	922	0	889	0	731	0	1135	0	672	0
vowth	low	544	0	599	6	717	0	938	0	837	0	712	8
weece	low	713	0	486	0	726	0	1075	8	805	7	718	9
zowth	low	502	9	636	0	750	0	794	9	768	8	664	0
bapt	low	512	0	708	0	587	0	793	18	858	0	598	0
dakt	low	736	9	512	0	542	0	1148	0	669	8	499	0
demf	low	580	8	567	0	712	9	905	0	721	0	801	0
demk	low	530	8	542	0	746	8	804	0	699	0	638	0
dild	low	609	0	548	0	642	0	1037	7	659	9	627	0
dund	low	650	8	567	0	592	0	937	0	694	0	587	0
fapt	low	532	6	566	9	748	0	915	0	810	0	648	0
femp	low	454	18	591	8	556	0	745	18	751	8	567	6
fenf	low	620	0	656	0	704	0	992	6	874	0	695	0
fimk	low	623	0	701	0	590	0	993	8	973	0	666	8
fomp	low	620	0	628	0	670	0	1014	0	892	0	622	0
fuld	low	585	0	666	0	579	6	959	18	896	8	611	13
hamf	low	457	6	643	8	733	8	854	6	966	0	720	0
hemk	low	599	6	610	9	702	9	967	0	811	0	719	0
hept	low	571	8	551	0	650	0	906	8	779	7	519	8
himp	low	591	0	668	6	865	17	1005	0	824	0	694	0
kect	low	682	0	546	0	648	0	1070	18	674	8	616	19
kimp	low	440	6	624	0	772	0	837	0	785	0	629	0
lamf	low	632	8	739	8	593	6	958	0	863	0	596	0
limf	low	548	8	524	0	614	0	878	0	913	0	542	0
lomk	low	480	7	604	0	702	0	816	0	825	0	635	0
lonf	low	519	25	734	0	488	7	910	0	882	0	531	0
mamk	low	750	8	558	0	592	6	1135	0	833	0	633	6
nald	low	591	0	719	17	669	8	928	0	839	0	596	0
nant	low	561	0	605	0	615	0	887	0	779	0	669	0
pomk	low	517	0	601	0	649	0	844	0	886	10	688	0
pumk	low	565	0	630	6	651	0	956	0	971	0	596	0

Appendix N (continued)

Item data from Experiment 7

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
ramf	low	690	0	752	8	643	0	988	0	911	0	620	0
rild	low	682	17	678	0	611	0	1097	0	862	8	608	0
samf	low	577	0	659	0	589	0	807	0	752	8	554	0
samk	low	555	6	781	9	715	0	912	6	961	0	595	0
semp	low	535	9	620	0	660	0	869	0	721	8	537	0
simk	low	519	0	584	0	689	0	854	7	727	0	669	17
suld	low	555	0	554	0	618	0	872	0	748	0	622	0
sumf	low	530	8	659	0	660	0	810	15	844	0	530	0
tamf	low	541	0	613	0	609	0	881	0	749	0	555	0
timk	low	613	8	631	8	538	6	990	0	801	0	545	0
timp	low	481	0	675	0	731	8	885	0	832	0	621	8
tuld	low	628	6	564	0	791	0	927	6	662	0	657	0
tunf	low	596	0	645	9	646	0	1101	0	767	0	626	0
wimf	low	613	10	606	0	693	7	919	0	822	8	629	0
wund	low	604	8	569	0	773	0	877	0	886	0	902	0
bouth	high	498	7	676	0	806	0	887	13	984	0	774	9
brench	high	697	0	689	0	644	0	1147	0	900	8	648	0
brate	high	703	0	625	0	720	0	1046	6	813	27	641	0
chank	high	570	0	604	0	609	0	948	0	767	0	641	0
chack	high	657	6	543	8	753	0	1015	0	730	8	616	8
chone	high	593	0	606	0	688	0	909	15	856	6	620	8
datch	high	561	0	687	0	394	0	948	0	851	0	462	0
drass	high	534	13	616	0	717	0	924	0	777	0	595	0
drave	high	579	0	541	6	659	0	973	17	706	0	574	0
fatch	high	593	0	530	0	708	8	916	0	730	9	602	0
flink	high	530	18	645	8	615	13	871	0	850	0	660	13
gatch	high	533	0	577	0	603	0	931	0	713	0	566	0
glave	high	806	0	528	0	680	0	1264	23	868	0	658	10
gouse	high	576	8	588	0	709	0	1077	15	793	6	670	0
grafe	high	668	0	472	0	751	0	1057	0	690	36	704	17
grame	high	566	8	600	0	707	10	884	8	848	0	652	10
jatch	high	609	0	609	0	728	0	984	6	851	10	673	25
louth	high	613	0	461	6	637	9	1012	0	685	0	555	0

Appendix N (continued)

Item data from Experiment 7

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
natch	high	570	8	620	0	727	0	965	0	821	6	714	9
pouse	high	549	8	606	0	654	0	969	0	880	8	734	0
prine	high	582	0	612	7	662	9	924	0	835	0	651	0
pross	high	660	0	560	0	732	0	981	0	738	6	642	0
prown	high	745	18	527	0	709	0	1068	0	809	13	599	0
shace	high	620	6	598	0	756	9	956	0	762	27	558	18
shalk	high	716	0	713	0	573	0	958	0	802	18	555	6
shork	high	563	8	523	6	550	9	794	8	701	6	560	0
shint	high	547	0	531	9	682	0	845	0	696	9	578	0
spave	high	564	9	649	0	650	6	910	0	776	17	612	6
spint	high	536	6	590	0	688	0	859	0	730	0	549	18
spoot	high	480	0	612	0	655	8	746	0	711	0	759	0
spile	high	575	9	658	0	595	0	888	9	810	0	565	0
spart	high	590	0	498	0	747	0	884	0	597	0	631	8
steet	high	524	6	545	0	813	9	1009	6	679	0	655	0
stell	high	595	0	662	0	692	0	941	0	831	0	529	0
stort	high	570	0	649	0	667	0	825	0	802	0	616	13
touth	high	432	0	794	0	732	0	719	0	1272	33	605	0
vatch	high	587	17	626	0	661	0	932	8	824	0	631	0
wouse	high	589	0	501	0	681	0	948	10	946	0	885	0
zatch	high	598	0	694	0	617	6	963	0	863	0	664	0
bant	high	586	0	664	0	626	0	900	0	827	0	607	0
dast	high	630	0	630	0	465	13	866	10	753	0	495	0
dend	high	590	0	547	6	709	0	973	0	730	0	617	8
dest	high	560	0	623	13	611	0	907	0	775	0	736	0
dind	high	531	0	561	0	727	0	887	0	731	9	636	9
dunt	high	540	0	666	8	677	0	825	0	769	0	578	0
fant	high	482	6	702	0	759	0	835	0	929	9	610	0
fent	high	574	0	734	0	655	0	918	0	890	0	587	0
fest	high	521	0	641	9	717	0	922	0	789	0	660	8
fint	high	720	8	555	0	533	8	1164	8	779	0	628	0

Appendix N (continued)

Item data from Experiment 7

		Task 1: Tone Identification						Task 2: Nonword Naming					
		50 msec SOA		250 msec SOA		750 msec SOA		50 msec SOA		250 msec SOA		750 msec SOA	
stimulus	Density	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E	RT	%E
fost	high	577	0	515	6	684	0	928	0	703	0	671	8
fust	high	622	0	606	0	622	6	950	0	769	0	547	6
hant	high	590	0	610	17	737	9	931	0	826	0	641	9
hend	high	559	0	594	0	680	0	955	6	746	0	601	8
hest	high	611	0	508	0	632	0	925	0	707	0	540	9
hust	high	578	0	545	7	644	8	882	0	737	0	592	0
kest	high	560	0	547	0	647	0	853	8	697	0	587	0
kint	high	587	0	620	9	697	0	908	0	739	0	548	0
lant	high	618	8	609	0	522	0	923	0	778	0	534	0
lind	high	560	0	576	0	602	0	883	7	764	0	527	0
lond	high	592	0	619	0	688	0	869	0	832	9	483	0
lont	high	611	0	595	8	634	7	866	0	756	0	650	7
mant	high	546	0	681	0	742	0	885	0	877	0	630	0
nast	high	543	13	652	0	673	0	914	0	775	0	577	0
nent	high	627	0	665	0	550	0	1016	0	896	0	704	0
pont	high	527	0	609	0	659	0	865	0	774	0	612	0
pust	high	526	0	601	0	713	0	858	0	876	0	767	0
rast	high	485	9	721	0	686	6	802	0	834	0	595	0
rint	high	569	8	501	8	614	0	870	8	740	0	608	0
sant	high	555	17	619	0	656	0	880	0	784	0	698	0
sast	high	562	0	637	0	670	0	886	0	782	0	564	0
sest	high	592	9	713	0	606	0	869	0	888	8	571	0
sint	high	581	0	546	0	699	0	932	0	642	9	553	0
sunt	high	472	0	522	0	599	0	798	0	713	0	610	0
sust	high	578	0	604	0	825	10	889	0	772	0	650	0
tant	high	566	0	626	7	689	0	825	0	732	0	670	0
tast	high	655	9	633	0	660	0	952	18	767	8	581	0
tind	high	612	0	623	0	680	0	1089	0	722	17	598	0
tunt	high	511	0	646	9	733	0	897	0	764	0	619	0
tust	high	592	0	634	0	737	0	1172	0	836	0	599	0
wint	high	585	0	816	0	660	0	876	0	976	0	697	6
wust	high	520	0	576	7	555	0	851	0	752	0	747	0

Appendix N (continued)

Item data from Experiment 7

			Task 2: Nonword Naming					
			Short SOA (50 msec)		Intermediate SOA (250 msec)		Long SOA (750 msec)	
number	stimulus	neighbourhood density	RT	%E	RT	%E	RT	%E
34	stegg	low	841	0	614	0	617	0
35	sturb	low	825	9	755	25	648	0
36	teece	low	731	0	1135	0	672	0
37	vowth	low	938	0	837	0	712	8
38	weece	low	1075	8	805	7	718	9
39	zowth	low	794	9	768	8	664	0
40	bapt	low	793	18	858	0	598	0
41	dakt	low	1148	0	669	8	499	0
42	demf	low	905	0	721	0	801	0
43	demk	low	804	0	699	0	638	0
44	dild	low	1037	7	659	9	627	0
45	dund	low	937	0	694	0	587	0
46	fapt	low	915	0	810	0	648	0
47	femp	low	745	18	751	8	567	6
48	fenf	low	992	6	874	0	695	0
49	fimk	low	993	8	973	0	666	8
50	fomp	low	1014	0	892	0	622	0
51	fuld	low	959	18	896	8	611	13
52	hamf	low	854	6	966	0	720	0
53	hemk	low	967	0	811	0	719	0
54	hept	low	906	8	779	7	519	8
55	himp	low	1005	0	824	0	694	0
56	kect	low	1070	18	674	8	616	19
57	kimp	low	837	0	785	0	629	0
58	lamf	low	958	0	863	0	596	0
59	limf	low	878	0	913	0	542	0
60	lomk	low	816	0	825	0	635	0
61	lonf	low	910	0	882	0	531	0
62	mamk	low	1135	0	833	0	633	6
63	nald	low	928	0	839	0	596	0
64	nant	low	887	0	779	0	669	0
65	pomk	low	844	0	886	10	688	0
66	pumk	low	956	0	971	0	596	0