PHONOLOGICAL MISMATCHES: HOW DOES THE POSITION AND DEGREE OF THE MISMATCH AFFECT SPOKEN WORD RECOGNITION?

DISSERTATION

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By

Erik C. Tracy, M.A.

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Dissertation Committee: Approved by

Professor Mark Pitt, Advisor

Professor Neal Johnson

Professor James Todd

Adviser
Psychology Graduate Program
ABSTRACT

The word recognition system is a remarkably robust system. Given this robustness, how tolerant is the system of noise within the speech signal, such as phonological mismatches? A phonological mismatch is when a phoneme is substituted in a word to create a nonsense word. For example, “bemocrat” differs from “democrat” in terms of the initial phoneme. Phonological mismatches vary along two dimensions: position (initial or medial) and distance. With regards to distance, a phoneme can be altered by either one distinctive feature (near change), or two or three distinctive features (far change). To investigate the issue of tolerance, simulations were first performed on TRACE, an influential model of word recognition, because it could provide actual results. The simulations demonstrated that the model is more tolerant of medial rather than initial mismatches, but the results were mixed concerning the distance of the mismatch. Next, three experiments were conducted. The first experiment, which utilized the phoneme monitoring paradigm, produced suspect results. The second experiment, which utilized the form priming paradigm, revealed that the recognition system is more tolerant of medial rather than initial mismatches, which confirms the results of the TRACE simulations. Similarly, the experimental results were mixed with regards to the distance of the mismatch.
Dedicated to
My Parents
&
Jeff
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VITA

July 27, 1979 ........................................Born – Amherst, New York

2000 ..................................................B.A., Psychology, SUNY Buffalo

2002..................................................M.A., Psychology,
                   The Ohio State University

2000 – Present..................................Graduate Teaching and Research
                   Associate, The Ohio State University

FIELD OF STUDY

Major Field of Study: Psychology
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CHAPTER 1
INTRODUCTION

One important property of spoken language is that the speech signal is inherently noisy. Stated differently, people are sloppy talkers. Speakers often vary their speech rate, add and delete phonemes from words, and do not clearly articulate their chosen words. For example, if a speaker is talking about the "county fair", when the word "county" is produced, the /t/ will often be deleted. Yet, upon hearing "counny fair", the listener is able to understand the message being conveyed. Given this natural variation within the speech signal, the listener, for the most part, is able to understand the message that is being conveyed by the speaker. This suggests that the word recognition system is a remarkably robust system, given how it can overcome noise and variation within the speech signal.

Given this robustness of the recognition system, one question facing researchers is how tolerant is the recognition system of changes, or deviations, in the speech signal? These changes can come in the form of phonological mismatches. A phonological mismatch is when a phoneme in a word is substituted with another phoneme to create a nonsense word (pseudoword). For instance, the /d/ in "democrat" can be changed to a /b/ in order to create the pseudoword "bemocrat". As was demonstrated in the earlier example, phonological mismatches can vary along two dimensions, which are not
mutually exclusive: distance and position of mismatch within the utterance. With regards to distance, a phoneme can be altered by either one-distinctive feature (near mismatch), or two or three distinctive features (far mismatch). Here, a distinctive feature is defined by either voicing, place of articulation, or manner of articulation. For example, the /d/ in "democrat" can be altered to either a /b/ (near mismatch) or /f/ (far mismatch) to create the pseudowords "bemocrat" and "femocrat", respectively. /b/ and /d/ differ in terms of voicing, while /d/ and /f/ differ in terms of voicing, place of articulation, and manner of articulation.

Altering the distance of the mismatch tests the tolerance of the recognition system. If the recognition system is tolerant of the degree of mismatch, then utterances containing near mismatches would result in high levels of lexical activation because they share common distinctive features with the original phoneme. Here, lexical activation refers to how much activation the word in memory has. Far mismatches would not result in high levels of lexical activation because they do not share these common distinctive features. If the processing system is intolerant of the degree of mismatch, then both near and far mismatch would result in lower levels of lexical activation. For example, if the recognition system is tolerant of near mismatches, then the word “democrat” will become activated when the pseudoword “bemocrat” is presented to the system.

With regards to position of the phonological mismatch, utterances can contain initial or medial mismatches. For example, “bemocrat” contains an initial mismatch,
while “denocrat” contains a medial mismatch. (Both mismatches are also near
mismatches.) Altering the position of the phonological mismatch not only tests whether
the recognition system is tolerant of initial or medial mismatches, but it can also test
whether a word’s initial phoneme holds a special status in word recognition. If the initial
phoneme has a special status in recognition, then altering it will greatly decrease the
likelihood that the intended word will become activated. For example, if the initial
phoneme has a special status, then the word “democrat” would be more likely to become
activated if the pseudoword “denocrat” was presented to the recognition system rather
than the pseudoword “bemocrat”.

Furthermore, if the recognition system is tolerant of only initial mismatches, then
lexical activation levels should be higher for initial mismatches rather than medial
mismatches. If the recognition system is tolerant of only medial mismatches, then lexical
activation levels should be higher for medial mismatches rather than initial mismatches.
If the recognition system is intolerant to either initial or medial mismatches, then lexical
activation levels should be low for both initial and medial mismatches. Moreover, would
the position of the mismatch have a greater effect on lexical processing than the distance
of the mismatch?

A number of steps will be taken here to provide clear answers to these questions.
First, simulations will be run in order to assess how TRACE (McClelland and Elman,
1986) processes phonological mismatches. Next, in order to clarify some of the
inconsistencies that have surfaced in the phonological mismatch literature, as well as to verify the TRACE simulations, a series of experiments will be run that test the effects of phonological mismatches.

TRACE was selected to investigate how it handles phonological mismatches for a variety of reasons. First, jTRACE (Strauss, Magnuson, and Harris, 2005), an implementation of TRACE, can provide actual results as to how TRACE processes phonological mismatches. Second, TRACE was chosen because it’s an influential model of word recognition. Experimental evidence matching the model’s output will increase support for the model. Conversely, experimental evidence that does not match the model’s output will decrease support for the model, and possibly suggest that another model more accurately reflects true lexical processing.

TRACE is composed of three different levels: the feature, phoneme, and word level. The feature level contains nodes representing different phonetic distinctive features, such as voicing. The nodes in the feature level are connected to the nodes in the phoneme level by bi-directional links. These links send excitatory activation back and forth between the two levels. The nodes in the phoneme level are also connected by excitatory bi-directional links to the nodes in the word level. As information enters TRACE, the feature nodes are activated first, which sends activation to the phoneme
nodes, which in turn, sends activation to the word nodes. The activated word nodes then send additional activation back down to the phoneme nodes, which in response, send activation to the feature nodes.

For example, if the word “democrat” was presented to TRACE, the /d/ would enter the processing system first. In response to this input, the relevant features nodes, such as “voicing”, “plosive”, and “alveolar” would become activated. Next, the feature nodes would activate the related phoneme nodes, such as “d”. Once the phoneme nodes become activated, they send excitatory activation to word nodes that contain /d/, such as “democrat” and “Deborah”. In turn, these activated word nodes then send activation back down to the phoneme nodes that are included in the respective words, such as “e” and “m”. These activated phoneme nodes then send activation to the relevant feature nodes, such as “voicing” and “nasal”. Therefore, in response to the presentation of a single phoneme, a host of phoneme nodes, word nodes, and additional feature nodes become activated. As more information enters the processing system, the nodes that match the speech signal increase their activation levels over mismatching nodes.

Furthermore, with regards to the word level, words are connected to other words via bi-directional inhibitory links. This allows for an activated word to inhibit other words in order for the activated word to increase its chances that it will become the recognized word. For example, if the phonemes /d/, /e/, and /m/ were presented to TRACE, then the words “democrat” and “demonstrate” would become activated, and
would be included in the initial cohort of words. However, as more phonemes are introduced to the model, such as /^/ and /k/, then “democrat” will increase its activation levels. In turn, “democrat” would also inhibit the other potential lexical candidate, “demonstrate”. Thus, it would be more likely that “democrat” would become the recognized word.

Compared to other models of word recognition, TRACE is relatively tolerant of phonological mismatches because of its feature matrix, which allows feature nodes to activate multiple phoneme nodes. For example, in terms of phonetic distinctive features, /d/ can be described as voiced, plosive (manner of articulation), and alveolar (place of articulation). Therefore, when the speech signal is presented to TRACE, the relevant feature nodes are also activated. These feature nodes, in turn, fully activate the phoneme node "d". However, these particular activated feature nodes also partially activate other related phoneme nodes, such as "t" and "b". /t/ can be described as plosive and alveolar, while /b/ can be described as plosive and voiced.

Yet, the question still remains as to which particular phonological mismatches are and are not tolerated by TRACE. Due to its feature matrix, it is predicted that TRACE is tolerant of near mismatches, but not far mismatches. With regards to the position of the mismatch, it is predicted that initial mismatches should prove more disruptive than medial mismatches because recognition in TRACE occurs in a sequential fashion. In other words, with an initial mismatch, the intended word would not be included in the
initial cohort of words. For example, if the pseudoword “femocrat” were presented to the model, then the initial cohort would include words that begin with /f/. The intended word, “democrat”, would not be included in this initial cohort and, thus, the intended word would have less of a chance of becoming the recognized word.

However, as reported in Frauenfelder and Peeters (1998), they found evidence that TRACE is unable to overcome initial near mismatches. They described simulations in which TRACE’s performance was well below 25% when utterances containing initial near mismatches, such as “shigarette”, were presented to the model. When the original words (“cigarette”) were presented to the model, performance was at 100%. While McClelland and Elman (1986) claim that TRACE is able to overcome initial near mismatches, such as “bleasant” (pleasant), Frauenfelder and Peeters contend that this is an anomaly. While Frauenfelder and Peeters only report on the initial near mismatch condition, it is unclear if the simulations also included medial and far mismatches. Therefore, in order to clarify whether TRACE is tolerant of initial near mismatches, simulations will be run in which initial near mismatches are tested against the words from which they were derived. Furthermore, to more fully investigate the tolerance of TRACE, initial far, medial near, and medial far mismatches will also be tested.

In order to properly investigate this matter, jTRACE (Strauss, Magnuson, and Harris, 2005) will be used, which is a user-friendly instantiation of TRACE. Here, the model will be presented words and their respective pseudowords, which contain initial
near (IN), initial far (IF), medial near (MN), and medial far (MF) phonological mismatches. Of interest is how the lexical activation levels of these utterances compare against the words’ lexical activation levels. The results of the jTRACE simulations will then be discussed in relation to human data that have tested the effects of phonological mismatches.
CHAPTER 2

TRACE SIMULATIONS

Simulations for twenty different words and eighty pseudowords were performed. Given the phonological mismatch conditions, each word resulted in four different pseudowords. As discussed previously, McClelland and Elman (1986) claim that TRACE is able to overcome initial near mismatches, but Frauenfelder and Peeters (1998) contend that their example is an anomaly. Therefore, to rule out anomalous effects, these various simulations were averaged together with regards to their respective condition. For example, all of the twenty word simulations were averaged together, as well as all of the IN simulations.

Method

Stimuli and Procedure

All of the words were chosen from jTRACE’s default lexicon and each contained at least two syllables. Two of the words (“luxury” and “possible”) contained three syllables. As mentioned previously, there were five different experimental conditions: Word, IN, IF, MN, and MF. (The Word condition served as a comparison condition.) For one of the simulations, “secret”, the input stimuli were as follows: word (/sikr^t/), IN (/ʃikr^t/), IF (/gikr^t/), MN (/sigr^t/), and MF (/siʃr^t/).
The default lexicon that was used contain approximately 214 words of varying frequencies that contained either one, two, or three syllables. The simulations were carried out using the default parameters of the model; Appendix A details these parameters. As for the actual simulation, each stimulus was presented to the system one at a time and the system was then run for approximately 100 cycles.

Results

The average response probabilities for the five experimental conditions are shown in Figure 1. Appendix B details the parameters that were chosen in graphing the data. Overall, the Word condition had the greatest response probabilities of the five conditions. Both medial mismatches had a greater response probability than both of the initial mismatches. With regards to distance of the mismatch, MN mismatch had a greater response probability than MF mismatch. This result is not surprising because TRACE’s feature matrix predicts that near mismatches will have more lexical activation than far mismatches. However, there is not much of a difference in the response probabilities for the initial mismatches. Only around cycle 80 does the IN mismatch have a greater response probability than the IF mismatch.

Inferential statistics were performed on the data to determine if the five experimental conditions differed from one another. To better assess if significant differences were present throughout the course of the simulation, the data were collapsed
across cycles 50 to 80, and a one-way ANOVA was performed in order to determine if any of the five conditions differed significantly from one another. These particular cycles were chosen because at cycle 50, the utterances begin to gain activation, some more than others. Cycle 80 was chosen because activation levels seem to peak at this point. After cycle 80, the lexical activation levels for the utterances begin to decrease.

The ANOVA revealed a significant effect, $F(4, 150) = 40.672$, $p < 0.001$. Bonferroni post-hoc tests revealed that the Word condition differed from each phonological mismatch condition, $p < 0.001$. The IN condition differed from the MN and MF condition, $p < 0.004$, and the IF condition also differed from the MN and MF condition, $p < 0.017$. The IN and IF conditions did not differ significantly from one another, $p = 1.00$. The difference between the MN and MF conditions was marginally significant, $p = 0.074$.

Discussion

Overall, the Word condition had the greatest response probability. All four phonological mismatches had a smaller response probability than the Word condition, which suggests that these particular utterances did not result in as much lexical activation as the words from which they were derived.

With regards to the position of the phonological mismatch, medial mismatches have a greater response probability than initial mismatches. This suggests that TRACE is sensitive to word-initial information. If the initial phoneme is altered, then it is assumed
that the intended word is not included in the initial cohort of words. The intended word may gain lexical activation later in the recognition process, but its lexical activation levels are greatly reduced. For example, if the utterance “shecret” were presented to TRACE, then the intended word, “secret” would not be included in the initial cohort. Rather, words beginning with /ʃ/, such as “shrubbery” and “shin” would be included in the initial cohort. It is not until later in recognition process, after more of the speech signal is processed, that “secret” begins to gain lexical activation.

A medial mismatch would prove less disruptive in TRACE because it does not play a central role in word recognition. If an utterance containing a medial near mismatch (“segret”) were introduced to the processing system, then upon presentation of the initial phoneme (/s/), the intended word (“secret”) would become initially activated. As additional phonemes enter the processing system, the intended word’s activation level increases. However, once the medial mismatch is encountered, the intended word would still retain some of its activation, even if the overall activation levels decrease relative to the original word.

With regards to the distance of the mismatch, there are hardly any differences in the response probabilities between the IN and IF mismatches. This suggests that TRACE is not sensitive to the distance of the initial mismatch, which confirms Frauenfelder and Peeter’s (1998) contention. If TRACE were able to overcome initial near mismatches, then a greater variety of potential words would be included in the initial cohort.
Returning to a previous example, is “shecret” were presented to TRACE, then words such as “shrubbery” and “secret” would both be included in the initial cohort since /s/ and /ʃ/ are phonetically similar. These simulation results suggest that this is not the case.

Overall, the MN condition had higher levels of lexical activation than the MF condition, although this finding approached significance.

In summary, the results of the simulations suggest that the position of the phonological mismatch affects recognition. TRACE is more tolerant of medial mismatches rather than initial mismatches. With regards to distance, TRACE is intolerant to both IN and IF mismatches, while TRACE is slightly more tolerant of MN rather than MF mismatches.

Phonological Mismatch Literature

Most of the experimental data concerning the effects of phonological mismatches do not match the TRACE simulations. To further confuse the situation, the experimental evidence is mixed when it comes to which phonological mismatches are tolerated by the recognition system and which mismatches are not tolerated. Some argue that the recognition system is relatively intolerant of phonological mismatches (Marslen-Wilson and Zwitserlood, 1989), while others contend that the recognition system is relatively tolerant of mismatches (Connine, Titone, Deelman, and Blasko, 1997).

Experimental evidence provided by Marslen-Wilson and Zwitserlood (1989) demonstrated that the recognition system is intolerant of any initial phonological
mismatch, regardless of distance. This finding matches the TRACE simulation results in that it was found that TRACE was relatively intolerant of both initial near and far mismatches. Using a cross-modal semantic priming task, Marslen-Wilson and Zwitserlood found that if an utterance contained an initial mismatch, lexical activation levels were significantly reduced compared to lexical activation levels for the word itself. For example, upon hearing the spoken word "honey", participants were relatively fast at responding to the visual probe, "bee". However, upon hearing the mismatched utterance "money", participants were slower at responding to the same visual probe. This finding occurred regardless of the distance of the mismatch.

Furthermore, from these results, the authors concluded that word onsets have a special status in word recognition. Marslen-Wilson, Moss, and van Halen (1996) also found similar results. Yet, the claims of Marslen-Wilson and Zwitserlood (1989) are not wholly supported by their findings. In their experiment, only the initial phoneme was altered, not a medial phoneme. The recognition system, in general, could be sensitive to any phonological mismatch, regardless of position. To make the claim that the recognition system is more sensitive to initial rather than medial mismatches, the lexical activation levels of an initial mismatching utterance should be significantly less than the lexical activation levels of a medial mismatching utterance.

Frauenfelder, Scholten, and Content (2001) demonstrated that the recognition system is intolerant of initial far mismatches and tolerant of initial near phonological
mismatches under certain conditions. Using a phoneme monitoring task, they found that an initial near phonological mismatch resulted in relatively fast reaction times, relative to a control pseudoword, but only when the to-be monitored (target) phoneme was situated at word-offset and not word-internally. For example, in the first condition, with respect to the word “vocabulary”, the target phoneme was /l/; in the second condition, the target phoneme was the final /i/. Reaction times were greater for stimuli with an initial near mismatch (“focabulary”) in the second condition than in the first condition. Stimuli with an initial far mismatch (“socabulary”) resulted in relatively slow reaction times in both conditions. The authors concluded that when the target phoneme occurred at word offset, there was enough bottom-up support to overcome the initial near mismatch. A target phoneme that occurred word-internally did not result in enough bottom-up support.

The results of this experiment are mixed with regards to the TRACE simulations. With regards to initial near mismatches, the TRACE simulations demonstrated that initial near mismatches are not tolerated, yet Frauenfelder et. al. (2001) demonstrated that the recognition system is somewhat tolerant of initial near mismatches. With regards to initial far mismatches, the TRACE simulations demonstrated that the recognition system is intolerant of these particular mismatches. This finding matches the results of Frauenfelder et. al. While the TRACE simulations partially match with these experimental findings, Frauenfelder et. al. clearly demonstrated that the recognition system is intolerant to initial far mismatches, but tolerant of initial near mismatches.
A second experiment by Frauenfelder et. al. (2001) revealed that the recognition system is intolerant of medial near mismatches. Reaction times for a word ("vocabulary") were relatively fast, regardless of the position of the target phoneme, which occurred at two different positions word-internally. For a mismatched utterance ("vocabunary"), the target phoneme either occurred directly before or after the mismatched phoneme. In this example, the target phonemes were the initial /æ/ or /j/ respectively. Reaction times were significantly slower when the target phoneme occurred after the mismatch rather than before the mismatch. This result suggests that the recognition system is intolerant to medial near mismatches. The experimental results are contradictory to the TRACE simulations. The TRACE simulations demonstrated that of the four phonological mismatch conditions, medial near mismatches resulted in the greatest amount of lexical activation.

In contrast to the previous findings, there is also ample evidence claiming that the recognition system is relatively tolerant of phonological mismatches (Allopenna, Magnuson, and Tanenhaus, 1998). Using a form-priming paradigm, Slowiaczek, Nusbaum, and Pisoni (1987) found that identification responses for utterances containing phonological mismatches were similar, regardless of the position of the phonological mismatch. In two experiments, participants had to identify a target word embedded in noise, which was preceded by a prime. In the first experiment, the prime and target differed only in terms of the initial phoneme, and in the second experiment, the prime and
target differed only in terms of the final phoneme. Example stimuli include “hand sand” and “still stiff”, respectively. Results demonstrated that participants were equally likely to identify the target word regardless of the position of the phonological mismatch.

From these results, it could be concluded that the position of the phonological mismatch did not have an affect on recognition. This conclusion contradicts the results of the TRACE simulation, which found that the position of the mismatch did have an affect on recognition. More specifically, the TRACE simulations demonstrate that initial mismatches are more detrimental than medial mismatches.

Connine, Blasko, and Titone (1993) found that the recognition system is relatively tolerant of both initial near and medial near mismatches. Using a cross-modal semantic priming task, a word's initial or medial phoneme was altered by either one or two distinctive features. For example, the word "many" could be changed to either "nany" or "mamy". Relative to the reaction times to the word condition, the authors found that reaction times for the initial near and medial near mismatch condition were both slower. Furthermore, there were no differences in reaction times between the initial near and the medial near conditions. From these results, it was concluded that the initial phoneme is not crucial for word recognition. Connine, Blasko, and Wang (1994) came to a similar conclusion. These results are contradictory to the results of the TRACE simulations. While the TRACE simulations found that an initial phoneme holds a special status in word recognition, the results of Connine et. al. (1993) suggest just the opposite.
The results of an additional experiment (Connine, Titone, Deelman, and Blasko, 1997) concluded that the recognition system is more tolerant of initial near mismatches than initial far mismatches. Using a phoneme monitoring task, the authors altered a word's initial phoneme by either a near or a far change. For instance, the initial phoneme in the word "cigarette" was changed to either /z/ (near mismatch) or /m/ (far mismatch). A control condition was included in which the initial three or four phonemes were altered ("vesurette"). It was found that reaction times to the target phoneme, which occurred word-finally, were fastest for the word condition, followed by the near mismatch condition and far mismatch condition respectively. Reaction times were slowest for the control condition. From these results, the authors concluded that as the similarity between the speech signal and the lexical representation increases, the probability that the intended word is recognized would also increase. These results suggest that the recognition system is more tolerant of initial near mismatches rather than initial far mismatches.

However, these results only occurred when the target phoneme was /t/. When the target phoneme was /k/, there were no differences in reaction times between the initial near and initial far mismatch. To explain this discrepancy in reaction times, the authors concluded that reaction times for the /t/ stimuli were the result of lexical influences, while the reaction times for the /k/ stimuli were the result of relatively fast reaction times made prior to the availability of lexical influences.
Contrary to the conclusions offered by Connine et. al. (1997), their experimental results seem mixed with regards to the degree of the mismatch. In some conditions, near mismatches produced greater levels of lexical activation than far mismatches. In other conditions, both mismatch conditions produced equal levels of lexical activation. Yet, the TRACE simulations offer a clear result with regards to the tolerance of the initial mismatch: both near and far mismatches are not tolerated. Therefore, the results of Connine et. al. conflict with the TRACE simulations.

To further confuse the situation, Boelte and Coenen (2002) found results contradictory to Connine et. al. (1997). Using a cross modal priming paradigm, they found that reaction times to the target were equivalent for an initial near and an initial far mismatch. For example, if the target was “paprika”, then the prime could either be an initial near mismatch (“baprika”) or an initial far mismatch (“zaprika”). These results seem to suggest that the recognition system does not distinguish between initial near or initial far mismatches, which contradicts a finding by Connine et. al. However, this finding is confirmed by the TRACE simulations.

In conclusion, experimental evidence has demonstrated that the recognition system is relatively tolerant to initial mismatches (Connine et. al., 1993; Connine et. al., 1994; Slowiaczek et. al., 1987), yet Marslen-Wilson and Zwitserlood (1989) contend that an initial mismatch severely disrupts lexical access. As for medial mismatches, the experimental results are mixed. Connine et. al. (1993) found that the recognition system
is relatively tolerant of medial mismatches, while Frauenfelder et. al. (2001) found the opposite result. While the empirical results are mixed, it seems as if there is a preponderance evidence suggesting that initial mismatches do not completely shut down lexical access. On the other hand, the results of the TRACE simulations clearly indicate that initial mismatches are more disruptive than medial mismatches.

With regards to distance of mismatch, the empirical evidence is again mixed. Some (Connine et. al., 1997) found evidence suggesting that the recognition system is more tolerant of near mismatches than far mismatches, while others (Boelte & Coenen, 2002) found evidence suggesting that the processing system is indifferent to either near or far mismatches. Furthermore, Marslen-Wilson and Zwitserlood (1989) contend that the recognition system is intolerant of any phonological mismatch. The results of the TRACE simulations are clear: there are no differences between IN and IF mismatches, while MN are tolerated slightly more so than MF mismatches.

In order to resolve these many discrepancies, a series of experiments will investigate how these four particular phonological mismatches (IN, IF, MN, and MF) affect recognition. Including these four different mismatch condition is beneficial in a number of ways. First, none of the previous studies have tested the effects of all four conditions. The current series of experiments will provide a more collective account of the effects of phonological mismatches. Secondly, the results of the TRACE simulations can then be interpreted in light of the new experimental evidence that included all four
phonological mismatch conditions. No single study has investigated the effects of these particular phonological mismatches with both human data and TRACE simulations. Finally, including both the IN and IF condition will help to resolve another discrepancy in the literature, which is how tolerant is the perceptual system of these particular mismatches?

To further investigate the effects of phonological mismatches, two different experimental paradigms will be used, which are the phoneme monitoring and form priming paradigms. Furthermore, the same stimuli will be used with both paradigms. This has the benefit of converging results, and it also allows for a replication across experiments. Furthermore, the use of two paradigms will rule out any anomalous effects.

These two paradigms were selected for various reasons. First, both paradigms have been used in previous experiments that investigated the effects of phonological mismatches. Connine et. al. (1997) and Frauenfelder et. al. (2001) used phoneme monitoring in their experiments, while Boelte and Coenen (2002) used form priming in their experiments. It would make sense, then, to use similar paradigms with this series of experiments.

However, even though the semantic priming paradigm was used by both Marslen-Wilson and Zwitserlood (1989) and Connine et. al. (1993), it will not be used here. One reason why this particular paradigm will not be used is due to the stimuli themselves. A large number of words will be used in this series of experiments, and it is unclear if a
majority of these stimuli have an obvious semantic associate. If there is not an obvious semantic associate, then this complicates the interpretation of the results. For example, while “democrat” might have an obvious semantic associate (“republican”), it is unclear if “salvation” and “nominate” have obvious semantic associates, even if these words have a high degree of familiarity. Furthermore, even if semantic associates were found for each word, the degree of association would vary for most of the stimuli. Some words, and their semantic associate, would have a high degree of relatedness, while other pairs would have a low degree of relatedness. This could further complicate the interpretation of the results. In the present series of experiments, a large number of words will be tested in order to rule out any items that would produce anomalous results. If only pairs of words that had a high degree of semantic relatedness were used, then this would severely limit the number of potential candidates. The phoneme monitoring paradigm and the form priming paradigm do not have these same constraints. Therefore, the semantic priming paradigm will not be used.
CHAPTER 3

EXPERIMENT 1A

Given the results of the TRACE simulation, would the results from a phoneme monitoring experiment confirm or refute these results? Furthermore, how tolerant is the recognition system of phonological mismatches? The Word condition should result in the fastest reaction times, which would indicate the highest levels of lexical activation. For example, if the string /dɛm^/ were presented to the listener, then the word “democrat” would result in high levels of lexical activation. Consequently, the respective phonemes of “democrat” would also become activated. Upon encountering /t/, participants would respond faster because /t/ has high levels of activation. For the phoneme monitoring paradigm, faster reaction times are assumed to reflect increased levels of lexical activation.

It is also predicted that if the system is relatively tolerant of phonological mismatches, then near phonological mismatches should result in greater lexical activation than the far phonological mismatches. Consequently, near phonological mismatches should result in faster reaction times than far phonological mismatches. If the system is relatively intolerant of phonological mismatches, then there should be little difference in the reaction times for near and far phonological mismatches.

With respect to the position of the phonological mismatch, if the recognition system is tolerant of only initial mismatches, then the reaction times for utterances
containing initial mismatches will be faster than the reaction times of utterances containing medial mismatches. This particular result would indicate that utterances containing initial mismatches would result in greater levels of lexical activation than utterances containing medial mismatches. If the recognition system is tolerant of only medial mismatches, then the opposite result would be found. Again, this would indicate that utterances containing medial mismatches would result in greater levels of lexical activation than utterances containing initial mismatches. The recognition system might also be intolerant to any phonological mismatch. In this instance, reaction times to utterances containing initial and medial mismatches would be significantly lower than the reaction times to the Word condition.

Method

Participants

One hundred and nine participants partook in the experiment in exchange for course credit. All of the participants reported being native speakers of American English and none reported any hearing problems.

Stimuli

All items were recorded onto a DAT tape by a male speaker and were transferred to a computer at a sample rate of 16,000 and a resolution of 16 bits. The items were then edited and stored on a Dell Dimension 8400 computer.
Targets. All target items had three syllables; they did not begin with a vowel and they ended in one of seven phonemes: /d/, /k/, /n/, /m/, /s/, /sh/, and /t/. The to-be monitored phoneme always occurred at the end of the utterance. There were 100 target words and 400 utterances containing phonological mismatches.

For each target word, the position of the medial mismatch always occurred before the word’s uniqueness point. Here, the uniqueness point is that point in the word in which the word diverges from all other words. For example, the uniqueness point in “democrat” comes at the /k/. No other word in the English language, other than “democrat”, has an initial phonetic string of /dem^k/.

Furthermore, neither the word, nor the resulting utterances, had a neighbor. A neighbor is defined as a word that differs from another word by either a phoneme substitution or a phoneme addition or deletion. For example, "delicious" has a neighbor, "malicious", whereas "democrat" does not have a neighbor.

In order for a phonological mismatch to be defined as either near or far, two criteria had to be met. First, a near mismatch differed from the original phoneme by one distinctive feature, whereas a far mismatch differed from the original phoneme by two or three distinctive features.

The second criteria used to define a distance mismatch were how similar two phonemes sounded to one another. The original phoneme and the near phonological mismatch should sound similar to one another, whereas the original phoneme and a far
mismatch should sound dissimilar to one another. A pilot experiment was conducted in which participants used a seven-point scale to rate the similarity of two phonemes. For example, if the phonemes /n/ and /m/ sound similar to one another, then the participant might give a rating of 7. For each phoneme that was tested in the pilot experiment, the three phonemes that were rated the highest in similarity and the three phonemes that were rated lowest in similarity to the original phoneme were chosen as potential near and far mismatches, respectively. If a phonological mismatch satisfied the first and second criteria, then it was defined as either a near or far mismatch respectively. For “democrat”, a near and far mismatch for /d/ would be /b/ and /f/ respectively. /b/ differs from /d/ by one distinctive feature, whereas /f/ and /d/ differ by three distinctive features. When compared to /d/, /b/ was one of the three phonemes that was rated highest in similarity, while /f/ was one of the three phonemes that was rated lowest in similarity. Given these criteria for target stimuli, example stimuli include “democrat” (word), “bemocrat” (IN), “femocrat” (IF), “denocrat” (MN), and “depocrat” (MF).

Fillers. All 340 filler items had three-syllables, and were divided into one of three groups: words, pseudowords, and words missing their final phoneme. There were 180 filler words and 160 filler pseudowords. Pseudowords did not sound similar to English words, although they were phonotactically legal. “Torlinef” and “bekrevish” are examples of nonsense words.
For the words, the to-be monitored phoneme occurred in the initial position for 65 items and in the medial position for 65 items. Fifty of these words were foil items, in which the to-be monitored phoneme was not present in the utterance. With regards to the pseudowords, the to-be monitored phoneme occurred in the initial position for 35 items and in the medial position for 35 items. The remaining 50 items were foil items. Forty words that were missing their final phoneme were included to help ensure that participants did not respond prematurely to the utterances.

Design

Five different lists of stimuli were constructed for this experiment. Each list contained 440 items, of which 340 were fillers. These filler items remained constant throughout the five lists. The remaining 100 items were target stimuli. These 100 items were further divided evenly among the five different experimental conditions. For example, 20 target words appeared in each of the five lists; the same is true for the other four experimental conditions. Moreover, to minimize priming effects, target items were rotated among the five lists. A target item and its related items never appeared in the same list. For example, the target word “democrat” appeared in the second list, while “bemocrat” appeared in the third list. To minimize expectancy effects from the participants, the position of the to-be monitored phoneme was evenly divided among the
initial, medial, and final position. Finally, the filler items without their final letter sound occurred once every eleven trials. The remaining items were randomly placed throughout the list.

**Procedure and Apparatus**

Participants were tested in groups of four. First, all of the participants were read the instructions and then they were placed in their individual booths. Next, they completed 18 practice trials. Both before and after the practice trials, participants were able to ask questions about the experiment. A break was offered to the participants about halfway through the experiment.

For each trial, participants first saw a letter that represented the target phoneme on a computer screen. The letter was displayed for 500 ms and then the auditory stimulus was immediately presented binaurally over a set of headphones. Next, the participants had to respond if they did or did not hear that particular target phoneme within the utterance. For example, if “t” was presented on the computer screen, then upon hearing “democrat”, participants would need to make an appropriate decision. In order to make such a response, participants responded on a button board with their two index fingers. Their left index finger rested over the button labeled “Letter Sound”, while their right index finger rested over the button labeled “No Letter Sound”. With the “democrat” example, participants would respond with “Letter Sound”; if the experimental stimulus was a foil, then the participant would respond with “No Letter Sound. Participants had
2500 ms to respond to the auditory item. If they did not respond within this time frame, a null response was recorded and the next trial commenced.

Results

Twenty of the participants were not included in the data analyses for a number of reasons. If it was discovered that the participant was not a native speaker of American English, then their data were not analyzed. This affected only a few of the participants. Also, if the participants missed 15 or more target trials, or did not achieve a 60% accuracy rating when determining if the to-be monitored phoneme was present in the utterance, then these participants’ data were removed from the analyses. Also, if a participant responded faster than 200 ms to 15 or more target trials, then this participant’s data was not included in the analyses. The majority of participants that were excluded either did not respond to 15 or more trials, or their reaction times were too fast for a number of the trials.

With regards to the measurement of reaction times, the timer began at the onset of the utterance and ended when the participant made an appropriate response. To assess the true reaction time to the utterance, the length of the utterance from word onset to the beginning of the final phoneme in milliseconds was subtracted from the overall reaction time; this was the reaction time that was used in the data analysis. Moreover, from this set of data, reaction times less than 200 ms were not included in the analyses. For
Experiment 1a, 1.98% of the data points were excluded from the analyses for this reason. Data from the filler and foil items were not analyzed.

The reaction times for each of the five experimental conditions are plotted in Figure 3; standard error bars are also included. As can be seen in Figure 3, the Word condition (714 ms) was responded to the fastest of the five conditions, which confirms the original prediction. The MN condition (828 ms) was responded to the slowest. The reaction times from the other three conditions fell within a range of 769 to 774 ms. Given these three experimental conditions, the Word condition was responded to faster by approximately 57 ms, while the MN condition was responded to slower by approximately 57 ms. The difference in reaction times between the Word condition and the MN condition was approximately 114 ms. What is surprising here is that the reaction times for the MN condition are so high, and the reaction times for the other three phonological mismatch conditions are almost the same. This pattern of results was not predicted. The large difference in reaction times between the MN and MF conditions is, perhaps, most perplexing. The cause of this difference will be discussed shortly.

The accuracy ratings, measured in percent correct, for each of the five conditions are noted on their respective bars. The Word condition was also the most accurate condition (94%), while the MN condition was the least accurate of the five experimental conditions (88%). The accuracy ratings for the remaining three conditions were between these two endpoints. The accuracy data mirrored the reaction time data. The Word
condition had both the fastest reaction times and the highest accuracy ratings, while the MN condition had both the slowest reaction times and the lowest accuracy ratings.

With regards to the inferential statistics, separate ANOVAs were run on the subjects (F1) and items (F2) data. First, a one-way ANOVA was run in which the Word condition and the four phonological mismatch conditions were treated as separate levels of the same independent variable. This was done primarily to investigate whether the Word condition differed significantly from the other four conditions. Results of the one-way ANOVA indicated that there was a significant effect, F1 (4, 352) = 20.579, p< 0.001; F2 (4, 495) = 8.93, p< 0.001. A Bonferroni post-hoc test found that the Word condition was responded to faster than the other four conditions.

For the second ANOVA, a 2x2 ANOVA was run on the data from just the four phonological mismatch conditions. These particular ANOVAs were run to investigate the effects of both position and distance. This ANOVA revealed a significant effect of position for the subjects, F1 (1, 88) = 6.578, p< 0.012, but not significant for the items, F2 (1, 396) = 3.453, p = 0.064. For the subjects data, a pairwise comparison revealed that initial mismatches were responded to significantly faster than medial mismatches. The effect of distance was significant for both subjects and items, F1 (1, 88) = 16.474, p< 0.001; F2 (1, 396) = 5.467, p< 0.02. A pairwise comparison revealed that far mismatches were responded to significantly faster than near mismatches. Finally, the interaction
between position and distance was significant for both subjects and items, $F_1 (1, 88) = 9.07, p< 0.003; F_2 (1, 396) = 4.299, p< 0.039$.

The same inferential statistics that were performed on the reaction time data were also performed on the accuracy data. A one-way ANOVA revealed a significant effect of condition, $F_1 (4, 440) = 4.774, p< 0.001; F_2 (4, 495) = 5.536, p< 0.001$. For the subjects data, a Bonferroni post-hoc test revealed that participants were significantly more accurate at responding to the Word condition than the IF and MN conditions, $p< 0.036$. For the items data, a Bonferroni post-hoc test revealed that the Word condition was more accurate than the IF, MN, and MF conditions, $p< 0.023$.

A 2x2 repeated measures ANOVA revealed that there was a significant effect of position, $F_1 (1, 88) = 4.256, p< 0.042; F_2(1, 99) = 2.116, p= 0.149$. For the subjects data, a pairwise comparison revealed that participants were more accurate at responding to the medial mismatches than the initial mismatches. There was not a significant effect of distance, $F(1, 88) = 0.10, p= 0.922; F_2 (1, 99) = 0.014, p= 0.906$. For the subjects data, there was a significant interaction between position and distance, $F_1 (1, 88) = 6.174, p< 0.015$. For the items data, there was not a significant interaction, $F_2 (1, 99) = 3.149, p= 0.079$.

Discussion

The pattern of results from Experiment 1a does not match the results of the TRACE simulations. With respect to the experimental evidence, the effects of both

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position and distance can be explained by the significant interaction: the MN condition was responded to slower than the other three phonological mismatch conditions. Thus, this is one piece of evidence suggesting that human data does not match TRACE’s results. With regards to the TRACE simulations, there was a clear effect of position: both medial mismatch conditions resulted in greater amounts of lexical activation than both of the initial mismatch conditions. Here, there is not a clear effect of position. The high reaction times for the MN condition suggests that this particular condition resulted in the least amount of lexical activation. The MF condition resulted in the same amount of lexical activation as both of the initial mismatch conditions.

With regards to the accuracy data, participants were fastest, and the most accurate, when responding to the Word condition, which is expected because this condition has the most lexical activation. Furthermore, the medial mismatches resulted in more accurate responses than the initial responses. This would seem to suggest that the medial mismatches resulted in greater amounts of lexical activation, but the reaction times do not suggest this. For this experiment, the accuracy data will not be mentioned again.

With regards to the reaction times for the initial mismatch conditions, there was little difference in reaction times for both the IN and IF conditions. This result replicates a finding by Boelte and Coenen (2002), although Connine et. al. (1997) found a different result. This discrepancy will be discussed in greater detail in the General Discussion,
although these data suggest that the processing system does not distinguish between the
distance of the initial mismatches.

With regards to the medial mismatch conditions, there is an effect of distance.
The MF condition resulted in greater amounts of lexical activation than the MN
condition, which is a perplexing result. In some respects, Frauenfelder et. al. (2001)
found a similar result: the MN condition resulted in slow reaction times. However, they
did not have a comparable MF condition. In order to explain the slow reaction times for
the MN condition, Frauenfelder et. al. claimed that this was due to the processing system
having a bottom-up inhibition component. For example, when a medial mismatch is
encountered in the speech signal, lexical processing is greatly hindered and there is not
enough successive bottom-up support remaining in the speech signal to overcome the
medial mismatch. This would not occur with initial mismatches because there is enough
successive bottom-up support after the initial mismatch to overcome it. This explanation
could partially explain these particular results. Yet, it would then be expected that the
MF condition should also be responded to slower than the initial mismatches, which is
clearly not the case. Another possibility is that these results are anomalous. These
anomalous results could be caused by either chance or the participants themselves.
Therefore, in order to rule out any anomalous results, a replication experiment was
performed.
CHAPTER 4

EXPERIMENT 1B

Method

Participants

Seventy-three participants partook in the experiment in exchange for course credit. All of the participants reported being native speakers of American English and none reported any hearing problems.

Stimuli, Design, Procedure, and Apparatus

These were the same as in Experiment 1a.

Results

With regards to excluding participants, the same standards that were used in Experiment 1a were used here. Furthermore, the majority of participants were excluded for either not responding to trials or responding too fast to a certain number of trials. Fifty-five participants were included in the data analyses. Participants were run in each of the experimental lists, except List 5. Participants were not run in this list because of external constraints; there was not enough time left to run the proper number of participants in this list. Even if participants were run in List 5, the pattern of results
would most likely have remained the same. 2.28% of the data points were excluded from the analyses. True reaction times were measured similarly in both Experiments 1a and 1b.

Reaction times are plotted in Figure 4. The Word condition was responded to fastest (695 ms), while the MN condition was responded to slowest (816 ms). The other three phonological mismatch conditions fell within a range of 754 and 772 ms. Standard error bars are also included. The overall pattern of results was similar to the pattern of results from Experiment 1a. The Word condition was responded to faster than three of the phonological mismatch conditions (IN, IF, and MF) by approximately 68 ms. The MN condition was responded to slower than the other three phonological mismatch conditions by approximately 53 ms. The difference in reaction times between the MN condition and the Word condition was approximately 121 ms. As in Experiment 1a, the MF condition was responded to faster than the MN condition. These results may be due to a strategy used by participants; these results do not seem to reflect lexical processing.

As in Experiment 1a, not only did the Word condition have the fastest reaction times, but it was the most accurate of the five conditions (94%). However, the MF condition was the least accurate condition (91%). The other three condition fell between these two endpoints. The accuracy data are displayed in Figure 4.

As with Experiment 1a, the same inferential statistics were performed on both the subjects (F1) and items (F2) data. First, a one-way ANOVA revealed that there was a
significant effect, $F_1 (4, 212) = 10.194, p < 0.001$; $F_2 (1, 53) = 7.828, p < 0.001$. For the subjects data, a Bonferroni post-hoc test revealed that the Word condition was responded to significantly faster than the IN, MN, and MF conditions, $p < 0.006$, and the Word condition was not significantly faster than the IF condition, $p = 0.822$. For the items data, a Bonferroni post-hoc test revealed that the Word condition was responded to significantly faster than all four phonological mismatch conditions.

Secondly, a 2x2 ANOVA revealed a significant effect of position for subjects, $F_1 (1, 53) = 6.221, p < 0.016$, but not for items, $F_2 (1, 316) = 2.32, p = 0.129$. For the subjects data, a post-hoc test revealed that initial mismatches were responded to faster than medial mismatches. There was a significant effect of distance, $F_1 (1, 53) = 10.31, p < 0.002$; $F_2 (1, 316) = 3.997, p < 0.047$. A post-hoc test revealed that far mismatches were responded to faster than near mismatches. There was not a significant interaction between position and distance, $F_1 (1, 53) = 0.224, p = 0.638$, $F_2 (1, 316) = 0.472, p = 0.492$.

With regards to the accuracy data, a one-way ANOVA revealed that there was not a significant effect of condition, $F_1 (4, 265) = 2.023, p = 0.092$; $F_2 (4, 395) = 2.282, p = 0.06$. A 2x2 repeated measures ANOVA revealed that there was not a significant effect of position, $F_1 (1, 53) = 2.508, p = 0.119$; $F_2 (1, 79) = 1.699, p = 0.196$. There was not a significant effect of distance, $F_1 (1, 53) = 5.042, p = 0.748$; $F_2 (1, 79) = 0.418, p = 0.52$. The interaction between position and distance was not significant, $F_1 (1, 53) = 2.449$, $p = 0.129$.  

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Discussion

The overall pattern of the reaction time results here is remarkably consistent with the pattern of results from Experiment 1a, which increases the results’ reliability. Therefore, the results of Experiment 1a are not anomalous. However, the unexpected pattern of results still remains: the MN condition resulted in slower reaction times than the MF condition.

As mentioned previously, this particular pattern of results may not be a result of lexical processing, but rather it could be caused by a strategy that participants employed during the experiment. In order to maximize their performance during the phoneme monitoring experiment, participants must pay close attention to the phonemes in the speech signal because any of these phonemes could be the target phoneme. If the current phoneme is not the target phoneme, then participants can ignore it; if the current phoneme is the target phoneme, then participants will make an appropriate response. Moreover, participants can build up expectations as to the identity of the utterance. For example, if the target phoneme is a /t/, and the first part of the utterance is /dem^kr/, then participants will respond faster to the /t/ because they may have already recognized the utterance as “democrat”.

p=0.811; F2 (1, 79) = 0.009, p= 0.926. Since there were no significant differences with regards to the accuracy data, this particular data set will not be discussed again.
When an initial mismatch is encountered, participants have no expectations as to the intended utterance. For example, upon hearing /b/ or /f/, the participant may not necessarily anticipate that the remaining part of the utterance is /ɛm^kræt/. This scenario possibly explains why there are no differences in reaction times between the IN and IF conditions. When a medial mismatch is encountered, participants may anticipate the intended utterance. If the target phoneme is /t/, and initial part of the utterance is /dɛn^kr/, then participants may become confused upon encountering the medial near mismatch. Participants were anticipating /m/, but were instead presented with /n/. Since the two phonemes sound similar to one another, the participants may take a moment to decide which phoneme they actually heard. Thus, this process could explain the slowdown in the MN condition. This would not occur in the MF condition because the medial phonological mismatch (/p/) and the original phoneme (/m/) are not confusable with one another. Upon hearing /dɛp^kr/, participants are not confused as to the identity of the medial mismatch, and thus, would not respond slower to the target phoneme.

Therefore, the results of Experiment 1a are not truly reflective of lexical processing because strategic effects potentially contaminated the data. To compensate for this, a different paradigm will be used in the follow-up experiments.
CHAPTER 5
EXPERIMENT 2

As mentioned previously, the second paradigm is the form priming paradigm, which was previously used by Boelte and Coenen (2002) to investigate the effects of phonological mismatches. As detailed in Zwitserlood (1996), there are many different versions of the form priming paradigm. The version that will be used here begins with the presentation of an auditory prime, followed by an interval of silence (ISI), which is then followed by an auditory target. Here, the phonological mismatch would be the prime, while the target would be the word from which the mismatch was derived. For example, the prime could be “bemocrat”, while the target could be “democrat”. This particular version of the form priming task was chosen because other relevant studies (Hamburger & Slowiaczek, 1996; Slowiaczek & Hamburger, 1992; Slowiaczek, McQueen, Soltano, & Lynch, 2000) also used this particular design.

With regards to the predictions, a couple of points should be made. First, the present predictions differ from the phoneme monitoring paradigm. More specifically, the results from Experiments 1a and 1b demonstrate that the Word condition resulted in faster reaction times than the four phonological mismatch conditions. The results of previous form priming experiments suggest that the Word condition will result in slower reaction times than the four phonological mismatch conditions. It has also been found that response times in form priming experiments are determined by the amount and
position of the phonological overlap between the prime and target. Slowiaczek and Hamburger (1992) found that when both the prime and the target were presented auditorily, reaction times were fastest when only the initial phoneme in both the prime and the target were the same. As the number of shared initial phonemes between the prime and target increased, reaction times also increased. For example, the prime and target utterance "still smoke" was responded to the fastest, while the prime and target utterance "still still" was responded to significantly slower. Reaction times to a prime and target utterance that shared two initial phonemes, such as "still steep" fell in between the two former conditions. Furthermore, these results do not replicate when the prime was presented auditorily and the target was presented visually. From these results, the authors concluded that the facilitation effects were due to excitation at the prelexical level, while the inhibitory effects were due to competition between items in the lexical level.

In terms of utterance-final overlap, it was found that reaction times decreased as the number of overlapping final segments between the prime and the target increased (Slowiaczek et. al., 2000). For example, the prime and target utterance "spin clash" resulted in the slowest reaction times to the target because there was no phonological overlap between the prime and the target. Reaction times to the target were fastest when there was nearly complete final overlap between the prime and the target. For example, the prime and target utterance “flash clash” resulted in the fastest reaction times. Finally,
the reaction times to the prime and target utterance "smash clash" fell in between the former two conditions because they had only two final overlapping phonemes. From these findings, the authors concluded that utterance-final overlap facilitation is partly due to both the activation of prelexical representations and a response bias; participants are biased to make a positive lexical decision response when the prime and the target rhyme. They also conclude that final-overlap facilitation is not due to lexical access. Norris, McQueen, and Cutler (2002) also found similar results with regards to utterance-final overlap. In conclusion, if the prime and the target share a number of initial phonemes, this leads to an increase in reaction times to the target, whereas if the two utterances share a number of final phonemes, this leads to a decrease in reaction times.

Besides the amount of phonological overlap between the target and the prime, the length of the silence, or inter-stimulus interval (ISI), between the target and the prime also has an effect on how quickly participants respond to the target (Radeau, Morais, and Segui, 1995). Radeau et. al. (1995) assert that participants will respond faster to a target if it is preceded by a short ISI (20 ms) rather than a long ISI (500 ms). Here, once a word has become initially activated, its activation will eventually return to its original resting level. Therefore, with a short ISI, the activation level of the prime will still be high when the target is presented. Thus, the target will elicit a faster response.

Furthermore, the length of the ISI also has an effect on whether or not participants are able to use a strategy in order to make a quick and accurate response to the target. A
short ISI will not allow enough time for participants to employ a strategy, whereas a long ISI will potentially give participants enough time to use a strategy (Radeau et. al., 1995). Therefore, if there are priming effects found with a short ISI, it could be concluded that the results are due to lexical processing and not strategic effects. If priming effects are found with a long ISI, there is the possibility that the effects are due to strategic effects and not lexical processing.

A number of experiments (Dufour and Peereman, 2003a, 2003b; Hamburger and Slowiaczek, 1996; Pitt and Shoaf, 2002) have investigated when participants are more likely to use a strategy during the experiment. Hamburger and Slowiaczek (1996) found that participants are more likely to use a strategy when the first and second phonemes overlap in both the prime and the target. Furthermore, participants are more likely to use a strategy when the ISI was long (500 ms) and when 75% of the trials in the experiment contained utterances that shared the first and second phoneme. If the prime and the target shared more than the initial two phonemes, then it was found that reaction times increased, which was also found by Slowiaczek and Hamburger (1992). However, this increase was found regardless of the length of the ISI and the proportion of related trials in the experiment.

Pitt and Shoaf (2002) found that reaction times were slower to a target that shares the initial three phonemes with the prime when this particular three-phoneme overlap trial was first encountered. If the same type of trial was encountered later in the experiment,
participants were faster at responding to the target. For example, if a three-phoneme overlap condition (“joy joint”) was first encountered at Trial 38, then reaction times to the target were relatively slow. However, if the last trial in the experiment was another three-phoneme overlap condition (“snack snap”), then reaction times to the target were faster. The authors concluded that upon first encountering a three-phoneme overlap condition there was a slowdown because of a surprise effect. Here, participants are surprised upon hearing such an utterance, and subsequently, their reaction times are slower. As participants become familiar with these particular utterances, their surprise diminishes and their reaction times decrease. In response to Pitt and Shoaf (2002), Dufour and Peereman (2003a, 2003b) found that priming effects for a target that shared the initial two phonemes with the prime were relatively constant across the entire experiment. They concluded that a surprise effect was not present. Thus, given this discrepancy in the literature, would a surprise effect be present in this particular experiment? In conclusion, while the form priming paradigm can provide considerable insight into lexical processing, the amount and position of the phonological overlap, the ISI, strategies that participants employ, and surprise effects can influence response times.

As in Experiment 1, the same experimental conditions (Word, IN, IF, MN, and MF) will also be used. However, as a result of the form priming paradigm, a sixth experimental condition will be included. In the Different Word condition, two different words were used as both the prime and the target (“caveat pollution”). The words used
here were not items that were used in the other experimental conditions. The Different Word condition was included for two reasons. First, it was included to reduce the likelihood of a strategy that participants may develop during the experiment. If this condition was not included, then upon hearing a word as a prime, participants could anticipate hearing the same word as the target, as is the case with the Word condition. Rather, upon hearing the prime, participants cannot predict the target. Secondly, this condition was included to assess the excitatory and inhibitory effects of having a word as both the prime and the target.

Therefore, given the experimental conditions (word, IN, IF, MN, MF, and Different Word), the predictions of this form priming experiment will differ from the predictions of the phoneme monitoring experiment. In the form priming paradigm, the Word condition is predicted to be responded to slower than the four phonological mismatch conditions. In this experiment, the same word (“democrat”) will be used as both the prime and target. Previous experiments (Slowiaczek and Hamburger, 1992; Slowiaczek et. al., 2000) found that as the number of shared initial phonemes between the prime and target increase, the reaction times increase. Therefore, if all of the phonemes overlap between the prime and target (Word condition), then this should result in relatively slow reaction times.

With regards to the phonological mismatch conditions, the same logic still applies. If the prime contains a medial mismatch, then the prime and target share initial
phonemes (“denocrat democrat”), and their reaction times should be relatively slow, although not as slow as the Word condition. If the prime and target differ only in terms of the initial phoneme (bemocrat democrat), then this should result in relatively fast reaction times.

With regards to distance of the phonological mismatch, if the processing system is relatively tolerant of mismatches, then near mismatches should be responded to faster than far mismatches. However, given the results from Experiments 1a and 1b, and Boelte and Coenen (2002), it is predicted that there should be no difference in reaction times to the IN and IF condition. There should only be a difference in reaction times with the MN and MF condition.

However, the predictions become somewhat complicated when the Different Word condition is included. In the prior experimental conditions, increased phonological overlap results in inhibition, which results in slower reaction times. In the Different Word condition, there is a lack of phonological overlap between the prime and the target. Therefore, in this condition, the prime should not inhibit the target, and the reaction times for the target should be the fastest of the six experimental conditions.
Method

Participants

Eighty-seven participants participated in the experiment in exchange for course credit. All of the participants were native speakers of American English and none reported any hearing problems.

Stimuli and Design

The same target and filler items that were used in Experiments 1a and 1b were used here. On each trial, a prime preceded a target with a 50 ms ISI between them. An example trial would be “bemocrat democrat”. A 50 ms ISI was chosen in order to reduce the tendency of listeners to use a strategy.

With regards to the experimental conditions, there were 20 Different Word condition trials. With regards to the remaining target items, 60 of the 100 target words were selected from Experiment 1a that had the highest familiarity rating. A pilot experiment was conducted in which all original 100 target words were visually presented to participants, who needed to rate their familiarity of each word on a 7-point scale. A score of 7 indicated that participants were highly familiar with the word and a score of 1 indicated that participants were not familiar with the word. It was hypothesized that if a participant was not familiar with a word (“caveat”) then there would be little, if any, lexical activation if presented with a derivative of that word (“gaveat”).
With regards to the experimental design, there were five different experimental lists, as was the case with Experiments 1a and 1b. To reduce priming effects a word and its derivatives never appeared within the same list as the prime. Rather, these items were rotated among the five lists as was done previously. For example, the utterance string “democrat democrat” appeared in List 5, whereas the string “bemocrat democrat” appeared in List 1. However, since there were no worries of priming effects with the Different Word condition, these trials were kept constant across the five lists.

With regards to the filler items, 100 filler items were included in this experiment, which were also kept constant across the five lists. The filler items were divided into three different groups of items. There were 58 word prime and pseudoword target trials (“silhouette guntisof”), 10 pseudoword prime and word target trials (“poskladim defective”), and 32 pseudoword prime and pseudoword target trials (“teeprody faradul”). Collectively, there was an equally likely chance that the target would either be a word or a pseudoword. Furthermore, the Word condition and the four phonological mismatch conditions constituted a third of the total number of trials.

Finally, as was done previously, each list was broken up into 15 blocks of 12 trials. Within each block, there were four target trials. This was done to ensure that the target trials were evenly spaced throughout the list and to test for a surprise effect. To
test for a surprise effect, reaction times to target trials that were presented in the first
block of trials could be compared against reaction times to target trials that were
presented in the last block of trials.

Procedure and Apparatus

The procedure and apparatus were essentially the same for this experiment and
the previous experiments. The only difference is that participants first heard the prime
binaurally over a set of headphones, then 50 ms of silence, and followed by the target.
Participants needed to then make a lexical decision on a button board. If the target was a
word, then participants would press the left button labeled “Word” with their left index
finger. If the target was a pseudoword, then participants would press the right button
labeled “Nonsense Word” with their right index finger.

Results

Of the 87 participants who participated in this experiment, nine people’s data
were not included in the statistical analyses. They were excluded for the same reasons
that other participants’ data were excluded from the analyses in Experiments 1a and 1b.
With regards to measuring reaction times, the timer started at the onset of the prime and
ended when the participant made an appropriate response to the target. To assess how
quickly participants responded to the target, the length of the prime and the ISI in
milliseconds was subtracted from the overall reaction time. This resulting value was the
reaction time value that was used in all of the statistical analyses. As in the previous
experiments, reaction times less than 200 ms were excluded from the analyses. 0.04% of the data points were excluded from the analyses.

Figure 5 details both the accuracy ratings and reaction times for the experimental conditions. Standard error bars are also plotted in Figure 5. For some of the conditions, participants were very accurate at categorizing the target. The Word condition was one of the least accurate condition (97% correct), while the MN condition was the most accurate (99% correct). The accuracy ratings for the IN, IF, and MF conditions were between these two endpoints. For these five conditions, participants were very accurate in their responses. However, for the Different Word condition, participants were not as accurate (88%).

Not only was the Different Word condition the least accurate of the six experimental conditions, but it also resulted in the slowest reaction times (1138 ms). The Word condition was responded to slower than the four phonological mismatch conditions (1003 ms). Of these conditions, IN was responded to the fastest (904 ms), while MF was responded to the slowest (968 ms). The IF and MN condition were in between these other two conditions with reaction times of 911 and 942 ms respectively.

As predicted, of the experimental conditions, the Different Word condition was responded to the slowest; the difference in reaction times between the Different Word condition and the next closest condition was approximately 135 ms. The Word condition was also responded to slower than the four phonological mismatch conditions. The
difference in reaction times between the Word condition and the next closest condition, MF, was approximately 35 ms.

Overall, the initial mismatch conditions were responded to faster than the medial mismatch conditions, which was predicted. Moreover, there appears to be a slight effect of distance with regards to the medial mismatch conditions. The MN condition was responded to faster by approximately 26 ms. As was found previously in Experiments 1a and 1b, there was little difference in the IN and IF condition (7 ms).

As with the phoneme monitoring experiment, the same inferential statistics were performed on both the subjects and items data. First, a one-way ANOVA was run on the subjects (F1) and items (F2) data. Here, the Word, Different Word, and the four phonological mismatch conditions were treated as different levels of the same independent variable. The purpose of this ANOVA was to assess if the Word and Different Word condition were responded to significantly slower than the four phonological mismatch conditions. The ANOVA was significant, $F1 (5, 385) = 83.623, p< 0.001$; $F2 (5, 319) = 9.234, p< 0.001$. For the subjects data, a Bonferroni post-hoc test revealed that the Different Word condition was responded to significantly slower than the other five conditions, $p< 0.001$. The Word condition was responded to significantly slower than three of the four phonological mismatch conditions (IN, IF, and MN), $p< 0.006$. The Word condition was not responded to significantly slower than the MF condition, $p= 0.57$. For the items data, a Tukey post-hoc test revealed that the Different
Word condition was responded to significantly slower than the other five conditions, $p<0.01$. The Word condition was responded to significantly slower than the IN and IF conditions, $p<0.015$. The Word condition was not responded to slower than the MN and MF conditions, $p=0.245$.

Next, a 2x2 ANOVA was run on only the four phonological mismatch conditions; position and distance were the two factors. Results indicated that the effect of position was significant, $F_1(1, 77) = 28.11$, $p<0.001$; $F_2(1, 236) = 6.595$, $p<0.011$. Initial mismatches were responded to faster than medial mismatches. The subjects data revealed a significant effect of distance, while the items data did not, $F_1(1, 77) = 4.217$, $p<0.043$; $F_2(1, 236) = 0.825$, $p=0.365$. For the subjects data, a post-hoc test revealed that near mismatches were responded to faster than far mismatches. Finally, the interaction between position and distance was not significant, $F_1(1, 77) = 2.089$, $p=0.152$; $F_2 (1, 236) = 0.262$, $p=0.609$.

With regards to the accuracy data, a one-way ANOVA revealed a significant effect, $F_1(5, 462) = 63.661$, $p<0.001$; $F_2(5, 394) = 14.094$, $p<0.001$. For both the subjects and items data, a Bonferroni post-hoc test revealed that the Different Word condition resulted in less accurate results than the other five conditions, $p<0.001$.

As mentioned previously, a surprise effect is somewhat common in form priming experiments (Pitt and Shoaf, 2002). Since the target items were distributed evenly across the experiment, each of the five experimental conditions (word, IN, IF, MN, and MF)
was divided into four blocks of three items each. The first block of three items represented the initial three items from those particular experimental conditions that were presented during the experiment. For example, “resident”, “tuition”, and “magnitude” were the first three items from the Word condition that were presented to participants in List 1. The last block of three items represented the final three items from those experimental conditions that were presented during the experiment. Therefore, to determine if there was a surprise effect present, the reaction times from the first block from each of the five conditions were compared against the reaction times from the fourth block. Figure 6 illustrates the reaction times from across the four different blocks of items for each of the five conditions. Results indicate that a surprise effect was present. A 2x5 repeated measures ANOVA was run in which block (first or fourth) and experimental condition were the two factors. The effect of block was significant, $F(1, 77) = 25.607, p< 0.001$. A pairwise comparison revealed that the items in Block 1 were responded to significantly slower than the items in Block 4, $p< 0.001$. The effect of condition was significant, $F(4, 308) = 17.288, p< 0.001$ and the interaction between block and condition was significant, $F(4, 308) = 11.958, p< 0.001$.

Discussion

The interpretation of the present data differ significantly from the interpretation of the data from Experiment 1. In that experiment, fast reaction times indicated greater
lexical activation. The opposite seems to be true here: an increase in reaction times indicates greater lexical activation.

For example, excluding the Different Word condition, the Word condition had the slowest reaction times. This slowdown is most likely caused by inhibition. After the prime is presented, the respective word node becomes activated and during the ISI, the node loses some activation. Perhaps, during this time period, the node is unable to properly activate itself. When the target is presented, that is the same utterance, the word node cannot become fully activated because the node is inhibiting itself. Similar results have been found in other areas of psychology, such as the refractory period in neurons and inhibition-of-return in the field of visual attention (Posner and Cohen, 1984). This inhibition of the word node does not completely shut down lexical processing because if it did, then reaction times to the Word condition would be the same as the reaction times to the Different Word condition. Furthermore, this same result does not occur with the four phonological mismatch conditions because when the prime is presented, the respective word node does not become fully activated. This partial activation does not lend itself to as much inhibition as if the word node could become fully activated. A second explanation concerning this pattern of results involves strategic effects, which are common in form priming experiments. Therefore, with regards to the form priming experiment, greater inhibition, which is demonstrated by slower reaction times, is equated with greater lexical activation.
Given the experimental results, the Word condition had the most lexical activation. This result matches the TRACE simulations, which also demonstrated that the Word condition had the most lexical activation. With regards to the phonological mismatch conditions, the medial mismatches were responded to slower than initial mismatches. These results lend support to earlier findings by Slowiaczek and Hamburger (1992) and Slowiaczek et. al. (2000) who found that reaction times increase when the first three initial phonemes overlap between the prime and the target. Furthermore, Slowiaczek et. al. (2000) found that initial mismatches resulted in faster reaction times. Thus, the present experimental results suggest that the medial mismatches had more lexical activation than the initial mismatches. This result is also supported by the TRACE simulations, which demonstrated that medial mismatches had more lexical activation than initial mismatches.

With regards to the distance of the mismatch, the results of this experiment are mixed. For the experimental data, there was an effect of distance with medial mismatches, but not with initial mismatches. The lack of a difference in reaction times between the IN and IF conditions is not surprising since this particular result matches with the TRACE simulations and replicates a finding by Boelte and Coenen (2002).

However, there is a difference in the reaction times for the medial mismatch conditions: the MN condition resulted in slightly faster reaction times than the MF condition, which suggests that the MF condition had slightly more lexical activation than
the MN condition. This results suggests that once a medial mismatch is encountered, the lexical activation levels for the potential lexical candidate decrease. For example, given the string /dɛ/, the word “democrat” becomes activated. However, once the /n/ (near mismatch) or /f/ (far mismatch) is encountered, the lexical activation levels decrease for “democrat”. Yet, as more of the string is processed (/^kræt/), the lexical activation levels increase for “democrat”, and it is likely that “democrat” will become the recognized word. The TRACE simulations, however, found the opposite result. The MN condition resulted in more lexical activation than the MF condition. Thus, TRACE seems sensitive to the degree of the medial mismatch. The feature matrix would make the model more sensitive to near, rather than far, mismatches.

Finally, the reaction times for the Different Word condition complicate the overall interpretation of the data. As mentioned previously, if the prime and the target overlap phonologically, then their reaction times should increase because of inhibition. It was predicted that since the prime and the target in the Different Word condition do not overlap phonologically, then this condition should have the fastest reaction times. However, the Different Word condition resulted in the slowest reaction times, which contradict the original prediction. If comparisons are only made between the Different Word condition and the Word condition, it could be concluded that phonological overlap facilitates reaction times. Furthermore, the same conclusion can be drawn if comparisons are made between the Different Word condition and the phonological mismatch
conditions. However, the data from the Word and phonological mismatch conditions clearly contradict this conclusion. There it was found that as phonological overlap increased between the prime and the target, reaction times also increased.

These conflicting conclusions suggest that there are different psychological processes at work in the six experimental conditions. Additional experiments are needed in order to tease apart this data set. One potential experiment could explore how much lexical activation the target has independent of the prime. In such an experiment, a click or buzz could be the prime and the target is a word. (Participants would still need to make a lexical decision response to the target.) If the reaction times for the Click condition are significantly slower compared to just the reaction times for the Word and Different Word conditions, then it could be assumed that having any word as a prime will facilitate responses to the target. If the reaction times for the Click condition fall between the Different Word and Word condition, then it can be assumed that if the prime and target overlap phonologically, then the prime facilitates responses to the target. If the prime and target do not overlap phonologically, then the prime inhibits responses to the target. Finally, if the reaction times for the Click condition are faster than both the Word and Different Word condition, then it can be assumed that having any word as a prime will inhibit responses to the target.

In a second potential experiment, the ISI could increase. As mentioned previously, the relatively slow reaction times for the Word condition are a result of the
word node inhibiting itself. This inhibition occurs because of the short ISI. If the ISI were increased, then the inhibitory effects of the word node have time to decrease, and it will be less likely that the Word condition will elicit relatively slow reaction times. Consequently, the reaction times should become faster for the Word condition.

Moreover, are inhibitory influences are causing the slowdown in the Different Word condition? If the ISI were also increased in the Different Word condition, and if the prime is inhibiting the target, then the reaction times should become faster for the Different Word condition. If the prime is not inhibiting the target, then the reaction times should remain constant. Therefore, increasing the ISI will help to determine if the slow reaction times in the Word and Different Word condition are caused by inhibition.

It should also be noted that the accuracy ratings are significantly slower for the Different Word condition compared with the Word and the phonological mismatch conditions. The high accuracy ratings for the Word and the phonological mismatch conditions indicate that there is a potential facilitatory connection between the prime and the target. Moreover, the low accuracy ratings for the Different Word condition suggest that there is not a potential facilitatory connection between the prime and the target. However, the relatively low accuracy ratings may be due to the words that were selected as the targets in this particular condition. Participants, for the most part, were not very accurate at making a lexical decision to relatively obscure words, such as “domicile” and “bombastic”. Future form priming experiments that utilize the lexical decision task
should take care to use relatively familiar words as targets, so that obscure words do not
decrease the accuracy ratings.

In summary, excluding the Different Word condition, the experimental results
match the TRACE simulations with regards to the lexical activation levels of the initial
and medial mismatches. The experimental results also match the TRACE simulations
with regards to the lexical activation levels of the IN and IF mismatches, but not the MN
and MF mismatches.

Previous Results

The present results also expand upon a number of previous results. First, past
studies (Norris et. al., 2002; Slowiaczek et. al., 2000) did not manipulate the distance of
the initial mismatch, whereas the present experiment did. The present results indicate
that the recognition system is intolerant to any word-initial mismatch. It should also be
noted that this result was also found in Experiment 1. This conclusion runs contrary to
the claim that the recognition system is more tolerant of initial near mismatches rather
than initial far mismatches (Connine et. al., 1997). This discrepancy will be discussed in
greater detail in the General Discussion.

Secondly, this experiment, as well as past experiments (Slowiaczek and
Hamburger, 1992), investigated the effects of medial mismatches. Slowiaczek and
Hamburger found that as the number of shared initial phonemes increase, reaction times
also increase, which was also found here. For example, the utterances “blast black”
would result in slower reaction times than “book black”. However, with regards to Slowiaczek and Hamburger, once the medial mismatch occurred, the remainder of the prime did not overlap with the target. For example, after the /æ/, “blast” and “black” do not overlap with one another. In the present experiment, once the medial mismatch occurred, the remainder of the prime overlapped with the target. For instance, “denocrat” and “democrat” share word-final phonemes. Thus, the results from Slowiaczek and Hamburger and this experiment suggest that word-initial overlap between the prime and target result in relatively slow reaction times, even if the prime and target share word-final phonemes.

Potential Strategies Used By Participants

With regards to the experimental paradigm itself, there are a number of factors which can alter, or skew, the data. One of these factors is the surprise effect (Pitt and Shoaf, 2002). In this experiment, a surprise effect is present. The first block of trials is responded to significantly slower than the fourth block of trials in all five of the experimental conditions. Blocks 2, 3, and 4 all have relatively the same reaction times. These results expand upon the findings of Pitt and Shoaf, who also found that a surprise effect occurred when the prime and the target had a complete phonological overlap. These results suggest that a surprise effect can also occur when there is partial phonological overlap between the prime and the target, as is the case with the phonological mismatch conditions.
Therefore, in order to eliminate the surprise effect and have a more accurate representation of reaction times, the next experiment will have within its design a series of “burn-in” trials. These trials are essentially an additional practice session in order for participants to gain more experience with the experiment before any target trials are introduced. This block of “burn-in” trials will contain only filler items; target trials will only be introduced after this block of trials is complete. If a surprise effect is still present, then the first block of target trials will be responded to slower than the subsequent blocks of target trials. If a surprise effect is not present, then the reaction times should be constant across the four blocks of trials.

Participants can also use an anticipatory strategy to predict the lexical status of the target item. If this occurs, then any results could be due to the use of this strategy and not normal lexical processing. Responses from a post-experiment questionnaire revealed that some participants could have used such a strategy during this experiment. For example, in filler trials, pseudowords did not sound like real words of English, although they were phonotactically legal. An example of this type of pseudoword would be “bekrevish”. Pseudowords in target trials, which were phonological mismatch items, did sound like real words of English (“bemocrat”). Therefore, if participants heard a pseudoword prime in a filler trial, then there were no expectations as to the nature of the target item: it could either be a word or a pseudoword. If participants heard a pseudoword prime from a target trial, then there was an expectation as to the nature of the target item. In other
words, participants could begin to adopt a strategy in order to maximize their performance. Upon hearing the prime “bemocrat”, participants could have recognized it as a derivative of the word “democrat”. If participants heard another target trial, such as “shigarette cigarette”, then they may have realized that if the prime sounds like a real word, then the actual word will then be the target. If participants adopt this particular strategy, then they can make a lexical decision to the target without fully processing it. Thus, in Experiment 3, this problem was resolved through the introduction of a number of different filler items. The nature of these filler items will be detailed when Experiment 3 is discussed.

Furthermore, if participants heard a prime that was a word, then the target could be one of three items: the same word (target trials), a different word (filler trials), or a pseudoword (filler and target trials). Participants could not anticipate the lexical status of the target if the prime was a word. However, as previously mentioned, if the prime was a pseudoword from a target trial, then participants could predict the lexical status of the target. This difference between the Word and phonological mismatch conditions could be another possible explanation as to the slowdown in the Word condition. To test if the results of this experiment are due to the use of a strategy by participants, a modified form priming experiment will be run in which the number and nature of the filler trials are altered.
CHAPTER 6
EXPERIMENT 3

Method

Participants

One hundred and six participants participated in this experiment in exchange for course credit. All of the participants were native speakers of American English and none reported any hearing problems.

Stimuli and Design

The design of this experiment has similarities and differences from the previous form priming experiment. With regards to the similarities, a 50 ms ISI was used for all of the experimental stimuli. Furthermore, the same 60 target words and their respective pseudowords were used here. The Different Word condition was also included here, but items other than the ones used in Experiment 2 were used. Furthermore, the targets in the Different Word condition were relatively familiar words, although a few obscure words were used as targets. Finally, the target stimuli were rotated throughout five lists in the same manner that was used in the previous form priming experiment. For example, the utterance “bemocrat democrat” appeared in List 3, while the utterance “democrat democrat” appeared in List 2. The filler items and Different Word items were kept constant throughout the five lists.
The number and nature of the filler items were the major difference between this form priming experiment and the previous form priming experiment. These additional filler items were included to both combat any strategy that the participants might have employed and reduce the surprise effect. Table 1 is provided to better illustrate the number and nature of the filler items.

One step used to reduce the surprise effect was to introduce a series of “burn-in” trials at the beginning of the experiment. With regards to Experiment 2, it was assumed that the initial slowdown in Block 1 could be due to participants’ inexperience with the experimental task. Therefore, if participants had more practice with the experimental task, then their reaction times to the first block of trials wouldn’t be as slow. In this experiment, after the practice trials, participants were given another 24 trials before any of the target items were included. This block of 24 trials consisted of filler items that were similar to the filler items used in the remainder of the experiment.

Another step that was taken to reduce the use of a strategy by participants was to include an additional set of trials in which the prime and the target, which were both words, completely overlapped phonologically. Hamburger and Slowiaczek (1996) hypothesized that if the number of complete phonological overlap trials increased, then the participants would be less likely to employ a strategy. There were 30 such trials.

Next, it was discovered from the participants’ questionnaire responses in Experiment 2 that they were able to predict the target upon hearing a prime that was a
phonological mismatch. For example, if “bemocrat” was the prime, participants noted that they anticipated that the target would be “democrat”. Therefore, to reduce the use of this strategy by participants, additional primes were used that contained a phonological mismatch. These items were phonological mismatches that were not used as target trials in Experiment 2, but were used as target trials in Experiments 1a and 1b. For these particular trials, the target was a word that was phonologically unrelated to the prime. An example trial would be “denuous gondola”. (“Denuous” is a derivate of “tenuous”.) If participants develop a strategy in which they can predict the target upon hearing the prime, then this strategy would be detrimental to them here because “denuous” does not predict “gondola”. There were 30 such trials.

Next, to further decrease the use of strategies, some words that were targets were missing their final letter sound. For example, the word “bassinet” was presented without the final /t/. In instances such as these, participants needed to make a “nonsense word” decision because “bassine*” is a pseudoword. This step was taken to ensure that participants did not respond prematurely to the targets. These particular targets were paired with primes that were phonological mismatches, as detailed in the previous paragraph. An example trail would be “dassinet bassine*”. There were 30 such trials. Furthermore, these targets were also paired with primes that were words. An example trial would be “location locatio*”. There were 33 such trials.
The remaining 93 trials included trials in which the prime was a word and the target was a pseudoword (30 trials), both the prime and target were pseudowords (30 trials), and both the prime and target were words (33 trials). In all of these instances, the pseudoword was a completely nonsensical word, such as “blarnisof”.

Procedure and Apparatus

The procedure and apparatus were the same as in Experiment 2.

Results

Of the 106 participants who participated in this experiment, 22 participants’ data were not included in the statistical analyses. They were excluded for the same reasons that other participants were excluded from the analyses in the previous experiments. Most of the participants were excluded for either not responding to trials or responding too fast to a certain number of trials. The same procedure that was used to measure reaction times to the target in Experiment 2 was also used here. 0.52% of the data points were excluded. Finally, data from the filler trials were not included in the analyses.

Figure 6 details the accuracy ratings and reaction times of the six different experimental conditions. Standard error bars are also plotted here. With regards to the accuracy ratings, the Different Word condition resulted in the least accurate responses (95%), while the IF condition resulted in the most accurate responses (100%). The other
four conditions fell between these two endpoints. The four phonological mismatch conditions, overall, resulted in more accurate responses than both the Word and Different Word condition.

As was the case with Experiment 2, the Different Word condition resulted in the least accurate responses, as well as the slowest reaction times (1312 ms). The Word condition was the next slowest condition (1237 ms). Of the phonological mismatch conditions, the IF condition was the fastest (1136 ms), while MF was the slowest (1189 ms). The IN and MN conditions were between the previous two conditions with reaction times of 1144 ms and 1177 ms respectively.

The Different Word condition was the slowest of the six conditions by at least 75 ms, while the Word condition was slower than the four phonological mismatch conditions by at least 48 ms. Of the four phonological mismatch conditions, both of the initial mismatches were slower than the medial mismatches by approximately 43 ms. There was not a large difference in reaction times between the IN and IF conditions (8 ms) and the MN and MF conditions (12 ms).

As in the previous experiment, inferential statistics were performed on both the subjects (F1) and items (F2) data. The same inferential statistics that were performed in Experiment 2 were also performed here. A one-way ANOVA revealed a significant effect, F1 (5, 415) = 45.739, p< 0.001; F2 (5, 328) = 12.599, p< 0.001. For the subjects data, a Bonferroni post-hoc test revealed that the Different Word condition was
responded to significantly slower than the other five conditions, p< 0.001. A Bonferroni post-hoc test revealed that the Word condition was responded to significantly slower than the four phonological mismatch conditions, p< 0.009. For the items data, a Tukey post-hoc test revealed that the Different Word condition was responded to significantly slower than the four phonological mismatch conditions, p< 0.001. The Different Word condition was not responded to significantly slower than the Word condition, although the difference was approaching significance, p=0.056. The same post-hoc test revealed that the Word condition was responded to significantly slower than both of the initial mismatches, p< 0.001, but not the medial mismatches, p=0.077.

A 2x2 ANOVA revealed that the effect of position was significant, F1 (1, 83) = 15.981, p< 0.001; F2 (1, 235) = 7.885, p< 0.005. A pairwise comparison revealed that initial mismatches were responded to faster than medial mismatches, p< 0.001. The effect of distance was not significant, F1 (1, 83) = 0.055, p= 0.815; F2 (1, 235) = 0.056, p= 0.813. The interaction between position and distance was not significant, F1 (1, 83) = 1.02, p= 0.315; F2 (1, 235) = 0.529, p= 0.468.

With regards to the accuracy data, a one-way ANOVA revealed a significant effect, F1 (5, 498) = 29.315, p< 0.001; F2 (5, 469) = 6.215, p< 0.001. For the subjects data, a Bonferroni post-hoc test revealed that participants were less accurate at responding to the Different Word condition than the other five conditions, p< 0.001. For
the items data, the same post-hoc test revealed that the Different Word condition was less accurate than the IN, IF, and MF conditions, \( p < 0.006 \).

As was the case with Experiment 2, a block analysis was performed to determine if a surprise effect was present. Figure 7 details the reaction times for the four block of experimental condition, except the Different Word condition. A 2x5 repeated measures ANOVA was run in which Blocks 1 and 4 were compared over the five experimental conditions. The effect of block was not significant, \( F(1, 83) = 0.38, p = 0.846 \). The effect of condition was significant, \( F(4, 332) = 6.239, p < 0.001 \). Pairwise comparisons revealed that the Word condition was responded to significantly slower than the IN, IF, and MN conditions, \( p < 0.009 \). The interaction between block and condition was not significant, \( F(4, 332) = 1.568, p = 0.183 \).

Discussion

While this pattern of results is the same as in Experiment 2, the only difference is that these reaction times, on the whole, are slower than Experiment 2’s reaction times. The increase in reaction times is most likely due to the inclusion of the filler trials in which the word’s final phoneme was deleted. This forced participants to listen to the entire utterance before responding, which resulted in slower reaction times. In Experiment 2, premature responses could have caused the relatively fast reaction times.

This experiment was also run to address of number of concerns with Experiment 2, namely that participants’ use of an anticipatory strategy could influence their
responses. With all of the precautions taken to ensure that participants’ would not use such a strategy, it can be concluded that strategic effects did not contaminate the experimental results. Therefore, the present results seem to reflect natural lexical processing.

With regards to the Word condition, one possible explanation as to why this condition was slower than the four phonological mismatch conditions in Experiment 2 was that participants were using a strategy. In response to this, the nature of the filler trials was altered in Experiment 3, yet the Word condition was still slower than the four mismatch conditions. Therefore, the slowdown in the Word condition is not due to the participants’ use of a strategy, but rather that the activated word node might be inhibiting itself.

Another issue that was addressed in Experiment 3 was the surprise effect, which was present in Experiment 2. A series of “burn-in” trials were added to eliminate, or reduce, the surprise effect. The reaction times for Block 1 and Block 2 are virtually the same; there is no decrease in reaction times. Moreover, there was not a significant difference in reaction times between Block 1 and Block 4; participants’ performance did not improve due to familiarity with the task. Thus, a surprise effect is not present. For future experiments, a possible solution to eliminating the surprise effect would be to increase the number of filler trials at the beginning of the experiment before any of the target trials are introduced.
CHAPTER 7

GENERAL DISCUSSION

This series of simulations and experiments investigated how tolerant the recognition system was of phonological mismatches. Given that the recognition system is remarkably robust, how tolerant would the recognition system be of phonological mismatches? A relatively tolerant recognition system would be more tolerant of near, rather than far mismatches. Moreover, with regards to the position of the phonological mismatch, would the recognition system be more tolerant of initial or medial mismatches? If the recognition system is intolerant of initial mismatches, then it is assumed that the recognition system places a special status on a word’s initial phoneme. Subsequently, any word-initial deviation would greatly hinder lexical access.

TRACE, one of the most influential models of word recognition, was used to test these different hypotheses because simulations of the model could provide actual results. The TRACE simulations offered a clear result with regards to the position of the mismatch: TRACE was tolerant of medial mismatches and intolerant of initial mismatches. It was hypothesized that TRACE was intolerant of initial mismatches because of the sequential nature of lexical processing in TRACE. When the initial phoneme enters TRACE, a cohort of words is activated. If an utterance containing an initial mismatch is presented to the model, then a cohort of words is activated that does
not contain the intended word. It seems, therefore, that upon processing the entire speech
signal that TRACE is unable to revise the original cohort so that the intended word is
included in it and, thus, become the recognized word. It isn’t until later on in the
recognition process that the intended word enters the cohort. These results indicate that
the intended word can enter the cohort only if there is enough bottom-up support in the
speech signal following the initial mismatch.

While clear results can be drawn about TRACE’s tolerance of initial and medial
mismatches, the simulations provided mixed results with regards to the degree of
mismatch. For initial mismatches, TRACE was intolerant of both IN and IF mismatches.
This particular result is somewhat surprising because it was assumed that TRACE would
be relatively more tolerant of initial near mismatches because of the feature matrix. The
simulation results indicate that the initial cohort of activated words is determined solely
by the initial phoneme. With regards to the MN and MF mismatches, the TRACE
simulations demonstrated that the MN mismatches had slightly more lexical activation
than the MF matches. This indicates that TRACE is sensitive to the degree of mismatch,
because of the feature matrix.

Along with the TRACE simulations, experiments were also conducted that
investigated how tolerant the recognition system was of phonological mismatches. The
first experiment, which utilized the phoneme monitoring paradigm, did not provide valid
results because it was hypothesized that participants became confused, and surprised,
when the medial mismatch was encountered. As previously discussed, it was believed that this confusion distorted the data, and did not reflect true lexical processing. However, it should be noted that this experiment did produce one result that was replicated across two additional experiments: reaction times to the IN and IF mismatches were of a similar magnitude. It was concluded that these two mismatches produced similar levels of lexical activation.

The next two experiments, which both utilized the form priming paradigm, did produce results which more accurately reflected lexical processing. These results indicated that there was a clear effect of position: initial mismatches resulted in faster reaction times than medial mismatches. The slower reaction times for the medial mismatches indicates greater inhibition, which in turn, indicates greater lexical activation. From these results, it was concluded that the recognition system is more tolerant of medial mismatches, rather than initial mismatches. Secondly, the results were mixed with regards to distance of the mismatch. For initial mismatches, both experiments demonstrated that reaction times were similar for both IN and IF mismatches. For medial mismatches, MN mismatches resulted in slightly faster reaction times compared with MF mismatches.

For the most part, the experimental results match the TRACE simulations. Both the simulations and the empirical evidence provide clear interpretations as to the tolerance of initial and medial mismatches. TRACE is more tolerant of medial
mismatches and the data suggest that the recognition system is more tolerant of medial mismatches. These experimental results indicate that word recognition could occur in a fashion that is similar to how words are recognized in TRACE. In the present instantiation of TRACE, a cohort of words becomes activated upon presentation of the initial phoneme. The TRACE simulations indicate that the model is unable to revise its original cohort of words to include the intended word if the speech signal contains an initial mismatch. Therefore, the recognition system relies on an initial cohort of words in order for word recognition to occur. If an utterance containing an initial mismatch is introduced to the recognition system, then the lexical activation of the intended word is greatly reduced, and there is less of a chance that it will become the recognized word.

This conclusion clarifies a conflict in the literature concerning the status of the initial phoneme. Connine et. al. (1993) found evidence suggesting that the initial phoneme does not hold a special status in recognition, while Marslen-Wilson and Zwitserlood (1989) argue that recognition is not possible if the initial phoneme is altered. While the conclusions of Marslen-Wilson and Zwitserlood are hampered by an incomplete experiment, their results appear valid. Any word-initial deviation greatly hinders the recognition process.

The conflicting results of Connine et. al. (1993) may be due to the experimental paradigm that was used. In the semantic priming paradigm, word recognition is achieved via semantic information. For instance, if the prime was “republican”, then its semantic
associate, “democrat”, would become activated. In the present version of the form priming experiment, recognition is achieved via phonological information. For instance, if the prime was “denocrat”, then phoneme nodes such as “d”, “ε”, and “n” would become activated. In turn, these activated phoneme nodes would activate phonologically related words, such as “democrat”. It may be the case that if recognition is achieved via phonological information, then the initial phoneme has a special status in recognition because the word-initial phoneme activates the initial cohort of words. However, the recognition process could occur in a different fashion if recognition is achieved via semantic information. Here, recognition would not rely on phoneme node activation and word recognition would not be dependent on the initial cohort of words. Thus, the initial phoneme may lose its special status in recognition.

With regards to the degree of mismatch, the experimental results partially match the TRACE simulations. In all three experiments, the IN and IF mismatches resulted in similar reaction times. The TRACE simulations demonstrated that these two mismatches resulted in the same amounts of lexical activation. From these results, it could be concluded that the recognition system is insensitive to the degree of the initial mismatch.

This body of evidence clarifies another discrepancy that has surfaced in the literature regarding the recognition system’s sensitivity of IN and IF mismatches. Previously, Boelte and Coenen (2002) found that IN and IF mismatches resulted in comparable reaction times, while Connine et. al. (1997) discovered that IN mismatches
produced faster reaction times than IF mismatches. Yet, this result was present for only certain items. A possible explanation for this discrepancy could be the focus of the participants’ attention. The target stimuli used by Connine et. al. contained only initial mismatches. Participants may have been conscious of this mismatch and instead focused their attention on the initial phoneme in the utterance. In the present series of experiments, mismatches occurred in the initial and medial positions. Thus, participants’ attention was not just directed to the initial portion of the utterance; it was spread across the entire word. The present experimental results could be due to a lack of focused attention to either the initial or medial positions in the utterance. Future experiments can explore this issue further by focusing participants’ attention to either of these two positions. If attention is focused to either of these positions, then participants may become more sensitive to the degree of the phonological mismatch.

However, with regards to the MN and MF mismatches, the experimental evidence and the TRACE simulations do not match. The TRACE simulations demonstrated that the MN condition resulted in slightly more lexical activation than the MF condition, while the experimental evidence suggested the opposite. This piece of evidence suggests that the recognition system is not that sensitive to the degree of mismatch if it occurs word-medially, while TRACE is sensitive to the degree of the medial mismatch. One of the possible reasons for this particular result from TRACE is top-down processing. As mentioned previously, once the word node becomes activated in TRACE, it sends
activation to its respective phonemes and feature nodes. For example, if the pseudoword “denocrat” was presented to TRACE, then it is highly likely that the word “democrat” will become highly activated. In turn, the “m” phoneme node, along with the “nasal”, “bilabial”, and “voicing” feature nodes, will also become activated. The “m” node will also increase in activation due to the bottom-up support from the medial /n/ since /m/ and /n/ share similar distinctive features. Subsequently, the model predicts that the MN condition will result in higher levels of lexical activation than the MF condition.

Since the experimental evidence suggests that the MN and MF condition result in similar levels of lexical activation, this would suggest that the words in the word recognition system do not send activation to their respective phonemes. On this crucial point, the experimental evidence diverges from the results of the TRACE simulations.

Collectively, the experimental results suggest that the recognition system is insensitive to the degree of the mismatch, but sensitive to the position of the mismatch. This suggests that once the recognition system encounters a phonological mismatch, the lexical activation levels of potential lexical candidates decrease, regardless if the mismatched phoneme shares distinctive features with the original phoneme.

**Other Models of Word Recognition**

Besides TRACE, there are other models of word recognition, such as the revised COHORT model, the distributed COHORT model (DCM), and SHORTLIST, that partially match the experimental evidence. The revised COHORT model (Marslen-
Wilson, 1987) operates similarly to TRACE in that the initial phoneme activates an initial cohort of words and as more of the speech signal is processed, the cohort shrinks until only one word remains. Due to this initial cohort, the revised COHORT model is sensitive to any deviation word-initially. This claim is also supported by the experimental evidence. However, it has been suggested that the revised COHORT model, because of its feature matrix, would be tolerant of initial near mismatches (Marslen-Wilson, 1987). For example, if the first phoneme in the speech signal is /d/, then words beginning with /b/ would also be included in the initial cohort of words. Since the experimental evidence suggests that the recognition system is intolerant of initial near mismatches, this is a piece of evidence that does not support the revised COHORT model.

Furthermore, the DCM (Gaskell and Marslen-Wilson, 1997; 1999) cannot account for the experimental evidence. The DCM differs mainly from the revised COHORT model in terms of the lexical representation. The lexical representation in the DCM is distributed across separate phonological and semantic output layers, while the original COHORT model has a localist lexical representation. With regards to phonological mismatches, the authors (Gaskell and Marslen-Wilson, 1999) state that the system is intolerant to minor deviations in words, although the model is able to handle variation that results from coarticulation, in which speech sounds overlap with one another. This claim would indicate that the model would be intolerant of any phonological mismatch,
whether it occur word-initially or word-medially. Yet, the experimental evidence suggests that the recognition system is tolerant of medial mismatches, for example. Thus, the DCM cannot account for the experimental evidence.

Finally, SHORTLIST (Norris, 1994), while relatively tolerant of phonological mismatches, cannot fully account for the experimental evidence. Within the model, recognition occurs over the course of two stages. In the first stage, an exhaustive lexical search produces a short list of potential word candidates that matches the input. Better-fitting word candidates will result in a higher score. For example, in most SHORTLIST simulations (Norris, 1994), matching phonemes receive a score of +1, while mismatching phonemes receive a score of −3. Therefore, if the current input is /d/, /ɛ/, and /m/, then words such as “democrat” and “demonstrate” will receive a score of +3, whereas words such as “Deborah” and “deck” will receive a score of −1. Words are included in the short list until they are displaced by a higher scoring, or better-fitting, word. In the second stage, candidates are wired into a lexical network and are connected to each other via inhibitory links. As one candidate receives more activation, it inhibits other phonologically-related candidates; subsequently, the candidate with the highest activation level is the recognized word.

Given this explanation of speech processing in SHORTLIST, the model assumes that all phonemes are treated equally during processing. If, for example, the initial phoneme had a special status in SHORTLIST, then a matching initial phoneme would
result in a higher preliminary score than would a medial phoneme. Since this does not occur in the model, it is assumed that all phonemes are given equal weighting. Yet, the experimental evidence suggests that the recognition system is insensitive of initial mismatches, which clearly contradicts SHORTLIST’s predictions.

Furthermore, SHORTLIST treats all phonological mismatches equally. If a phoneme does not match with the lexical representation, then the representation’s score will be lowered. Given this, SHORTLIST would not differentiate between near and far phonological mismatches. The experimental evidence also suggests that this is true. Therefore, SHORTLIST can partially account for the experimental results. Thus, taking into consideration these other models of word recognition, it seems as if TRACE can best account for the experimental data; the other models cannot explain as much of the data as TRACE can.

In conclusion, both the TRACE simulations and the present series of experiments explored the issue of tolerance in word recognition by altering a single phoneme within a word. While clear results have been found with regards to the position and distance of the phonological mismatch, a larger questions still need to be addressed. First, with regards to Experiments 2 and 3, why are the reaction times for the Different Word condition so slow? As mentioned previously, there are two potential experiments which could attempt to answer this question. Secondly, how tolerant is the perceptual system in general? For example, would the perceptual system be tolerant of multiple phonological
mismatches? Future experiments could explore this question by varying the distance of both the initial and medial mismatch. For example, an utterance could contain both initial near and medial near mismatches.
APPENDIX A

PARAMETERS USED FOR JTRACE SIMULATIONS
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Frequency post-act 0
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FETSPREAD.gra 6
FETSPREAD.voi 6
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Nreps 1
SlicesPerPhon 3
APPENDIX B

PARAMETERS USED FOR GRAPHING JTRACE SIMULATIONS
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APPENDIX C

TABLES AND FIGURES
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Table 1

Filler Items Used in Experiment 3
Figure 1
Figure 2
Results from Experiment 1b

Figure 3
Results of Experiment 2

Figure 4
Block Analysis from Experiment 2

![Graph showing reaction times for different conditions across blocks.](image)

Figure 5
Results of Experiment 3

Figure 6
Block Analysis from Experiment 3

Figure 7
BIBLIOGRAPHY


