WHEN ORTHOGRAPHY AND PHONOLOGY COLLIDE: THE EFFECT OF ORTHOGRAPHY ON THE PHONETIC PRODUCTION OF HOMOPHONES

(Under the Direction of Margaret Renwick)

ABSTRACT

This study is the first to investigate the effects of orthography on the phonetic production of spontaneous speech. It is also unique in that it utilizes corpus speech data. The speech utilized for this study is extracted from the Buckeye Speech Corpus and the Santa Barbara Corpus of Spoken American English. Homophone pairs with differing orthographic vowels were compared acoustically in tokens from these corpora. The results of two-tailed t-tests show that speakers may have different pronunciations in words with different orthographic vowels and the difference appears primarily in the F2. However, many of the control pairs were also found to be significantly different in their acoustic measurements. Therefore, any significant changes to the acoustics of the homophone productions could be caused by a variety of factors not necessarily including orthography. Further investigation with more homophone pairs and greater token numbers is required to clarify these findings.

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BY

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For Henry,
because I couldn't have done it without you by my side.
And for Erowyn and Edwin,,
because without you I never would have made it this far.

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I. INTRODUCTION

1.1 Background

Just as in many other facets of research and human existence, in language it is often difficult to study one single variable without interaction from any others. The elements of speech and language are often referred to and thought of as separate entities, but the reality is that these elements are closely intertwined. Orthography and phonology function in this way as well. The phonetics of a language do not and cannot exist in a vacuum; these elements are always intertwined with and influenced by other variables no matter how small the influence. The present study is based on this hypothesis of interconnectivity, and the belief that whether consciously or subconsciously, the human speech mechanism will always take influence from the brain in control of its operations. Therefore, the only time the speech mechanism can produce purely uninfluenced sounds is when they're produced mechanically, such as when the larynx of cadavers is removed and manipulated in order to study human speech. Because of this, the notion posited here is that the orthography of written languages will affect the production of language by literate speakers based on the subconscious influence of the vowel qualities of backness, rounding, and height from orthographic vowels on the phonetic quality of the spoken vowels. This subconscious effect of vowel qualities on the phonetic realization of language should affect the speaker's articulation such that the speaker's articulators shift enough to create an acoustic difference. I hypothesize that this effect will be evident when comparing the formant measurements of the vowels in homophones in which the orthography of the vowels is different in each member of the pair.

1.2 Description

This study is the first to investigate the effects of orthography on the phonetic production of spontaneous speech. It is also unique in that it uses corpus speech data, rather than laboratory speech. The speech utilized for this study is extracted from the Buckeye Speech Corpus and the Santa Barbara Corpus of Spoken American English, the former contains speakers from Ohio, and the latter contains speakers from all over the United States. Homophone pairs with differing orthographic vowels were compared acoustically in tokens from these corpora through two-tailed t-tests. The results of these two-tailed t-tests show that speakers may have different pronunciations in words with different orthographic vowels and the difference appears primarily in the F2 measurements. However, many of the control pairs were also found to be significantly different in their acoustic measurements. Therefore, significant changes to the acoustics of the homophone productions could be caused by a variety of factors, though the possibility remains that orthography could be involved in the changes.

1.3 Hypotheses

The main hypothesis of this study is that speakers will modify their articulatory plan for the production of homophones in which the orthographic vowels of the homophone pair are different. This hypothesis will be tested through two-tailed t-tests in order to determine if there is a measurable difference between the two vowel productions for each member of the respective homophone pairs. I hypothesize that during the process of learning to read, speakers create a mental association between orthographic vowels and a corresponding phoneme. This phoneme will typically be the most common pronunciation for each orthographic vowel, or the most common pronunciation in simple words which would typically be used in teaching children to read. This hypothesis is influenced by the finding that highly literate speakers may activate orthographic representations when forming speech; however this effect may not occur as strongly in individuals with poor phonetic distinction (Zhang & Damien, 2012). Regardless, this study pilots the idea by investigating whether a significant difference does exist between the homophone pairs that differ orthographically. I hypothesize that the effect of the orthography of these homophone pairs and the others chosen in this study will be significant enough to illustrate a phonetic difference in the realization of these words such that they will be evident and measurable in the acoustic results.

1.4 Format

This thesis is arranged to begin with the hypotheses and central concepts, followed by a literature review of relevant studies and findings which influence and lend support to the ideas and goals of the present study. Following the review of literature is a discussion of the methods used to perform the present research. Directly after that, the results of the study are outlined basically, followed by a more in-depth discussion of their meaning and implications for both the present and future research. Finally, the last section of the thesis is a summary of the hypotheses, findings, and implications, as well as ideas for further research and expansion of the ideas presented here.

II. CENTRAL CONCEPTS

The main hypothesis of the present study is that there will be a measurable difference between the formant levels of homophone pairs with different orthographic vowels. Encompassed within this hypothesis is the prediction that there will be no significant difference in the formant measurements of control homophone pairs in which the orthographic vowel is the same. These hypotheses are based on several notions of speech and language.

1. An exemplar-theoretic approach to phonology indicates that exemplars are stored with many dimensions of linguistics and experiential information associated to them, possibly including orthography. Therefore, changes in orthography may be related to differences in the way speech is produced.
2. The unique anatomy of the human speech mechanism and process through which the articulators must move to create speech is so precise that a small amount of variation will produce a measurable difference in the production of phones even given the allowable variability in production of sounds by humans.
3. The way humans process and plan language creates an environment in which highly literate speakers will activate their orthographic knowledge when producing spoken language.
4. Historical evidence of spelling pronunciations and spelling exceptions causing changes in spelling to fit pronunciation or pronunciation to fit spelling seem to support the idea that orthography does affect pronunciation and vice versa.

2.1 Exemplar Theoretic Approach to Phonology

Initially, exemplar theory was introduced as a model of perception and categorization in cognitive psychology. More recently it has been extended to speech sounds by Johnson (1996). In linguistics, an exemplar model demonstrates the idea that a category, in this case a word or phoneme, is represented in memory by a cloud of numerous remembered token instances of that category. These tokens are organized in a cognitive map such that memories that are more similar are stored more closely, while those that are less related are stored further apart. Stored exemplars encompass all the possible variation that can occur within the category in physical manifestations (Pierrehumbert, 2001). Examples of exemplars for a phoneme would include information about vocal tract anatomy, surrounding phonemes, hypo- or hyper-articulation, duration variations, phonemic position within the word, etc. The phonetic parameter space is mapped onto the various labels of the category, and the number of exemplars in each category helps explain frequency effects (Lavie, 2007). When new exemplars are introduced to the cloud, new experiences are recognized only in relation to old experiences, and thus create a partial re-experiencing of exemplars in memory (Johnson, 2005). In other words, “the entire system is… a mapping between points in a phonetic parameter space and the labels of the categorization system” (Pierrehumbert, 2001, p.4).

As explained by Johnson (2005), individual speaker and dialect-specific variations are not governed by rules, but rather by experiences. Memory can be divided between recognition memory and declarative memory. Declarative memory is comprised of a person’s knowledge of expressible facts, things that could be written down or gained through reading a book, for example. In contrast, recognition memory encompasses knowledge acquired through direct experiences, such as muscle memory or the ability to pick up instructions for similar tasks more easily with increased exposure. These experience-based differences are also shown through studies of word-specific pronunciations variations such as those outlined in Lavoie’s (2002) investigation of the realizations of ‘four’ and ‘for,’ which indicate that homophones have different reduction patterns in connected speech. Specifically, in conversational speech homophones do not have identical variant frequencies, and may not even always have the same leading pronunciation.

> "While grammars and dictionaries are indeed powerfully useful representations of language, exemplar-based modeling of phonology seeks to explore a representation of phonological knowledge that may be a little closer to the richness of language as it is experienced and stored by native speakers (Johnson, 2005, p. 298)."

Words have their own phonetic histories – encompassed within their clouds – which affect their realizations and perceptions.

Based on this exemplar-theoretic approach to phonology, it is believed that all phonetic and nonphonetic factors affect the speech production and perception of each linguistic building block, individually. Interacting activation between phonetic and nonphonetic information alters the production and perception of phonetic material which allows this information to change the production and perception processes. In this study, the building blocks examined are vowel phonemes and word-level homophones. Because of this, it is a natural leap to assume that the orthographic representation of a word or phoneme would naturally be a part of its cloud, and, therefore, would affect the pronunciation and perception of each, respectively.

2.2 Anatomy of the Speech Mechanism

The anatomy of the speech mechanism plays a unique role in the production and formulation of our language. Humans are the only species to have these uniquely structured speech production mechanisms and, thus, have been the only species discovered to use language. The speech mechanism of humans is arranged in such a way that based on the position of the articulators in the mouth, different phones are produced. The production of vowels, specifically, is based on: the point of constriction, the degree of constriction, the degree of lip rounding, and the degree of muscle tension (Seikel et al., 2009).

The significance of this configuration to the present study is that the articulatory constrictions must be very specific in order to create each unique vowel. There is a gradient of articulatory positioning which will produce each specific phoneme, and along the gradient, with differing constrictions or laxness in the muscles of the mouth, the phones that are produced begin to sound like others. There is a spectrum of sound production in which hearers can recognize a sound as being one particular phoneme until the articulators move enough from their specific path that the sound output begins to be identified as another phoneme (Pardo, 2006). This includes the effects of coarticulation in which surrounding phones take on the influence of one another. Speakers are still able to recognize these variable productions within a spectrum as the specific intended phoneme and, when isolated, these sounds should hypothetically show the influence of both their surrounding sounds and their orthography.

2.3 Psychology of Speech Processing

> “Although we may not feel, consciously, that the phonology corresponding to a printed word may be part of the process of accessing the meaning, it is still possible that such information is typically required at an unconscious level.” (Lee, 2008, p.333)

How do people think about language and speech production while it’s happening?

Levelt (1999) proposed the model of language production that is most widely agreed upon by modern psycholinguists. In Levelt's model, the production of spoken language happens on three major levels: conceptualization, formulation, and lexicalization, with formulation being divided into grammatical and phonological encoding. Conceptualization guides the generation of preverbal messages that specify the concepts that will be expressed verbally. Formulation is the level that concerns this study and includes the mapping of preverbal messages into their final linguistic form. In this stage both grammatical and phonological information is retrieved and utilized to choose semantically appropriate lexical items and create the appropriate articulatory plan to produce the desired utterance. This articulatory planning stage is the point at which phonemes are selected and the plan of articulation is formulated, being buffered and then executed (Jescheniak & Levelt, 1994). This articulatory plan and its execution is the subject of the present study.

Support for the present hypothesis comes from studies focusing on how language is processed through orthographic and phonological codes (Kim et al., [2004], Lee [2009], McKague et al., [2008], & O'Brien et al. [2013]). The spoken production of words involves the retrieval of phonological, semantic, and syntactic representations; however, literate speakers may also activate orthographic representations. There is a high degree of interconnectedness between linguistic codes of different formats in the mental lexicon, with phonological information being accessed in parallel to orthographic information (Zhang & Damien, 2012).

2.4 Spelling Pronunciations & Exceptions

Perhaps the most well-known effect of orthography on phonetics is the case of spelling pronunciations and spelling exceptions. Spelling pronunciations are pronunciations in which a word is pronounced exactly as it is spelled. A spelling exception occurs when the spelling of a word and its pronunciation are in contention. This spelling exception can be corrected by either changing the spelling to match the pronunciation or changing the pronunciation to match the spelling. An excellent example of a word undergoing this process right now is ‘often.’ Most English speakers pronounce this word as /ɑfņ/ or /ɔfņ/ with a silent ‘t,’ and this has been the pronunciation for the past few hundred years. In Middle English, however the ‘t’ was pronounced as were many other orthographic characters in the English language that are now silent, such as the ‘k’ in know, the ‘p’ in words like pneumonia, and the ‘gh’ in words like ‘knight.’ However, due to a sound change, the ‘t’ in the ‘ftn’ cluster was lost so that by the 18th century ‘often’ was consistently pronounced with a silent ‘t’ (Skousen, 1982). Now, though, people have begun again pronouncing the ‘t’ in this word, perhaps as part of a natural progression through the process of spelling pronunciation to exception and back again. It should be noted, though that this has not applied to the word ‘soften’ which has shown no evidence of reviving its now-silent ‘t’. This is because spelling pronunciations are often idiosyncratic and thus do not affect all situations of the same spelling irregularity. Additionally, there is the possibility that this distinction could be due to the influence of frequency.

However, it is not always the case that spelling pronunciations reflect earlier pronunciations in the language. They can also often be reflective of their origins. For instance, there are numerous words in English that have been borrowed from French, but whose spelling was later changed to reflect the original Latin form. An example here would be the word ‘perfect’ which was borrowed from the French as ‘parfit’, but in the 17th century was frequently spelled ‘perfect’ on the basis of its original Latin form ‘perfectus.’ This etymological spelling later resulted in the spelling pronunciation of perfect as it is heard today (Watts, 2011).

III. LITERATURE REVIEW

There are many linguistic studies that support the idea that phonology and orthography influence one another in the processing and planning of speech and language. The purpose of this section is to survey studies that discuss the ideas central to the present work. This section is divided into three parts separated by the direction of influence between phonology and orthography. The first section surveys studies which present evidence of an intrinsic link between orthography and phonology; the second section presents studies illustrating the effect of phonology on orthography; and the third section outlines studies which present findings indicating an effect of orthography on phonology. The significance of each of the studies presented on the current research will be highlighted along with their findings.

3.1 Orthographic and Phonological Links

There have been a multitude of studies done on homophones, orthography, and phonology, both individually and in combination. One of the most notable studies in recent years on the realization of homophones is Gahl’s (2008) study on lemma frequency in homophones. This study shows that although frequently spoken words tend to shorten, homophone pairs like ‘time’ and ‘thyme’ do not shorten equally, as the more frequent member of the pair tends to shorten more than its infrequent homophone partner. Gahl's (2008) study paved the way for the present study by planting the idea that homophones may not, in fact, be as homophonous as they originally seem. This birthed the hypothesis of the present study that orthography may play a role in influencing the phonetic production of speech and may therefore create subtle differences in homophone production such that acoustic measurements would show a change.

The majority of linguistic studies involving homophones utilize homophony judgments as part of their methods. A few of those studies concentrate on areas relevant to the study at hand. Kim et al.'s (2004) study involved three separate experiments in which homophone decision tasks were used with the two Korean scripts, *hanja* and *hangul*. *Hanja* is a logographic script and *hangul* is alphabetic. For both scripts, speakers showed a high error rate in correctly judging that there was another word identically pronounced with it when sublexical information did not support whole-word homophony. Therefore, these results showed that the process of making homophone judgments reflects the relationship between orthography and phonology as mediated through the sublexical units which were activated from orthography to phonology, and from phonology to orthography, called Orthography-Phonology-Orthography Rebound (OPO). Homophony judgement must be based on links between orthography and phonology at the word level. Therefore, the detrimental effect of sublexical incompatibility found in this study indicates that the sublexical link between orthography and phonology plays a role in these links at the word level.

Escudero and Wanrogi (2010) investigated bilinguals and the activation of L1 and L2 phonological knowledge utilizing auditory cues, and found that orthography does, indeed, influence the learning and processing of spoken non-native words. In the first of two experiments, Spanish learners of Dutch along with a control group of native Dutch speakers were tasked with classifying Dutch vowels either by choosing from auditorily-presented options or from the orthographic representations of Dutch vowels. The results of the vowel categorization tasks showed that the easiest vowels to classify in the auditory task were the most difficult in the orthographic task. The opposite was also found to be true; the easiest vowels to classify in the orthographic task were the most difficult to identify in the auditory task. The second experiment replicated these results with native speakers of Peruvian Spanish and confirmed the existence of orthographic effects. When listening to audio stimuli only, native speakers of Spanish had greater difficulty classifying Dutch vowels regardless of the degree of their experience with the Dutch language. Most significantly, these experiments show that when orthographic response options are available, L1 orthography may, in fact, influence non-native vowel perception.

Another study that lends support to the influence of orthography and phonology on each other is Tilsen and Cohn's (2016) study investigating the relationship between metalinguistic judgments and articulatory control, based on the hypothesis that the two share a common representation. The experiment conducted in this study utilized syllable count judgments and word productions of target words with tense vowel/diphthong nuclei and liquid codas which are known to have variable syllable counts in native English speakers. The prediction of the authors was that the differences in metalinguistic judgments, in this case syllable number judgments, should be correlated with differences in the acoustic characteristics of the responses. The main result of the study found this to be true, such that the phonetic aspects of articulation are correlated with syllable count judgments. Specifically, rime durations and formant trajectories were found to be significantly different between productions that were associated with greater than one syllable and one syllable respectively. These results indicate that meta-task intuitions can utilize the same representations as the articulatory control process. Thus, syllable count judgments are derived from the same representations that speakers use for controlling the timing of the articulatory process. These results provide an interesting support and research question relevant to the present study; one of the target words utilized in Tilsen and Cohn's (2016) study is 'hire.' One might ask based on their results if, perhaps the orthographic difference between 'hire' and 'higher' would affect the syllable judgments of these words, and then consequently the rime duration, but perhaps also the formant measurements of productions of these words. This sort of question is what influenced the creation of the present study.

3.2 Influence of Phonology on Orthography

Phonology is linked to orthography at the grapheme, morpheme, and word levels, and when a word is presented visually, the phonological units, activated at all levels, are tapped in order to generate a pronunciation (Kim et al., 2004).

> "No matter what type of script it is written in, a printed word is always associated with pronunciation. The primary function of orthography is that of visually communicating the spoken words of a language" (Kim et al., 2004, p. 187).

In the spelling abilities and learning process of beginning spellers, there is a close interplay of orthography and phonology. The spelling process is studied because it can highlight the linguistic knowledge that people bring to the task of writing and the processes that they use in order to accomplish the task. Beginning spellers use a variety of strategies based on their phonetic knowledge in order to segment words and represent those segments as written entities. Treiman et al., (1997) studied this principle by comparing the spellings of beginning spellers who spoke American and Southern British dialects of English, but had similar socioeconomic statuses. The significance of this comparison is that most American English dialects are rhotic, while Southern British is a non-rhotic dialect. This means that typically, non-initial ‘r’s are not realized in the British English spoken in Southern England, while they are in American English. Because of this distinction, the researchers aimed to determine if these dialect differences would play a role in the way that the children learned to spell words, and indeed it did. The results showed that the American children were much more likely to include only an ‘r’ with no vowel in words like ‘girl’ and ‘blur,’ while the British children were much more likely to include a vowel and no ‘r.’ This finding illustrates that spelling is heavily based on phonology, and that spelling is a linguistic process which draws on the spoken language knowledge of the speller.

A similar effect of Treiman et al.’s (1997) study was observed again in Treiman and Bowman’s (2015) study, but this time the focus was final consonant devoicing typical of African American Vernacular English in African American children. In line with the hypotheses of both of these studies, these researchers again found evidence to support that African American children were significantly less accurate in spelling the final ‘d’ of words like ‘salad’ than non-African American students after all other spelling abilities were taken into account. Specifically, the African American children were much more likely to replace the final ‘d’ of ‘salad’ with a ‘t.’ Furthermore, these errors were much more common in African American children who utilized more final devoicing in their speech than those who produced less. This result further illuminates the connection between phonological processing and orthographic learning, pointing towards a strong link between orthography and phonology in both the perception and production of language.

Additionally, Wang et al. (2008) illustrate the importance of phonological learning and knowledge in gaining good reading skills, even for children who speak sign language. This paper outlines the fact that good readers must possess phonological and phonemic awareness in order to facilitate their understanding of the link between phonemes and graphemes. In English, as in other languages that have an alphabetic writing system and are spoken, orthographic representations encode their phonemic counterparts; graphemes represent phonemes, even in a language like English, which is not as phonetically transparent as other languages. This is further illustrated in Arab-Moghaddam & Senechal's (2001) study on Persian-English bilingual children, in which predictors of spelling performance in the children differed between the two languages; English language performance was based equally on phonological and orthographical knowledge, while Persian relied mostly on orthographic processing skills. This highlights the importance of phonological and orthographic links, once again, in the spelling and linguistic performance of English-speakers, indicating that our ability to spell and read is directly connected to our knowledge of both the sounds and graphemes of our language.

Interlingual homophones provide another unique investigative environment. Haigh and Jared (2007) explored whether bilinguals activate the phonology of both of their languages when reading silently in one. This study compared lexical decision latencies in both interlingual homophones in French and English as well as in matched English control words. The bilingual participants in this study performed tasks in both their first language and their second language, in order to test whether the homophone facilitation effect is truly language nonselective. French-English bilinguals completed the lexical decision task significantly faster and more accurately for interlingual homophones than matched English control words. The results point toward the activation of phonological representations being both language-specific and language-general depending on the proficiency of the bilinguals. This effect also varied based on whether the speakers were reading in their weaker or stronger language. Similar findings were produced in Carrasco-Oritz et al. (2012) in which they utilized event-related potentials (ERPs) to also investigate whether the phonological representations of both L1 and L2 were activated during silent reading of L2 words. Their findings suggest parallel activation of both L1 and L2, and point toward a more language-nonselective model for bilinguals at the phonological level of representation. These results indicate that bilinguals cross-linguistically utilize phonological representations in language processing. These findings point to the relevance of phonology even when reading silently, lending proof to the absolute interconnectedness of orthography and phonology, and indicating that phonology may be more utilized in tasks that may not obviously require its activation, like silent reading.

Important support for this study's hypothesis of language processing comes from research on the language processing of dyslexic individuals. It is well-documented that dyslexia is correlated with a phonological coding deficit when reading printed words whether aloud or silently. This phonological coding deficit in processing written language is preceded and predicted by earlier phonological problems with spoken language, most notably in phonological awareness. In O'Brien's (2012) study on the relationship between orthography and phonology and their influence on the reading of dyslexic individuals, dyslexic groups differed from chronological-age matched controls by having an increased number of false-positive errors in their homophone perception. Children in these groups also made more false-positive errors on spelling-control foils. The findings of this study suggest that individuals with dyslexia tend to lack sufficient knowledge of actual word spellings in comparison to age and reading-level matched peers. These results indicate, therefore, that the phonological knowledge of speakers has a great deal to do with how they process the orthography of language, signifying that the relationship in linguistic processing between orthographic and phonological knowledge is intrinsic to competent language comprehension. This reflects the potential for these knowledges to be equally important in the converse context of language production.

"Orthographic representations are paved with phonological information" (Ehri, 1992, p.97). Orthographic representations can start being specified for novel phonological word forms even before visual exposure occurs. Meaning that once a word is spoken, even if the hearer does not know that word, they can begin imagining the word's spelling without ever having come in contact with it before. The feedback from phonology to orthography is heavily involved in the orthographic learning process, and the orthographic code develops around a consonant frame that can be developed from the speech signal before encountering the printed form. McKague et al.'s (2008) study investigated this point and determined that initial variability in orthographic representations in adult second language learners of English is most likely to lie with the vowel content, because English vowel spellings are much more variable and difficult to predict than their consonantal counterparts. This lends credence to the hypothesis that vowels are more likely to be variable in our psychological perception of word orthography. Though this only proves the effect of phonology in language perception rather than production, it does hint that the effect may also be present there.

3.3 Influence of Orthography on Phonology

Orthographic features of a word are crucial to the identification of that word (Frisson et al., 2014). There is a fast and automatic language nonselective activation of phonological information during the preliminary stages of visual word recognition. However, this activation is dependent on the orthographic properties of the initial stimulus (Dimitropoulon et al., 2011). Despite the fact that the current study utilizes spontaneous speech corpora, this finding is still relevant because the current hypothesis being tested relies on the idea that speech involves a mental ‘picture’ of orthographic characters, which influences speakers subconsciously. Furthermore, Kaminska’s (2003) study of the effect of the interaction between lexical and non-lexical processes in spelling investigated the effect of orthography and phonology on spellings by Polish children. Orthographic choice for non-words was assessed under free and primed spelling in both children and adults utilizing both direct and associative priming. The findings of these experiments showed that lexical orthography does influence the resolution of non-lexical phonology in spelling. Additionally, the study identified two sources of influence on the results, the first in unprimed spelling in which long-standing orthographic knowledge affected non-word orthographic choice, and the second in primed spelling in which orthographic solutions to non-words were influenced by the orthography of the prime. In fact, lexical orthography not only informs the resolution of phonology in cases of ambiguity, but also overrides phonology when the resolution is ambiguous. The most significant finding of this study is the most powerful evidence for lexical influence, which is that the effect of orthography is so strong that it can actually override the effect of phonology. Specifically, lexical influence was found not only to inform phonological resolution when phonology underspecifies orthography, but can also override phonology when orthography is fully specified. This finding lends support to the present hypothesis that the orthography of written language may affect the phonology of spoken language, perhaps overriding speakers' knowledge of how words are supposed to sound and superimposing itself over the underlying phonology to create a unique pronunciation in homophones with different orthographic vowels.

The effect of orthography and phonology's interconnectivity is further evidenced through the many studies on bilingual speakers and the relationship between orthography and phonology in the unique context of their language knowledge and processing. Some of these studies explore the effect of specific writing systems on the phonetic processing of their speakers, such as Lin and Collins (2011), which focused on the unique distinction between Chinese and English utilizing participants who were either native Japanese or English speakers. English is an alphabetic language in which graphemes correspond to phonemes, while Chinese is a morphosyllabic language in which characters correspond to syllables. Japanese is similarly represented by both the Latin alphabet used in English, and Kangi, which utilizes morphosyllabic characters much like Chinese. The differences in these writing systems provide an interesting linguistic environment for research of orthographic-phonetic links, and, in fact, the study did conclude that the L1 phonology and writing systems of both English-speaking and Japanese-speaking Chinese language learners affected their Chinese character learning. The accuracy data analyzed in this study showed that the Japanese-speaking Chinese language learners were more skilled at reading Chinese characters, even after controlling for Chinese language familiarity. Additionally, both the subject-level and item-level analyses showed that Japanese speakers made greater use of sublexical features than their English-speaking cohorts.

Drummond's (2014) investigation into the role of orthography on L2 acquisition highlights the strength of the influence of orthography on pronunciation, particularly interlinguistically and when the languages in question have different degrees of orthographic depth. Focusing on Polish and English, this study investigates the role of orthographic representation in the production of the local variant of the STRUT vowel in the speech of Polish migrants living in Manchester. A previous study by Drummond in 2013 showed that acquisition of the local English variant depended on various social factors; however, this research only took into account conversation data, leaving some word list data yet to be analyzed. A comparison of the two data sets revealed a difference in degree of acquisition, with the word lists data producing more of the local vowel. The author explains this, not as a case of dialect acquisition as such, but more as an effect of orthography triggering a connection to the L1 phonology, the particular nature of which mimics acquisition of the local variant. This is perhaps because seeing the words written out made them more conscious of their spelling and therefore more likely to modify their speech based on that; however, such effects may exist in spontaneous speech if the speakers are still conscious of the spelling of their words, as might be the case in visual learners or highly literate individuals. Regardless, this study helps to highlight the importance of considering orthography when investigating issues related to pronunciation.

Another study relevant to the investigation of homophones and orthography is Warner et al.'s (2003) study on subphonemic durational differences in homophones and their perception in Dutch. This study begins with the idea that speakers produce small differences in duration of homophones and that listeners can make use of these differences in order to distinguish apparent homophones. Through five experiments, they extend the investigation of this topic and find that: durational differences termed incomplete neutralization are pervasive; listeners can perceive and utilize these differences to distinguish words with different underlying forms; vowel duration, being the most likely cue found in the production results, is perceptually useful; and these durational differences can be used by listeners for perception even when they are not consistently observed in production. Most importantly to the present study, Warner's study indicates that a primarily orthographic difference, rather than an underlying difference, can cause this durational change. Warner, et al.'s study focuses on the production and perception of homophone pairs, and how members of homophone pairs are produced differently and these differences are used to distinguish between members of the pairs. These questions are fundamentally the same as the ones being asked in the present study, with the difference being durational differences versus vowel quality differences. Therefore, these findings provide weight to the theories posited in this thesis.

Languages differ in how they represent spoken language in written form. Typically languages are either alphabetic, meaning that the language's graphemes stand for individual phonemes, or morphosyllabic, in which the language's characters represent syllables. Additionally, languages are said to be either phonetically transparent or opaque, which describes how easily the sounds of the language can be gleaned from its written form. English is an alphabetic language, though nearer to the opaque side of the phoneme-grapheme link spectrum than many other alphabetic languages (Chen et al., 2008). Zhang and Damian's (2011) study focused on just this distinction in orthographies when they investigated the role of orthographic representation on spoken word production in speakers of Chinese and English. An oral reading task was utilized for this study. In Experiments 1 and 2, participants were asked to memorize four word pairs one by one, and then to produce the response word when the cue word was presented. In Experiment 3 the prompt-response word pairs were presented auditorily and repeated until the participants indicated that they had memorized them. The results of the first two experiments indicated a reliable facilitative orthographic effect in the oral reading task, suggesting that orthography does indeed play a role in spoken language production. However, this effect disappeared when the stimuli were presented auditorily, suggesting that it may be attributed to the memorization stage of the task. Regardless, this orthographic effect is linked to the correspondence between orthography and phonology of a language even if it was only found in tasks where the orthography was directly relevant.

Damian and Bowers (2003) investigated potential influences of spelling on single word speech production in English. A form-preparation task that showed priming effects in words with initial form overlap was used to investigate whether words with form overlap but different spelling also showed priming. The results of this first experiment showed that these words did not benefit from the form overlap, which suggests that the incongruent spelling disrupted the form-preparation effect. The second experiment replicated the first with an independent set of items and an improved design, but also showed a disruptive effect of spelling. The third experiment was conducted auditorily in order to distract the participants from the spelling of the words, however it yielded the same results. Finally, the fourth experiment found that matching initial letters without matching sounds did not produce this same priming effect. These four experiments using a form-preparation paradigm demonstrate the effects of orthography on speech production. Altogether, these results uncover the possibility that orthography is mandatorily activated in speech production when produced by literate speakers.

One study which provides promising support for the present study’s hypothesis of orthography influencing phonology after speakers learn to read is Hanssen, Schreuder, and Neijt’s (2015) study on t- and d-bias in Dutch children. Previous studies have shown that young Dutch children display a t-bias in the medial position of words in their pronunciation, while first graders display a d-bias in the same medial position. This study investigates children’s spelling and pronunciation of word medial d and t to examine this apparent contrast. The results indicate that first graders started out with t-bias in their spellings while later displaying a d-bias. This also corresponded to a change in pronunciation – kindergarteners displayed a t-bias while second graders displayed a d-bias instead. The explanation offered for this by the authors is an effect of overgeneralization due to the differences in Dutch pronunciation and orthography. However, the conclusion is made that the orthographic system, although learned later in life than the phonological system, affects children’s previously acquired pronunciation. This finding is significant in that it illustrates the existence of the general hypothesized effect of orthography on phonology and how this effect can appear after literacy is achieved. Therefore, this finding provides not only more support for the current hypothesis, but also for the supposition that more literate speakers will display a greater influence of orthography on phonetic productions.

3.4 Influence on the Present Study

The hypothesis posited here, which is that orthographic differences in homophone vowels will cause a difference in the phonetic realization of these vowels, was constructed based on the findings outlined in the above studies. Multiple researchers have investigated and confirmed that orthography and phonology are interconnected, and the present study is most basically built upon this idea. Because of the work of Zhang & Damian, (2012) and Damian and Bowers (2003) and their consensus that speakers activate orthographic knowledge when performing phonological tasks, along with the findings of Treiman et al. (1997) and Treiman & Bowman (2015) indicating that spelling is highly influenced by phonology, the hypothesis was formed that if spelling is affected by phonology and orthography is activated when highly literate speakers produce speech, then the effect of orthography should appear in spontaneous speech production. If the speakers utilized for this study are literate, they should activate their orthographic knowledge when they speak, and we should expect to find an effect of orthography on the acoustic data observed in this study.

IV. METHODS

4.1 Target Words

The first step of this study was the creation of the homophone list that was used as the basis of token collection. In order to create a list of viable homophones I consulted multiple online homophone lists of American English (i.e.: allaboutlearningpress.com; englishclub.com; lccc.edu; homophone.com). These lists were mined for homophones that are specifically distinct from one another in vowel orthography in such a way that the phonemes corresponding to the vowel graphemes would differ in combinations of height, backness, and rounding.

The corpora used in this study are the Buckeye Speech Corpus, which centers on speakers from central Ohio, and the Santa Barbara Corpus of Spoken American English, which contains speakers from all over the country. Therefore, only pairs that are true homophones in most American English dialects were considered, meaning that pairs that are only homophonous in dialect areas where certain mergers are present were avoided. These mergers include pairs like the pin/pen merger present in Southern American dialects in which the /ɪ/ and /ɛ/ vowels are no longer phonetically differentiated before tautosyllabic nasal consonants. However, members of vowel mergers present for the majority of American English speakers were not eliminated. An example of such a case would be the horse/hoarse merger, which is present in most of the country aside from a few older Southern American and New England dialects (Labov et al., 2006). Mergers that may affect the central Ohio area specifically, such as the pre-rhotic Mary/marry/merry merger, were also avoided.

In this process there was also an effort to maintain a widespread inclusion of as many phonetic vowels as possible in addition to including as many orthographic vowels and vowel combinations as possible along with a myriad of unique spellings present in the surrounding consonants. Specifically vowel differences were desirable if the spelling of one homophone was markedly different from that of its partner such that either multiple letters were changed in the spelling of the vowel component of each word. The initial list of potential homophone pairs is illustrated in Table 4.1, which incorporates their frequency as listed in the Wiktionary Frequency Lists (2006) of words in TV and movie scripts. This frequency list was chosen over other lists because the frequency measurements come from the scripts of TV and movies, removing any stage directions and only incorporating the lines spoken by actors. Therefore, this frequency list is more accurate to the frequency of spoken language in contrast to many other frequency lists, whose data is more accurate to written language. Frequency is an important factor in comparing homophones and their acoustic measurements because higher frequency words are realized with shorter duration than infrequent words, and it has been found that more frequent members of homophone pairs will shorten more than their more infrequent homophone partner (Gahl, 2008). Therefore, if any unique patterns occur in the acoustic results, it is useful to compare them to the frequency distribution of the words in order to determine if frequency could be a factor.

Table 4.1 – Initial Target Words and Frequencies

The initial set of potential targets collected for the present study. These words are listed along with both their rank and their frequency as listed in the Wiktionary frequency lists compiled from TV and movie scripts (2006). Those marked with a '-' were not present in the list and can therefore be determined to be comparably very infrequent.

More Frequent Member	**Rank**	**# of Occurrences**	**Less Frequent Member**	**Rank**	**# of Occurrences**
air	769	3126	**heir**	5925	181
for	17	216535	**four**	492	6014
course	239	15866	**coarse**	24163	17
idle	12384	54	**idol**	11874	58
or	92	55062	**oar**	32752	9
pray	2026	873	**prey**	9261	87
profit	4658	261	**prophet**	10593	70
piece	747	3239	**peace**	1234	1711
sure	115	40757	**shore**	5234	221
way	103	49794	**weigh**	6101	172
wait	154	27920	**weight**	2154	805
baron	16110	35	**barren**	16386	34
bridal	8122	109	**bridle**	-	-

call	162	25880	**caul**	-	-
i	2	1052546	**eye**	784	3063
descent	14233	43	**dissent**	27780	13
more	117	40239	**moor**	20286	23
rain	2018	879	**reign**	9417	85
wore	2960	511	**war**	869	2690
you'll	248	14958	**yule**	21631	20
oral	-	-	**aural**	-	-
ball	1029	2200	**bawl**	27953	13
bizarre	3899	341	**bazaar**	25061	16
hanger	13296	48	**hangar**	20367	23
board	1192	1786	**bored**	2754	572
brood	14433	42	**brewed**	22772	19
elicit	37686	7	**illicit**	19044	26
bruise	8449	102	**brews**	26896	14
shown	3286	440	**shone**	29481	11
manner	4328	293	**manor**	8701	96
mall	2859	540	**maul**	34717	8
through	209	18903	**threw**	1522	1286
time	75	64891	**thyme**	34087	8
current	3641	380	**currant**	-	-
minor	3355	427	**miner**	27484	13
mustered	-	-	**mustard**	7193	133
earn	4302	296	**urn**	9401	85
eight	879	2655	**ate**	2281	747
basil	13167	49	**basal**	-	-
been	91	55235	**bin**	5438	208
by	132	35500	**buy**	610	4345

Once the list was compiled, the words were searched for in both corpora used in this study, the Buckeye Speech Corpus and the Santa Barbara Corpus of Spoken American English. Based on the availability of the words in those corpora, the pairs were narrowed to a final word list, shown in Table 4.2, which would be used as the targets for the experiment.

Table 4.2 – Final Target List

Contains the final list of targets collected for the present study. Included in this table are the target vowels in each homophone and the phonemic transcription of each pair.

Homophone 1	**Homophone 2**	**Relevant Vowels**	**Phonemic Transcription**
board	bored	<oa> vs <o>	/bɔɹd/
buy	by	<uy> vs <y>	/baɪ/
ate	eight	<a> vs <ei>	/eɪt/
eye	I	<eye> vs <i>	/aɪ/
peace	piece	<ea> vs <ie>	/pis/

threw	through	<e> vs <ou>	/θɹu/
war	wore	<a> vs <o>	/wɔɹ/
weigh	way	<ei> vs <ay>	/weɪ/
weight	wait	<ei> vs <ai>	/weɪt/

4.2 Control Data

In addition to the list of target homophones, a list of control homophone pairs was created containing pairs that have no orthographic difference in their vowels. This list was created to compare against the phonetic results of the target words in order to determine if any observable differences present in the target homophone pairs were truly due to the effect of orthography and not some other confounding variable such as speaker, word context, or part of speech. These homophones were mined from the same online lists of English homophones and were also chosen with the intent to include as many possible phonetic and orthographic vowels as possible. The initial control list is shown in Table 4.3.

Table 4.3 – Initial Control Words and Frequencies

Contains the initial set of potential controls collected for the present study. These words are listed along with both their rank and their frequency as listed in the Wiktionary frequency lists compiled from TV and movie scripts (2006). Those marked with a ‘-‘ were not present in the list and can therefore be determined to be comparably very infrequent.

More Frequent Member	**Rank**	**# Of Occurrences**	**Less Frequent Member**	**Rank**	**# Of Occurrences**
holy	1755	1068	wholly	26036	14
we’d	755	3205	weed	6083	173
which	265	13652	witch	1246	1684
phase	3730	363	faze	30106	11
browse	23486	18	brows	-	-
cannon	8015	111	canon	21018	22
sensor	16734	32	censor	23458	18
dessert	2949	515	desert	3180	461
tax	3432	411	tacks	28190	12
locks	6276	166	lox	25552	15
night	168	24900	knight	5193	224
our	119	39896	hour	612	4325
cord	6805	146	chord	16638	33

cell	1077	2036	sell	1146	1885
core	4617	265	corps	7819	116
but	33	159109	butt	1415	1413
muscle	4101	316	mussel	34652	8
cash	1257	1670	cache	22765	19
chance	365	9081	chants	33577	9
chased	5680	195	chaste	21007	22

This list was narrowed in the same way and based on the same criteria as the target list was. Those homophones available in the corpora were kept as targets, and those that were not available or were very infrequent were discarded. After narrowing the list based on frequencies, the final list of control words, shown in Table 4.4, was compiled.

Table 4.4 – Final Control List

Contains the final list of targets collected for the present study. Included in this table are the target homophones and the phonemic transcription of each pair.

Homophone 1	**Homophone 2**	**Phonemic Transcription**
know	no	/no/
our	hour	/aʊɹ/
which	witch	/wɪʧ/
whole	hole	/hol/

4.3 Corpora

For this study, unlike any of the studies surveyed in the literature review, speech data was extracted from corpora rather than collected firsthand. Utilizing corpus data increases the contribution of this study by using a new type of data, however it does reduce the amount of control that can be taken over the speech collected. The targets and controls were searched for in two corpora of spontaneous spoken American English: the Buckeye Speech Corpus and the Santa Barbara Corpus of Spoken American English. The Buckeye corpus is a collection of interviews with forty speakers from Columbus, Ohio in which the speakers are speaking freely with the interviewer. This corpus was compiled in 2000, includes audio as well as tagged transcriptions, and classifies each speaker by gender and age grouping being either under or over forty (Pitt et al., 2000). The Santa

Barbara Corpus is a collection of recordings of over 60 speakers across the United States, typically in face-to-face conversations, though other interview methods, such as telephone conversations are included as well. This corpus was assembled from 2000-2005 and includes transcriptions and audio. Each interview contains what speaker data the researcher knew or could glean from their conversations. This data is not standardized across all interviews, and thus the same information is not necessarily available for all speakers (Du Bois et al., 2000).

The Buckeye and Santa Barbara Corpora both contain transcriptions of the audio data with timestamps for the beginning and end of each word or phrase. The Buckeye Corpus is transcribed by word, having start and end times for each word listed in the transcription files, while the Santa Barbara Corpus is transcribed by phrase, listing start and end times for each phrase. In order to extract the targets from the corpora, each token was searched for in the transcription data of both corpora, and the start and end times for each chunk was recorded. After extracting all of the tokens of each word from the corpora, a script in the audio analysis software, Praat, was utilized to extract the chunks in the audio files corresponding to the transcribed data and create text grids for each of these audio chunks (Boersma & Weenink, 2016). Once the chunks were created, they were analyzed one by one in order to ensure the quality of the recordings, meaning that the target could be heard clearly with no overlapping speech or noise. At this time, each chunk was labeled with the exact location of each target within it, as well as the target vowel within those words. Tokens which were unclear or obscured by either background noise or overlapping speech were removed.

There are benefits and disadvantages of utilizing corpus data in this study. One of the major benefits of utilizing corpus data is not having to perform the speech collection portion of the experiment oneself. Additionally, corpora have many more speakers' worth of data to draw from than would have been possible for me to study in a single speech experiment. However, the major drawbacks of using corpora center on having significantly less control over the speech data that was collected. Ideally for this experiment, I would have had access to complete linguistic backgrounds on every speaker; I would know for sure that each and every audio file was coded and labelled correctly because I had done it myself; and I could be absolutely sure of the audio quality because I was present when it was recorded. These disadvantages did cause some overall difficulties, but, for me, the benefits outweighed them.

4.4 Analysis

The next step of this study was the analysis of the finalized tokens. Once the files were broken down, another Praat script was utilized to extract the formant values of each vowel. The vowels were measured for F1, F2, and F3 at the vowel onset, 25% through, 50% through, 75% through, and the end of each vowel. These measurements were taken in order to determine if the vowel differences might occur at a certain point in the vowel, or if the vowels of both homophones in a pair each move in the same way throughout their duration. Once these formant values were extracted, they were checked for mistakes and outliers, and any problems were either fixed or excluded.

Finally, the formant measurements were subjected to quantitative analysis using the statistics software R (R Core Team, 2013) and compared with both two-tailed and one-tailed t-tests. The two-tailed tests were utilized to compare the control and target pairs for significance, and the one-tailed tests were utilized to test the formant-specific hypotheses for each target pair. The t-tests were performed for each homophone pair on the relevant formants, with a test being done for each vowel comparison at 25%, 50%, and 75%. These results were then analyzed for significance and compared in order to determine if any patterns were present.

V. RESULTS

5.1 Tokens

After the acoustic analysis and formant check, the final token counts are shown in Tables 5.1 and 5.2, with Table 5.1 showing the token counts for all of the target pairs and Table 5.2 showing the token counts of the control pairs.

Table 5.1 – Final Target Token Count

The final number of tokens collected for each target homophone after eliminating tokens that were obscured by background noise, too quiet, not present in the audio chunk at all, or produced unreadable formant values.

Homophone 1	**Total**	**Female Total**	**Male Total**	**Homophone 2**	**Total**	**Female Total**	**Male Total**
ate	14	11	3	eight	105	43	62
board	72	29	43	bored	11	5	6
buy	108	51	57	by	157	74	83
eye	47	26	21	I	77	38	39
peace	19	8	11	piece	38	20	18
threw	17	8	9	through	151	68	83
Wait	118	85	33	weight	33	19	14
war	58	25	33	wore	9	6	3
way	172	68	104	weigh	18	15	3

Table 5.2 – Final Control Target Count

The final number of tokens collected for each target homophone after eliminating those tokens that were obscured by background noise, too quiet, not present in the audio chunk at all, or produced unreadable formant values.

Homophone 1	**Total**	**Female Total**	**Male Total**	**Homophone 2**	**Total**	**Female Total**	**Male Total**
hole	26	6	20	whole	164	100	64
hour	163	67	96	our	147	41	106
know	157	128	29	no	161	110	51
which	167	86	81	witch	7	7	0

5.2 Vowel Description

The vowels are plotted in Figures 5.1 – 5.13 in the Appendix showing the F1 and F2 of each homophone pair at 25%, 50%, and 75% through the vowel's duration. The two words in each pair are distinguished in the plots by color and shape, the first being black and round and the second being red and triangular. Figures 5.1 – 5.9 show the vowels of the target homophone pairs, and 5.10-5.13 show the vowels of the control pairs. All of the charts do seem to show a close relationship between the vowels of the two homophones throughout the duration of the vowel, meaning that they do, indeed, seem to be very similar. However, the presence of significant differences does indicate that these words are being realized differently at various points in the vowel duration.

5.3 Statistical Analysis

Two-tailed t-tests were run in R for each pair of homophones from both male and female speakers. The t-tests compared each homophone pair's F1 and F2 for both sexes at 25%, 50%, and 75% through each vowel. No specific hypotheses were made about F3 differing between the homophone pairs, as F3 primarily signifies the presence of an /r/ which is not relevant to the differentiation of the target vowels. Therefore, F3 was not included in the tests.

The results of the two-tailed t-tests are illustrated in Table 5.5 and 5.6. Table 5.5 shows the results that proved to be significantly different in these tests, and Table 5.6 shows those that were not. The two-tailed tests indicate that the pairs differed more significantly in their F1 and F2 measurements than in their F3, which is what was expected. There were a number of significant differences found in the target pairs, which is encouraging for the hypothesis of these vowels being realized differently; however the finding of significance in all four of the control pairs indicates something else may be at play here other than orthography or that these pairs may share some element that is confounding the results.

Table 5.5 – Significant Homophone Pairs

This table shows both the target and control homophone pairs that differed significantly in their formant values. The table includes each pair, the gender of the speaker, the formant being measured, the percentage through the vowel at which the measurement was taken, the p-value, the means of each homophone, and whether the pair was a target or control.

Pair	**Sex**	**Formant**	**%Vowel**	**t-value**	**DF**	**p-value**	**Target/ Control**	**Mean x**	**Mean y**
ate-eight	F	F2	50	3.5313	23.079	0.00178	Target	2554.311	2271.576
eye-i	F	F2	25	-5.4554	59.518	9.94E-07	Target	1438.921	1690.317
eye-i	F	F2	50	-5.2895	45.569	3.38E-06	Target	1554.169	1818.542
eye-i	M	F1	50	2.8525	47.803	0.00639	Target	730.0158	643.4330
eye-i	M	F2	25	-2.259	50.362	0.02824	Target	1339.786	1442.052
buy-by	F	F1	25	3.2423	119.922	0.001535	Target	824.6376	755.6415
buy-by	F	F1	50	4.1777	122.263	5.56E-05	Target	811.0163	714.0901
buy-by	F	F1	75	2.8272	117.063	0.005524	Target	706.9545	637.4563
buy-by	F	F2	25	-4.0716	122.411	8.32E-05	Target	1443.178	1579.032
buy-by	F	F2	50	-3.1647	104.367	0.002034	Target	1627.899	1745.083
buy-by	M	F1	25	-1.8015	96.614	2.64E-02	Target	686.8629	658.6527
buy-by	M	F1	50	2.2444	137.421	2.66E-06	Target	690.0082	618.8537
buy-by	M	F1	75	4.9035	135.007	3.984-08	Target	625.0851	527.6032
buy-by	M	F2	25	5.8335	131.735	1.17E-08	Target	1203.630	1333.777
buy-by	M	F2	50	-6.0889	131.515	2.26E-07	Target	1379.985	1520.441
hole-whole	F	F2	25	-5.457	134.099	0.00294	Control	917.4979	889.6249
hole-whole	F	F2	50	-2.0484	118.953	0.000225	Control	898.7606	832.3650
hole-whole	F	F2	75	-3.886	10.162	0.008788	Control	916.6296	813.5340
hole-whole	M	F1	50	-4.5614	18.58	0.03392	Control	559.0237	579.4054
hole-whole	M	F1	75	-3.1226	12.031	0.02007	Control	526.2892	567.5978

hole-whole	M	F2	75	-2.5122	5.683	0.02545	Control	871.6985	1086.304
hour-our	F	F2	25	2.2134	32.901	0.000277	Control	1733.803	1564.313
hour-our	F	F2	75	2.4718	26.885	3.12E-07	Control	1303.627	1529.115
hour-our	M	F1	75	2.3692	26.3	8.23E-08	Control	651.8422	628.8099
hour-our	M	F2	25	3.7662	102.044	0.009181	Control	1413.370	1327.659
hour-our	M	F2	75	-5.4894	98.824	2.13E-07	Control	1154.717	1272.546
know-no	F	F1	75	3.2889	68.376	0.01916	Control	715.4405	666.4690
know-no	F	F2	75	3.0824	78.578	0.02305	Control	1331.643	1435.315
know-no	M	F2	25	-5.5832	186.772	0.004874	Control	1418.776	1273.46
know-no	M	F2	50	2.631	199.007	0.01845	Control	1364.674	1207.157
know-no	M	F2	75	-5.4235	159.787	0.000311	Control	1393.377	1154.051
peace-piece	M	F1	75	2.2616	196.117	0.04127	Target	398.7381	394.7811
peace-piece	M	F2	25	3.1602	181.374	0.045	Target	2128.880	2293.103
peace-piece	M	F2	75	3.7431	169.386	0.007322	Target	2189.273	2269.356
threw-through	F	F2	25	2.3604	212.989	0.000877	Target	1264.580	1704.117
threw-through	F	F2	50	-2.2884	224.321	0.008641	Target	1211.673	1640.062
threw-through	F	F2	75	-2.3691	228.903	0.0421	Target	1211.948	1628.653
which-witch	F	F2	25	-2.6717	235.586	0.009971	Control	1505.456	1990.014
which-witch	F	F2	50	2.919	62.576	0.002475	Control	1707.891	2023.491
which-witch	F	F2	75	2.4177	64.646	0.001157	Control	1891.081	2052.832

Table 5.6 – Non-Significant Homophone Pairs

This table shows both the target and control homophone pairs that were not significantly different in their formant values. The table includes each pair, the gender of the speaker, the formant being measured, the percentage through the vowel at which the measurement was taken, the t-value, the p-value, and whether the pair was a target or control.

Pair	Sex	Formant	%Vowel	t-value	DF	p-value	Target/Control
ate-eight	Female	F1	25	0.9461	37.96	0.3501	Target
ate-eight	Female	F1	50	0.4884	19.446	0.6307	Target
ate-eight	Female	F1	75	1.598	12.796	0.1344	Target
ate-eight	Female	F2	25	0.6032	17.884	0.554	Target
ate-eight	Female	F2	75	0.745	11.999	0.4706	Target
ate-eight	Female	F3	25	0.1487	22.134	0.8831	Target
ate-eight	Female	F3	50	1.6727	13.33	0.1177	Target
ate-eight	Female	F3	75	1.9236	15.355	0.07315	Target
ate-eight	Male	F1	25	1.3845	2.587	0.2735	Target
ate-eight	Male	F1	50	0.655	2.111	0.5766	Target
ate-eight	Male	F1	75	1.1624	2.123	0.3591	Target
ate-eight	Male	F2	25	-0.0077	2.444	0.9944	Target
ate-eight	Male	F2	50	-0.2719	2.264	0.8085	Target

ate-eight	Male	F2	75	-0.5259	2.07	0.6499	Target
ate-eight	Male	F3	25	0.7195	2.094	0.5436	Target
ate-eight	Male	F3	50	-0.1665	2.378	0.8809	Target
ate-eight	Male	F3	75	0.4357	2.073	0.7042	Target
eye-i	Female	F1	25	-1.3711	59.732	0.1755	Target
eye-i	Female	F1	50	-0.1208	54.722	0.9043	Target
eye-i	Female	F1	75	-0.6805	49.622	0.4993	Target
eye-i	Female	F2	75	0.0532	48.45	0.9578	Target
eye-i	Female	F3	25	0.807	52.256	0.4233	Target
eye-i	Female	F3	50	-0.0971	55.541	0.923	Target
eye-i	Female	F3	75	-0.6812	49.468	0.4989	Target
eye-i	Male	F1	25	0.8941	44.322	0.3761	Target
eye-i	Male	F1	75	0.792	57.025	0.4316	Target
eye-i	Male	F2	50	-1.2855	57.768	0.2038	Target
eye-i	Male	F2	75	-0.5557	44.099	0.5812	Target
eye-i	Male	F3	25	-0.0475	36.542	0.9624	Target
eye-i	Male	F3	50	1.4468	39.267	0.1559	Target
eye-i	Male	F3	75	-0.5171	36.42	0.6082	Target
board-bored	Female	F1	25	-0.8714	5.124	0.4225	Target
board-bored	Female	F1	50	-1.3714	4.572	0.2337	Target
board-bored	Female	F1	75	-0.5874	4.858	0.5832	Target
board-bored	Female	F2	25	-1.2096	4.676	0.284	Target
board-bored	Female	F2	50	-1.2777	4.307	0.2659	Target
board-bored	Female	F2	75	-0.7188	4.47	0.5081	Target
board-bored	Female	F3	25	-0.3943	5.123	0.7092	Target
board-bored	Female	F3	50	-1.4213	4.523	0.2204	Target
board-bored	Female	F3	75	-0.0612	8.759	0.9526	Target
board-bored	Male	F1	25	-0.9679	5.298	0.3752	Target
board-bored	Male	F1	50	-0.6282	6.103	0.5526	Target
board-bored	Male	F1	75	0.1889	6.022	0.8564	Target
board-bored	Male	F2	25	1.0638	6.398	0.3259	Target
board-bored	Male	F2	50	0.7403	5.886	0.4876	Target
board-bored	Male	F2	75	0.0396	5.347	0.9699	Target
board-bored	Male	F3	25	-1.1071	6.705	0.3064	Target
board-bored	Male	F3	50	-1.2498	8.507	0.2446	Target
board-bored	Male	F3	75	-1.5419	8.264	0.1605	Target
buy-by	Female	F2	75	0.5971	112.157	5.52E-01	Target
buy-by	Female	F3	25	-1.239	110.621	0.218	Target
buy-by	Female	F3	75	-1.6075	122.965	0.1105	Target
buy-by	Male	F2	75	-0.6601	135.547	5.10E-01	Target
buy-by	Male	F3	25	1.1655	113.508	2.46E-01	Target
buy-by	Male	F3	50	-1.2477	104.151	0.2149	Target
hole-whole	Female	F1	25	-0.3449	6.589	0.7409	Control

hole-whole	Female	F1	50	-1.1318	10.847	0.2821	Control
hole-whole	Female	F1	75	-2.2202	8.911	0.05383	Control
hole-whole	Female	F3	50	-0.4734	5.292	0.6548	Control
hole-whole	Female	F3	75	-0.9309	5.461	0.3912	Control
hole-whole	Male	F1	25	1.6284	44.66	0.1105	Control
hole-whole	Male	F2	25	0.6905	32.746	0.4947	Control
hole-whole	Male	F2	50	1.7445	26.491	0.09267	Control
hole-whole	Male	F3	25	-1.1976	28.88	0.2408	Control
hole-whole	Male	F3	50	-0.2135	30.278	0.8323	Control
hole-whole	Male	F3	75	1.1706	28.597	0.2514	Control
hour-our	Female	F1	25	1.4622	105.518	0.1467	Control
hour-our	Female	F1	50	1.0963	81.507	0.2762	Control
hour-our	Female	F1	75	-0.5869	95.182	0.5586	Control
hour-our	Female	F2	50	0.3983	98.105	0.6913	Control
hour-our	Female	F3	25	1.2882	84.083	0.2012	Control
hour-our	Male	F1	25	1.4196	193.675	0.1573	Control
hour-our	Male	F1	50	-0.703	164.452	0.4831	Control
hour-our	Male	F2	50	0.573	185.65	0.5673	Control
know-no	Female	F1	25	0.5427	194.385	0.588	Control
know-no	Female	F1	50	1.062	178.638	0.2897	Control
know-no	Female	F2	25	-0.8892	229.64	0.3748	Control
know-no	Female	F2	50	-1.703	186.834	0.09022	Control
know-no	Female	F3	25	-0.0566	235.679	0.9549	Control
know-no	Male	F1	25	-0.5328	66.569	0.5959	Control
know-no	Male	F1	50	-0.8468	77.394	0.3997	Control
know-no	Male	F1	75	-0.6357	73.113	0.527	Control
know-no	Male	F3	25	1.7461	77.996	0.08472	Control
know-no	Male	F3	50	1.6261	73.206	0.1082	Control
know-no	Male	F3	75	1.7624	77.979	0.08191	Control
peace-piece	Female	F1	25	0.9595	7.632	0.3667	Target
peace-piece	Female	F1	50	0.4375	7.699	0.6738	Target
peace-piece	Female	F1	75	0.0632	9.194	0.951	Target
peace-piece	Female	F2	25	-0.5391	7.495	0.6055	Target
peace-piece	Female	F2	50	-0.6585	7.847	0.5291	Target
peace-piece	Female	F2	75	-0.4034	7.481	0.6979	Target
peace-piece	Female	F3	25	0.5762	8.35	0.5797	Target
peace-piece	Female	F3	50	0.3961	7.945	0.7025	Target
peace-piece	Female	F3	75	0.4139	8.959	0.6887	Target
peace-piece	Male	F1	25	-0.2481	19.149	0.8067	Target
peace-piece	Male	F1	50	-1.1421	16.434	0.2698	Target
peace-piece	Male	F2	50	1.8275	26.227	0.07902	Target
peace-piece	Male	F3	25	0.3124	24.846	0.7574	Target
peace-piece	Male	F3	50	0.4262	25.242	0.6736	Target

peace-piece	Male	F3	75	-0.2696	17.306	0.7907	Target
threw-through	Female	F1	25	1.6981	7.449	0.1307	Target
threw-through	Female	F1	50	0.1195	11.044	0.907	Target
threw-through	Female	F1	75	0.6945	12.791	0.4998	Target
threw-through	Female	F3	25	-0.1141	8.483	0.9118	Target
threw-through	Female	F3	50	-0.2337	8.174	0.821	Target
threw-through	Female	F3	75	0.4907	8.003	0.6368	Target
threw-through	Male	F1	25	-0.7558	20.993	0.4582	Target
threw-through	Male	F1	50	-0.1182	12.621	0.9078	Target
threw-through	Male	F1	75	-0.0866	12.245	0.9324	Target
threw-through	Male	F2	25	0.5517	9.35	0.5941	Target
threw-through	Male	F2	50	0.0713	8.888	0.9448	Target
threw-through	Male	F2	75	0.5358	9.819	0.604	Target
threw-through	Male	F3	25	0.9271	9.189	0.3776	Target
threw-through	Male	F3	50	0.4583	9.32	0.6573	Target
threw-through	Male	F3	75	-0.1442	9.744	0.8882	Target
wait-weight	Female	F1	25	-0.6228	40.778	0.5369	Target
wait-weight	Female	F1	50	1.0634	50.456	0.2927	Target
wait-weight	Female	F1	75	1.0259	50.88	0.3098	Target
wait-weight	Female	F2	25	-1.521	30.686	0.1385	Target
wait-weight	Female	F2	50	-0.3471	33.437	0.7307	Target
wait-weight	Female	F2	75	0.3637	34.235	0.7183	Target
wait-weight	Female	F3	25	0.5372	24.737	0.5959	Target
wait-weight	Female	F3	50	0.496	22.745	0.6247	Target
wait-weight	Female	F3	75	1.057	24.553	0.3008	Target
wait-weight	Male	F1	25	-0.5021	18.027	0.6217	Target
wait-weight	Male	F1	50	-0.0906	30.745	0.9284	Target
wait-weight	Male	F1	75	-0.0556	30.666	0.9561	Target
wait-weight	Male	F2	25	-0.4326	20.099	0.6699	Target
wait-weight	Male	F2	50	-1.0888	31.188	0.2846	Target
wait-weight	Male	F2	75	-1.8753	29.289	0.07076	Target
wait-weight	Male	F3	25	-1.3681	21.719	0.1853	Target
wait-weight	Male	F3	50	-1.1217	18.996	0.276	Target
war-wore	Female	F1	25	0.1865	9.467	0.856	Target

war-wore	Female	F1	50	-0.8571	22.612	0.4004	Target
war-wore	Female	F1	75	-1.421	25.725	0.1673	Target
war-wore	Female	F2	25	0.2263	10.431	0.8253	Target
war-wore	Female	F2	50	-0.5632	6.598	0.5919	Target
war-wore	Female	F2	75	-0.7663	6.163	0.4718	Target
war-wore	Female	F3	25	-0.0563	12.974	0.9559	Target
war-wore	Female	F3	50	-0.1117	20.326	0.9122	Target
war-wore	Female	F3	75	1.1186	26.597	0.2733	Target
war-wore	Male	F1	25	-0.1158	2.394	0.9168	Target
war-wore	Male	F1	50	-0.2858	2.659	0.7958	Target
war-wore	Male	F1	75	-1.1963	5.002	0.2852	Target
war-wore	Male	F2	25	-0.0029	2.429	0.9979	Target
war-wore	Male	F2	50	-0.0762	2.235	0.9455	Target
war-wore	Male	F2	75	0.0699	2.997	0.9486	Target
war-wore	Male	F3	25	2.936	2.836	0.06504	Target
war-wore	Male	F3	50	1.9643	2.376	0.1679	Target
way-weigh	Female	F1	25	0.0915	22.753	0.9279	Target
way-weigh	Female	F1	50	0.3873	23.812	0.702	Target
way-weigh	Female	F1	75	0.6011	47.26	0.5507	Target
way-weigh	Female	F2	25	-0.2174	19.171	0.8302	Target
way-weigh	Female	F2	50	-0.0352	23.299	0.9722	Target
way-weigh	Female	F2	75	0.271	20.366	0.7891	Target
way-weigh	Female	F3	25	0.9644	21.508	0.3456	Target
way-weigh	Female	F3	50	1.1695	22.168	0.2546	Target
way-weigh	Female	F3	75	0.1094	23.171	0.9139	Target
way-weigh	Male	F1	25	-0.741	3.175	0.5097	Target
way-weigh	Male	F1	50	-0.3583	34.953	0.7223	Target
way-weigh	Male	F1	75	1.3793	6.156	0.2158	Target
way-weigh	Male	F2	25	3.0678	2.62	0.06521	Target
way-weigh	Male	F2	50	2.1013	3.311	0.1179	Target
way-weigh	Male	F2	75	0.416	2.446	0.7111	Target
way-weigh	Male	F3	25	0.6406	2.065	0.5856	Target
way-weigh	Male	F3	50	0.7752	2.041	0.5179	Target
way-weigh	Male	F3	75	-0.4027	2.072	0.725	Target
which-witch	Female	F1	25	-1.0605	6.871	0.3248	Control
which-witch	Female	F1	50	-1.9897	6.28	0.09163	Control
which-witch	Female	F1	75	-2.3959	6.512	0.05037	Control
which-witch	Female	F3	50	-1.7979	7.752	0.1111	Control
which-witch	Female	F3	75	0.4206	7.557	0.6857	Control

VI. DISCUSSION

6.1 T-tests

As is illustrated through Tables 5.5 and 5.6, both target and control homophone pairs were found to be significant and non-significant. All four of the control pairs showed significant differences during some point in the vowel realizations, so the claim cannot be made that any significant results found are purely due to orthographic influence. However, the presence of significant results does indicate variables present that are causing homophones to be realized differently, which is encouraging to the ideas presented in this study. Though the hypothesis that the homophone pairs would show significant differences in formant measurements in the target pairs and no difference in the control pairs was not proved, the overarching hypothesis that there is some effect of orthography that occurs during speech production requires further data to investigate its validity.

The greatest differences in the means of the significant results occur specifically in the F2 (ate-eight, hour-our, know-no, through-threw, and which-witch), which indicates that this is the formant level that contains the most relevant information to the question of whether these targets are realized differently based on their orthography. The source of this variability could be due to the F2 containing the most likely vowel information to vary between pair members. This could also be the most salient feature in vocalic homophone differences, where differences may occur in both F1 and F2, but the F2 differences are more easily or frequently realized. Additionally, the majority of these greatest-difference pairs occur specifically in the productions of the male speakers, which poses an interesting question for further research on this topic and the differences in productions between genders.

One of the variables that may be skewing the results of the two-tailed t-tests could be orthographic in origin. The presence of glides in most of the control pairs, specifically /w/ in the words ‘whole,’ ‘know,’ ‘which,’ and ‘witch.’ The /w/ phoneme and corresponding ‘w’ grapheme may be causing a change in the vocalic pronunciation of these homophones in the control pairs due to its sonorance and closeness to the target vowels in each of these pairs. The presence of a glide directly preceding or following the target vowels in these words could cause a change in the articulation of the vowels due to the highly sonorant and almost vowel-like quality of glides. This context could have skewed the segmentation of the words, and it also could create a series of articulatory movements that would be unique to this particular context, potentially changing the way the phonetics of the vowels in these words are realized. The glides might lengthen the vowel or skew the F1 or F2 in the direction of the glide away from the expected values for each vowel. This hypothesis can be checked through further research.

6.2 General Discussion

There are always variables that can confound results, and further research would be needed in order to determine the exact cause of the formant differences in these homophone pairs. In this case, there is the definite possibility of the orthographic effect hypothesized here based on the significant results of the two-tailed t-tests, but these results point to other variables being involved as well, considering that a portion of the significant results found in these tests came from the control homophone pairs. Because of these contradictory findings, we must assume that although orthography may be playing a role in these results, there are most likely additional variables causing a difference in phonetic realization. In this study, there are the word context, part of speech, and speaker characteristics that could account for some of these differences. Further investigation and careful categorization of homophones would be required to determine what variables are at play causing these changes in acoustics.

Another possibility for the results found here is that the part of speech and word context might have affected the phonological measurements. Gahl's (2008) study illustrates that word frequency affects word duration. A similar regression study of conversational speech by Bell et al., (2009) showed that frequency, contextual predictability, and repetition have separate contributions to word duration despite their many substantial correlations. The results indicate that content and function word durations are affected more by their frequency and predictability. Content words are shorter when more frequent, and shorter when repeated, while function words are not affected as much. Overall, function words have shorter pronunciations even after controlling for frequency and predictability. Because of these effects of frequency, the vowel changes may not have been as fully phonetically due to shorter vowel and word durations in more-frequent members of the target homophone pairs and in certain homophone pairs in which the two members of the pair are different types of words, such as buy/by, in which 'buy' is a content word and 'by' is a function word. This may have also caused some of the significant differences in the realizations of the control homophone pairs as more frequent words might have shortened and changed the vowel realization enough to produce a significant formant difference.

Other variables which could be taken into account in future studies are presented in Lavoie's (2003) study on the differences of realizations in 'for' and 'four.' Lavoie illustrates the difference that can be caused not only by each word's frequency and part of speech, but also shows how spontaneous versus read speech may affect the productions of these words. Lavoie's findings indicate that the difference between spontaneous and read speech show that instead of viewing function words as having discrete, weak, strong, or intermediate allomorphs, a continuum resulting from gestural interaction is a more accurate representation of the reality. Additionally word-initial phoneme onset times are shown to be greatly affected by the preceding prosodic boundary, while the duration and composition of the word's rime is affected by foot structure and segmental content. Overall, in future studies, it should be noted that multiple variables may affect the realization of homophones and very targeted studies with large sample sizes will be required in order to uncover what specific differences are caused by which specific factors, as well as to find more tokens of rarer homophone pairs.

6.3 Future Research Directions

Though this study is a good beginning to a line of questioning, there is plenty of room for further research. Future studies may incorporate multiple types of speech data, such as corpus versus experimental, or spontaneous versus read speech. Additionally, hypotheses could be tested on the production of homophones versus homographs. If orthographic differences can effect production and frequency can affect production, the differences in the behavior of homophone and homograph pairs, both of which typically contain a more-frequent and less-frequent pair member, could provide an interesting linguistic environment for study. Future studies should build upon the questions asked here with greater token counts and more speaker data, in order to more accurately view the effects of each variable on the vowel qualities of the target homophones.

VII. CONCLUSION

The question asked by this study was whether orthography would influence the phonetics of speakers' production of homophones in a spontaneous speech corpus, and the results seem to indicate that this effect may exist, however the results remain ambiguous in pointing toward a specific cause for the formant changes. Further research must be done in order to investigate the results obtained through this study and determine if orthography does affect the production of speech enough that it can be acoustically measured and perceived. Other studies might focus on spontaneous speech versus reading aloud, or possibly focus only on speakers who achieve a score on a literacy test above a certain threshold as the influence of orthography on speech production has been found specifically in highly literate individuals. Additionally, it may also be worthwhile to target only literate speakers who consider themselves to be visual learners, or to include in a study of this topic a learning style test and then compare the productions of the visual learners with the kinetic and auditory learners in order to see if learning style in addition to literacy could affect phonetic productions.

Though the hypothesis that the homophone pairs would show significant differences in formant measurements in the target pairs and no difference in the control pairs has been disproved, the overarching hypothesis that there is some effect of orthography that occurs during speech production has not been disproved and requires further data to investigate its validity. Many studies have investigated phonology, orthography, homophones, and their interaction with one another, and this study continues a line of research in asking a question about the intertwining of orthography and phonology and their effect on one another. If anything, these results indicate that this question was worth asking, and still is.

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IX. APPENDIX

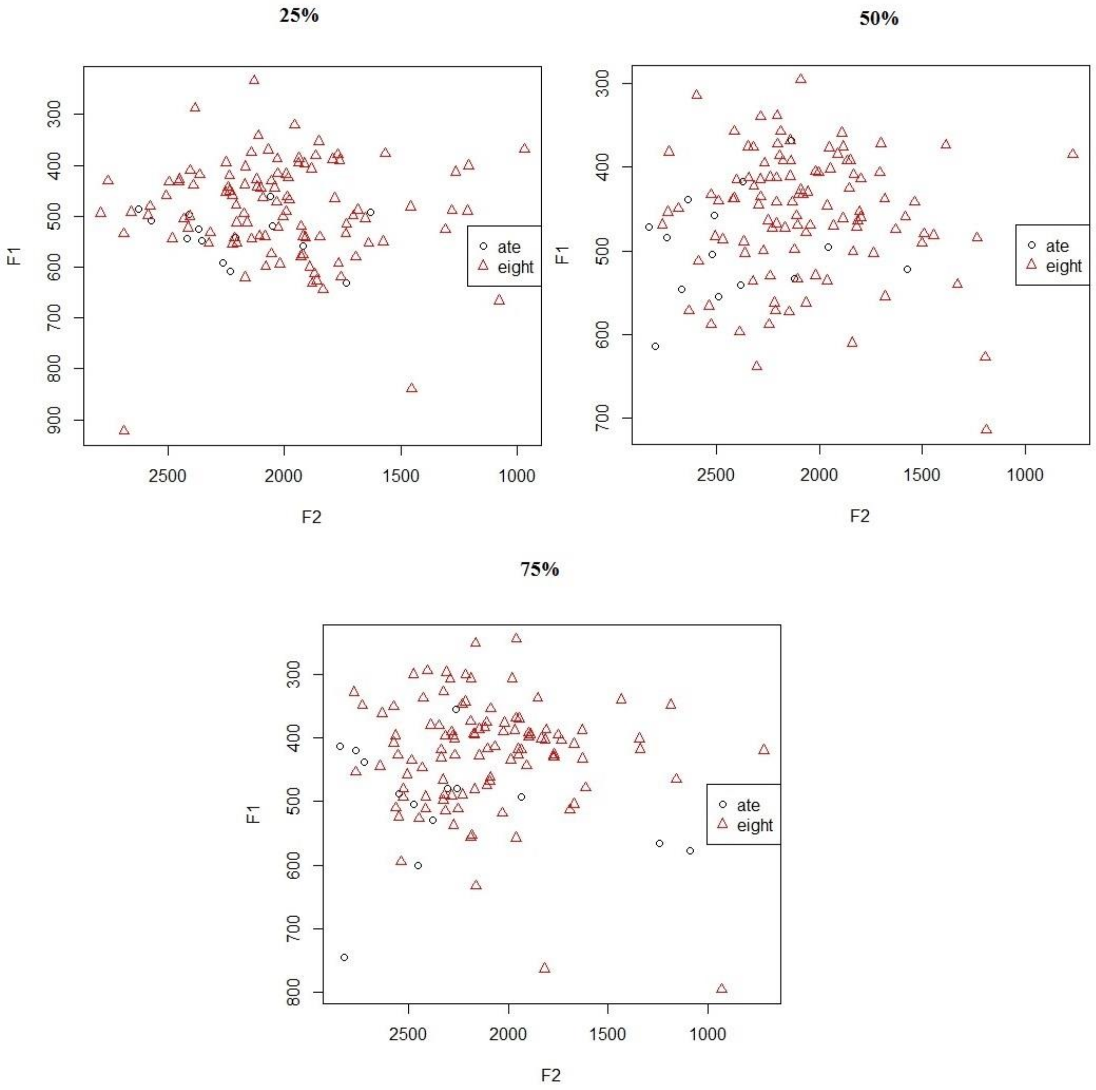

Figure 5.1 - ‘ate’ versus ‘eight’

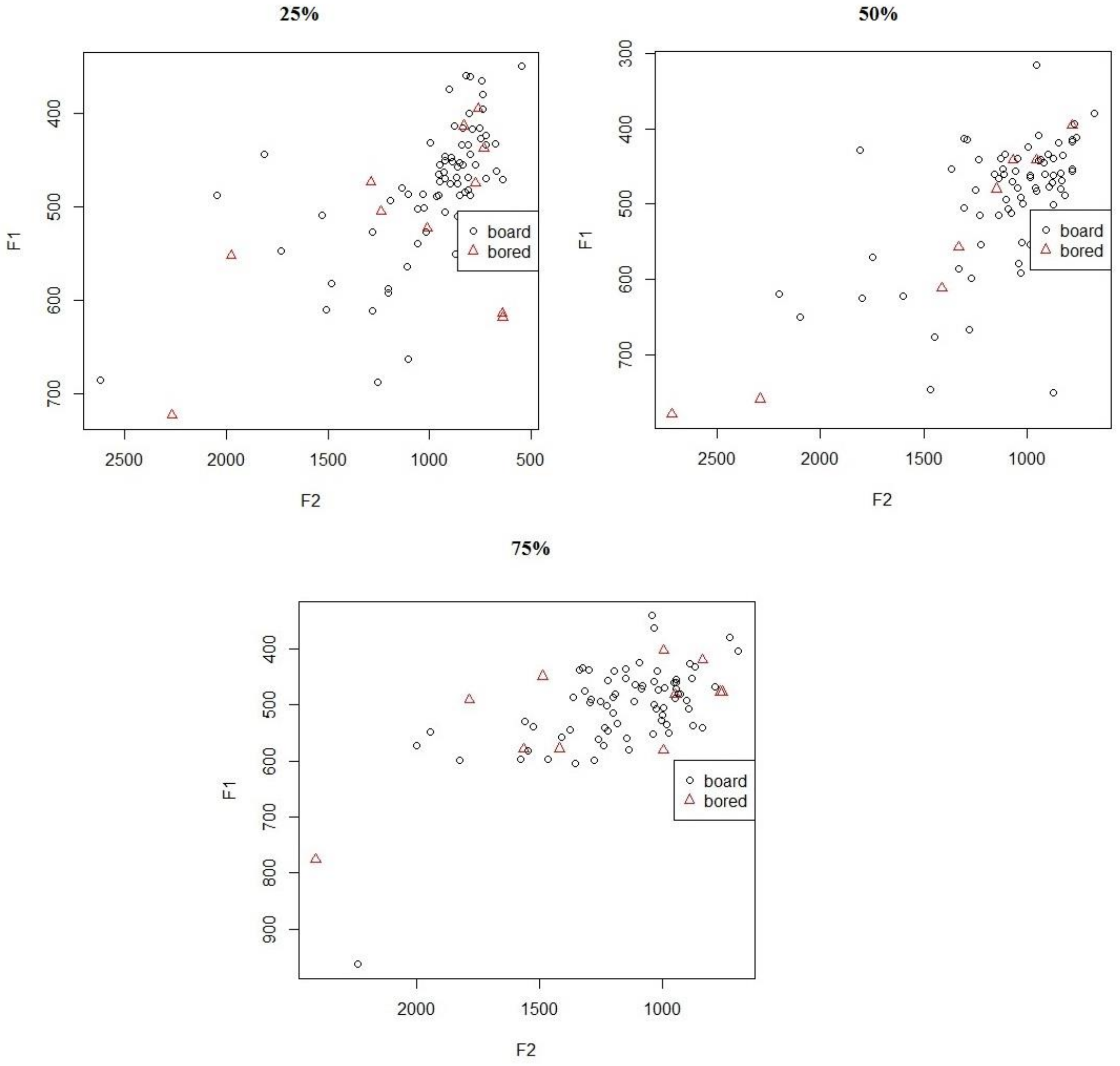

Figure 5.2 – ‘board’ versus ‘bored’

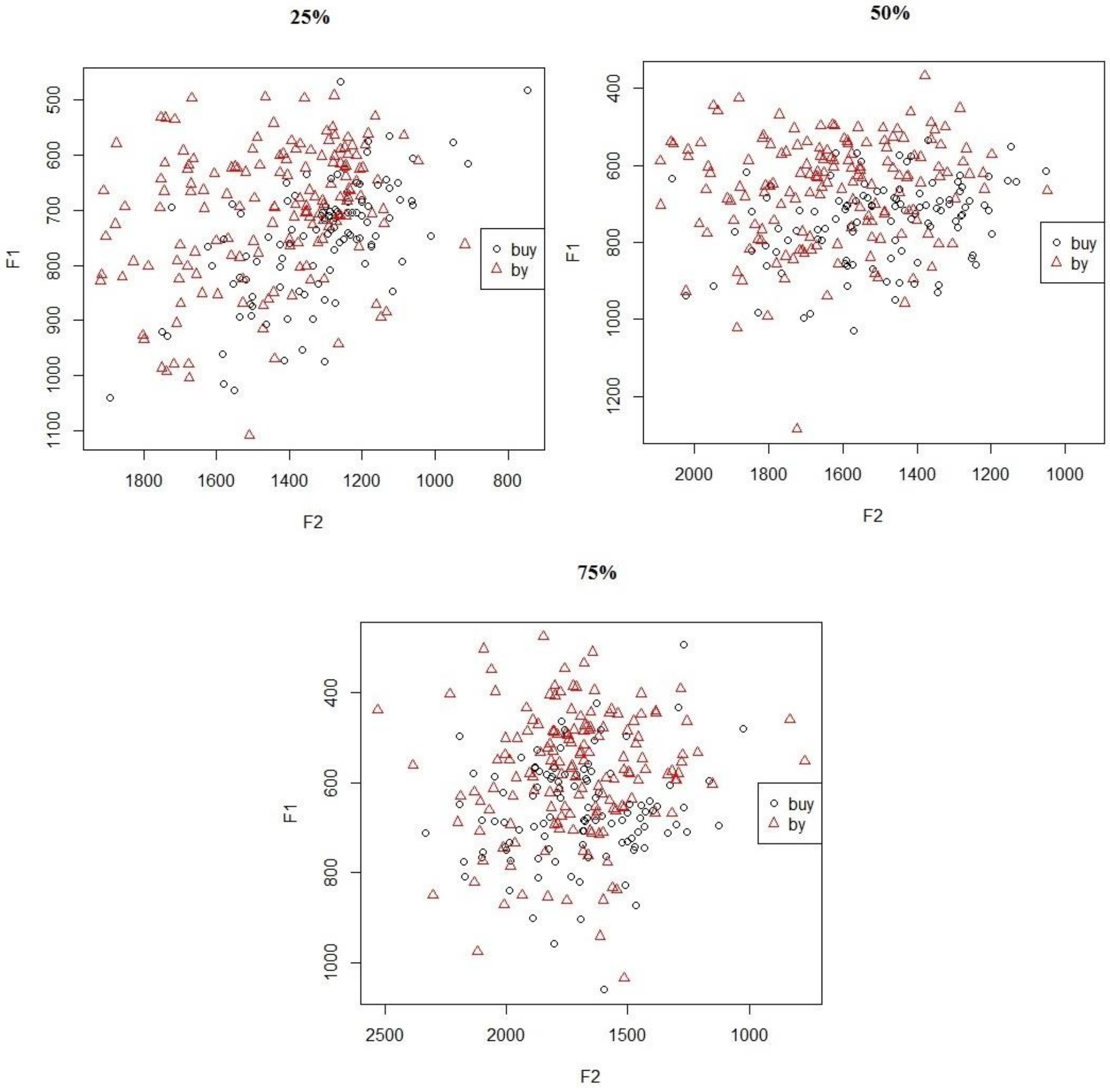

Figure 5.3 – ‘buy’ versus ‘by’

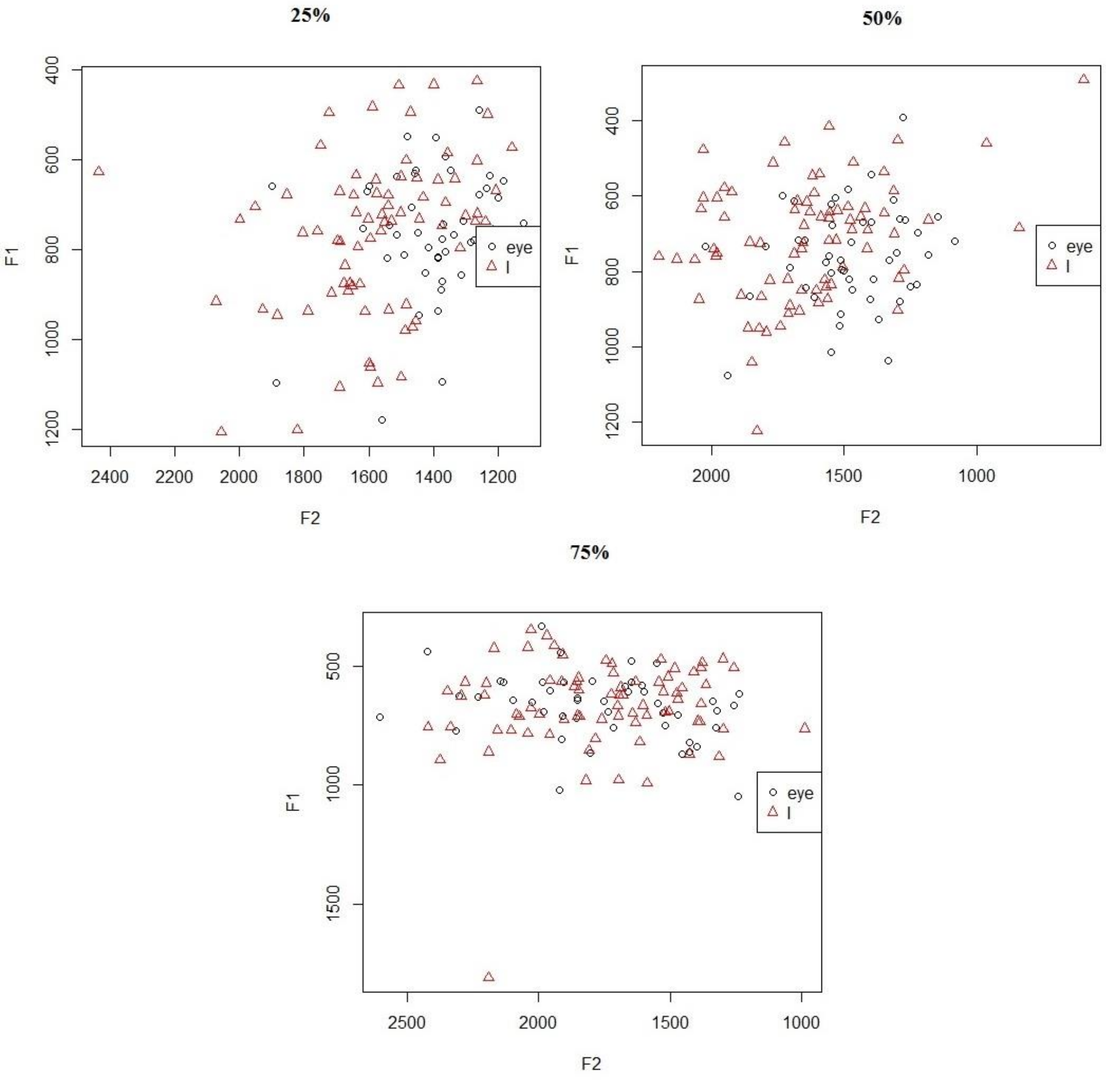

Figure 5.4 – ‘eye’ versus ‘I’

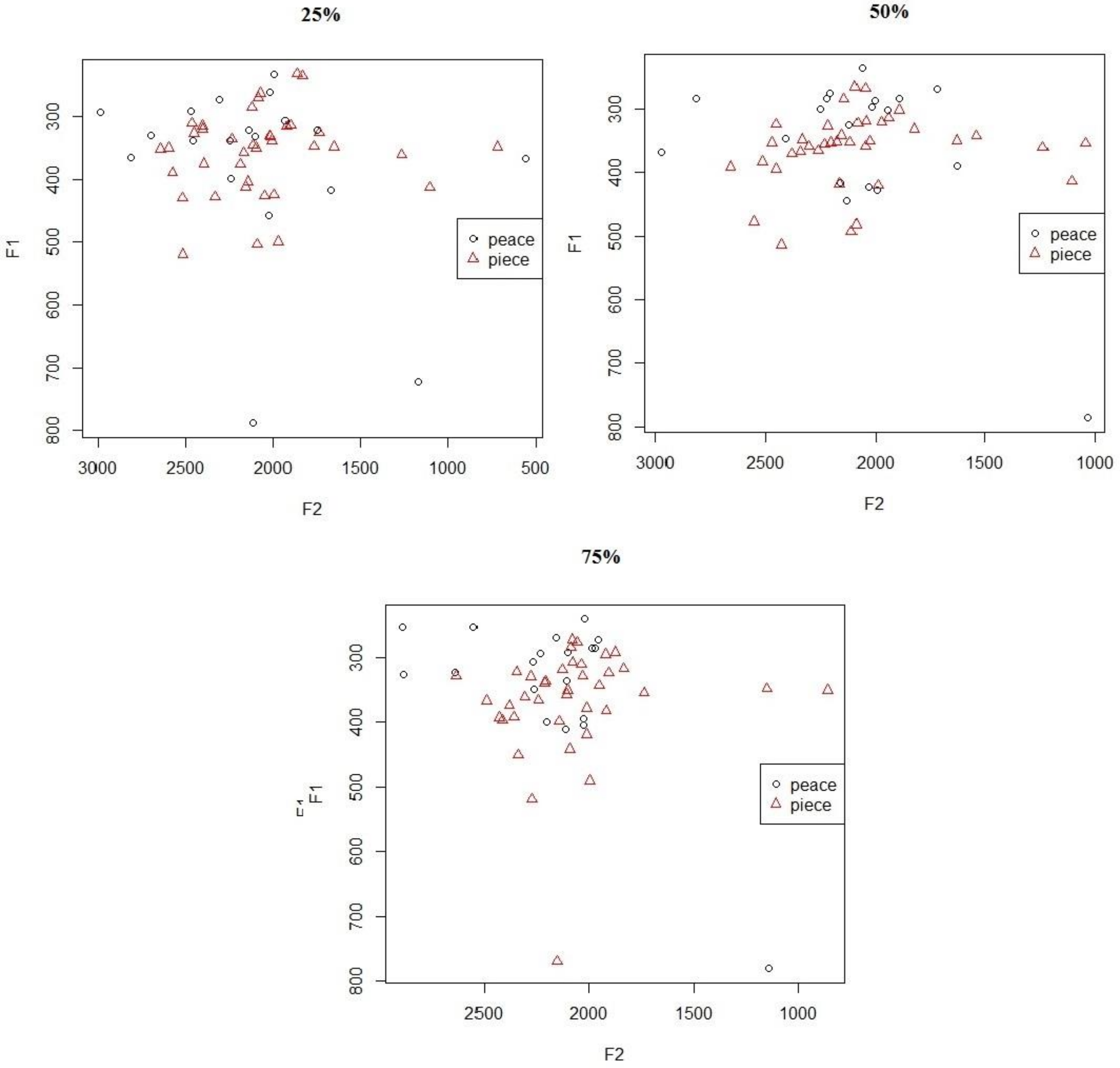

Figure 5.5 – ‘peace’ versus ‘piece’

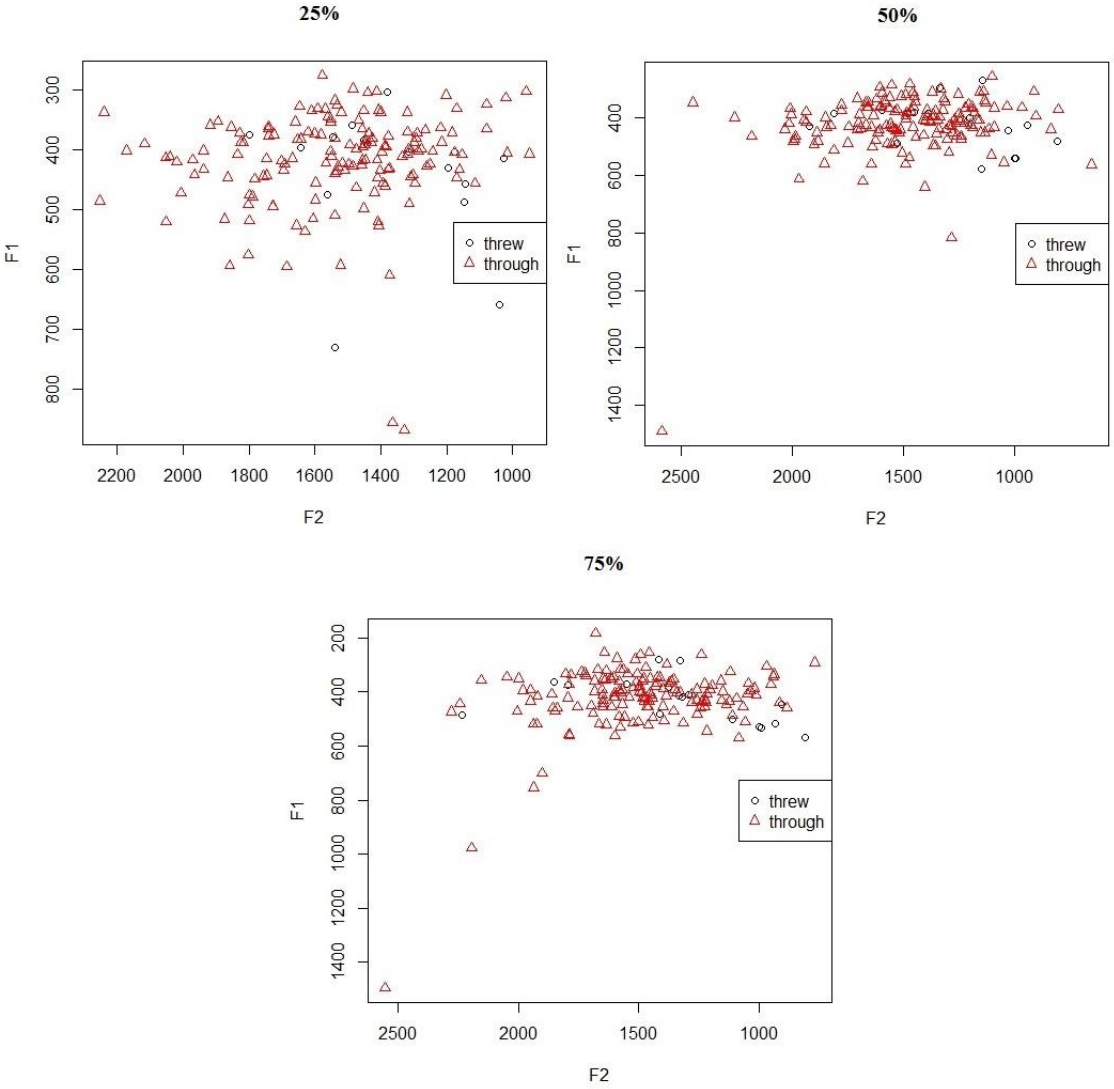

Figure 5.6 – ‘threw’ versus ‘through’

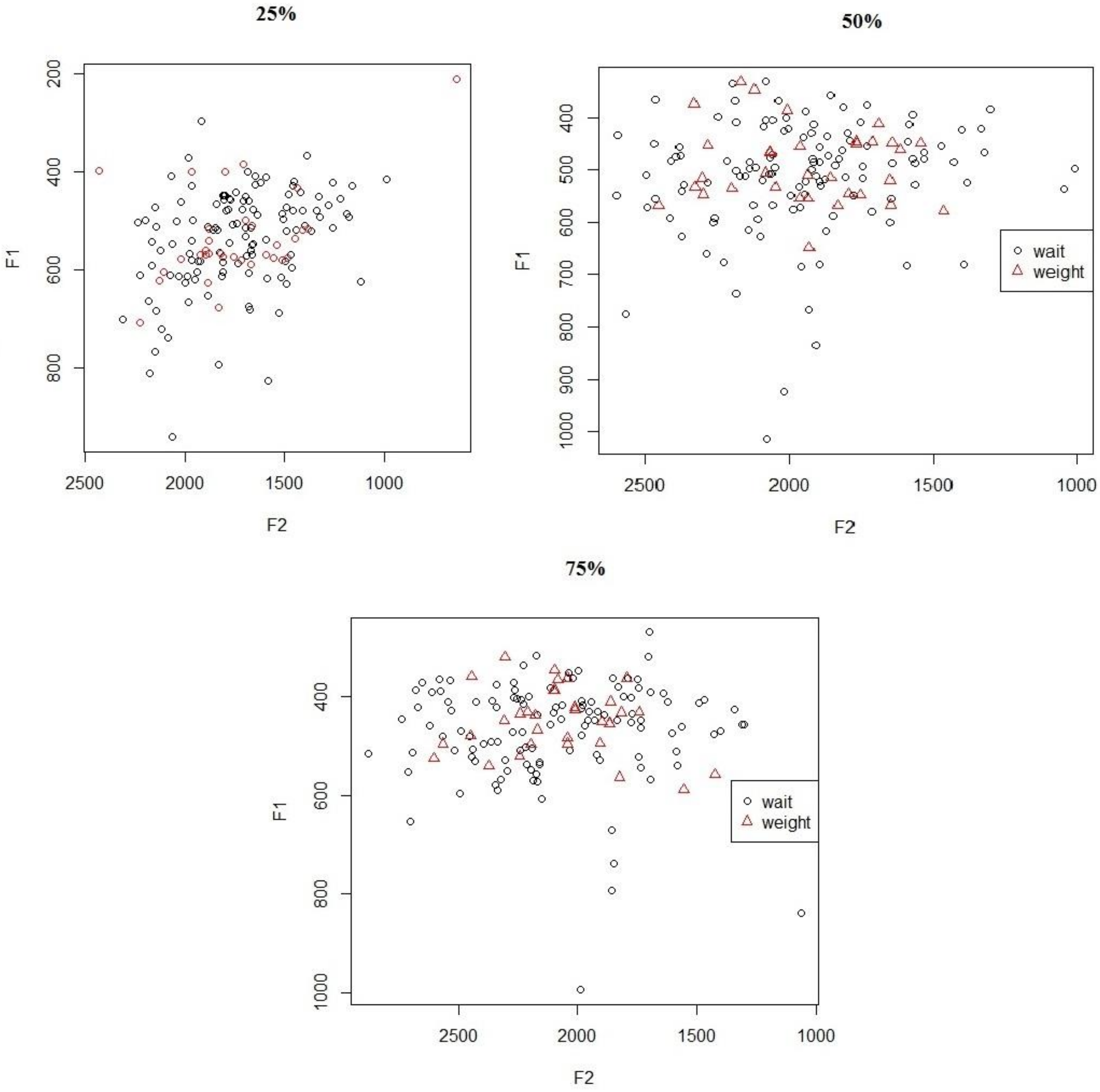

Figure 5.7 – 'wait' versus 'weight'

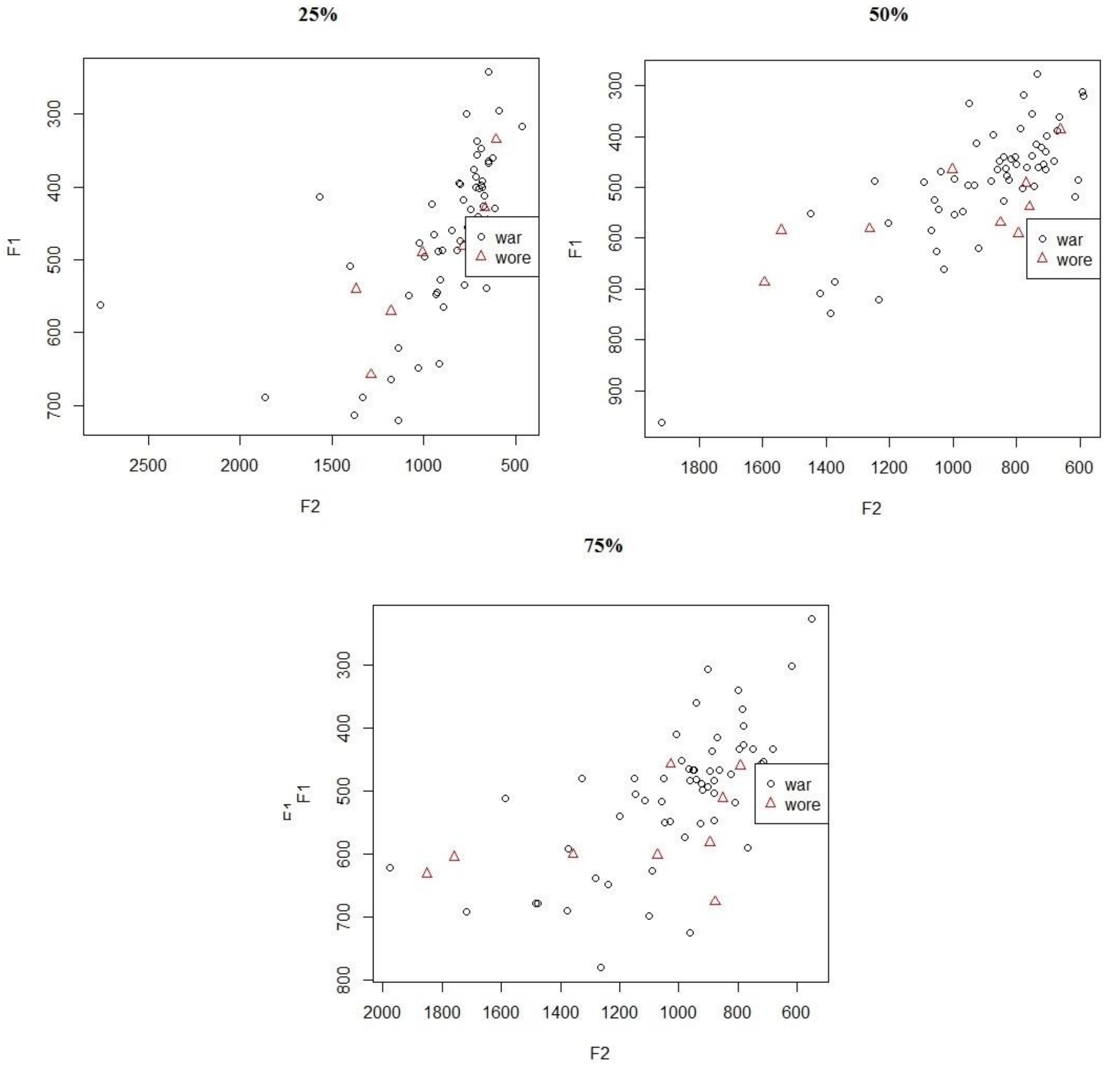

Figure 5.8 – ‘war’ versus ‘wore’

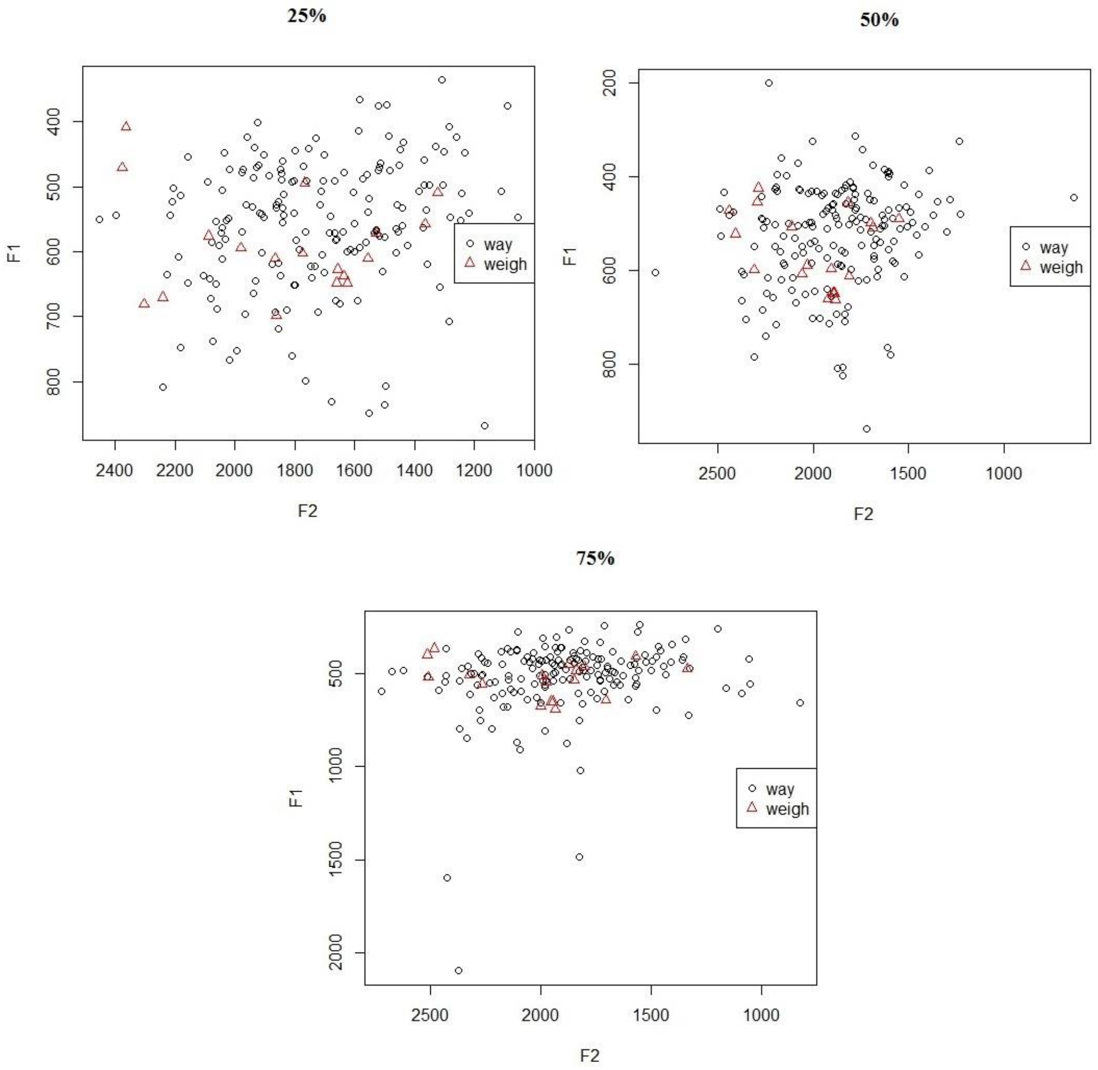

Figure 5.9 – ‘way’ versus ‘weigh’

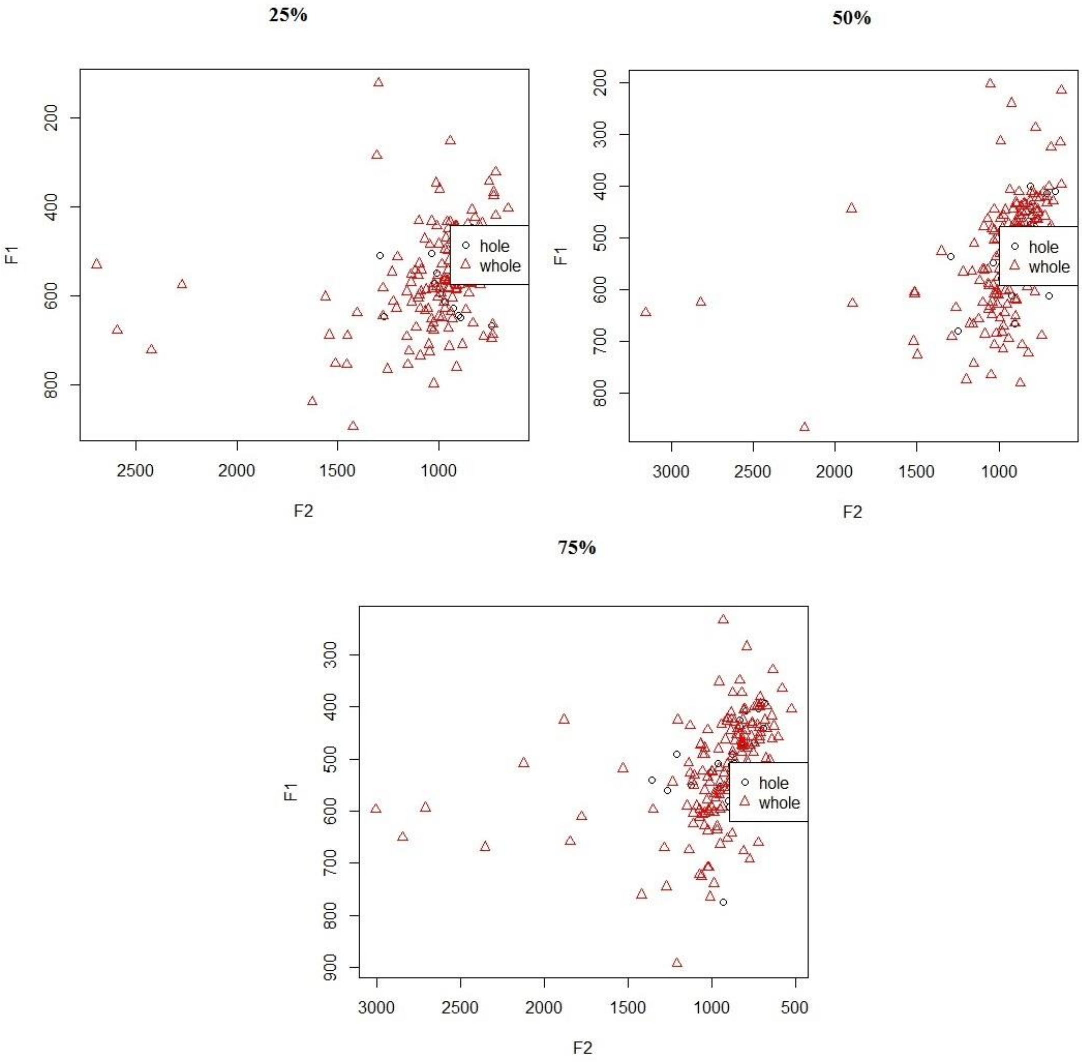

Figure 5.10 – ‘hole’ versus ‘whole’

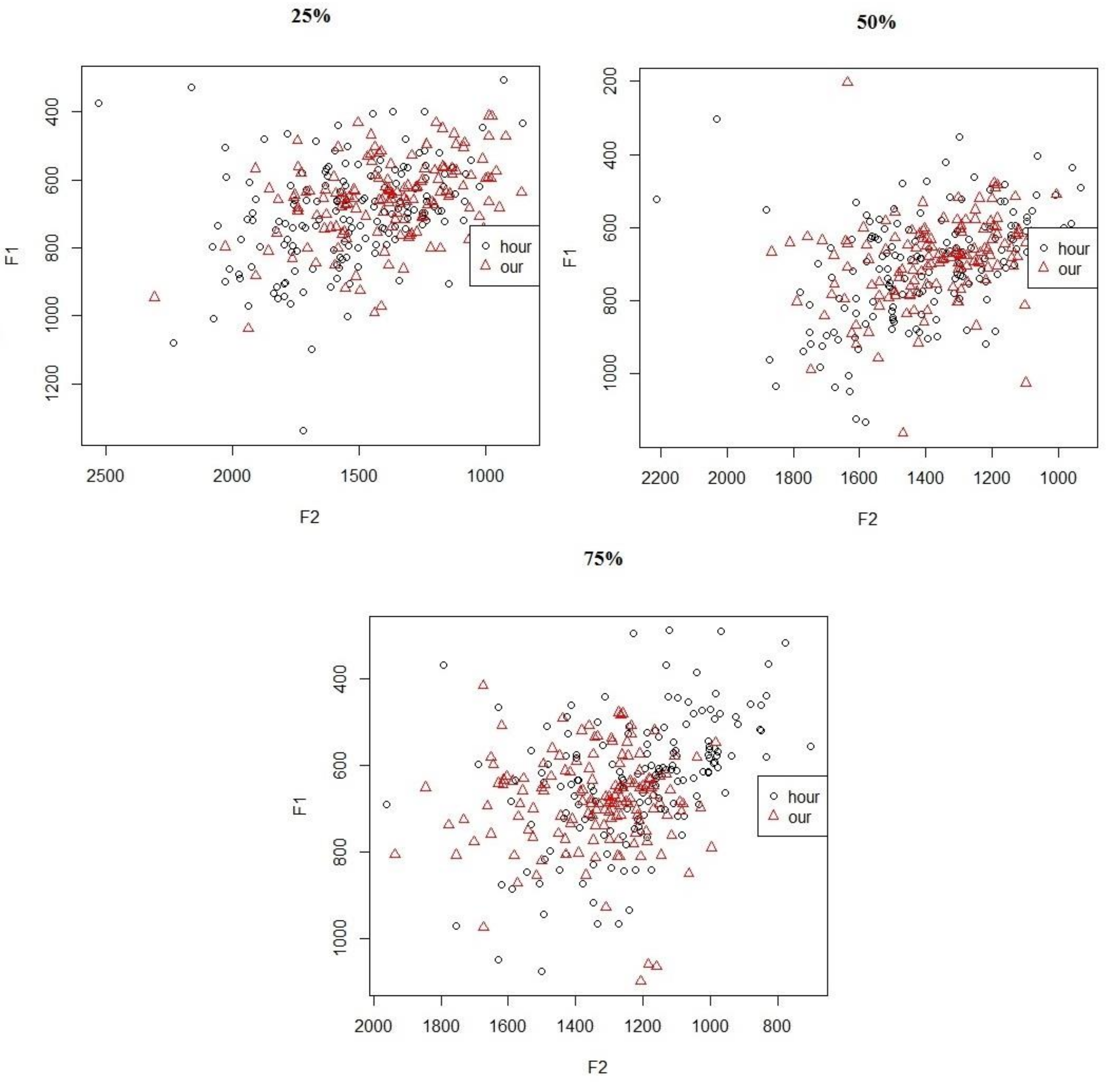

Figure 5.11 – ‘hour’ versus ‘our’

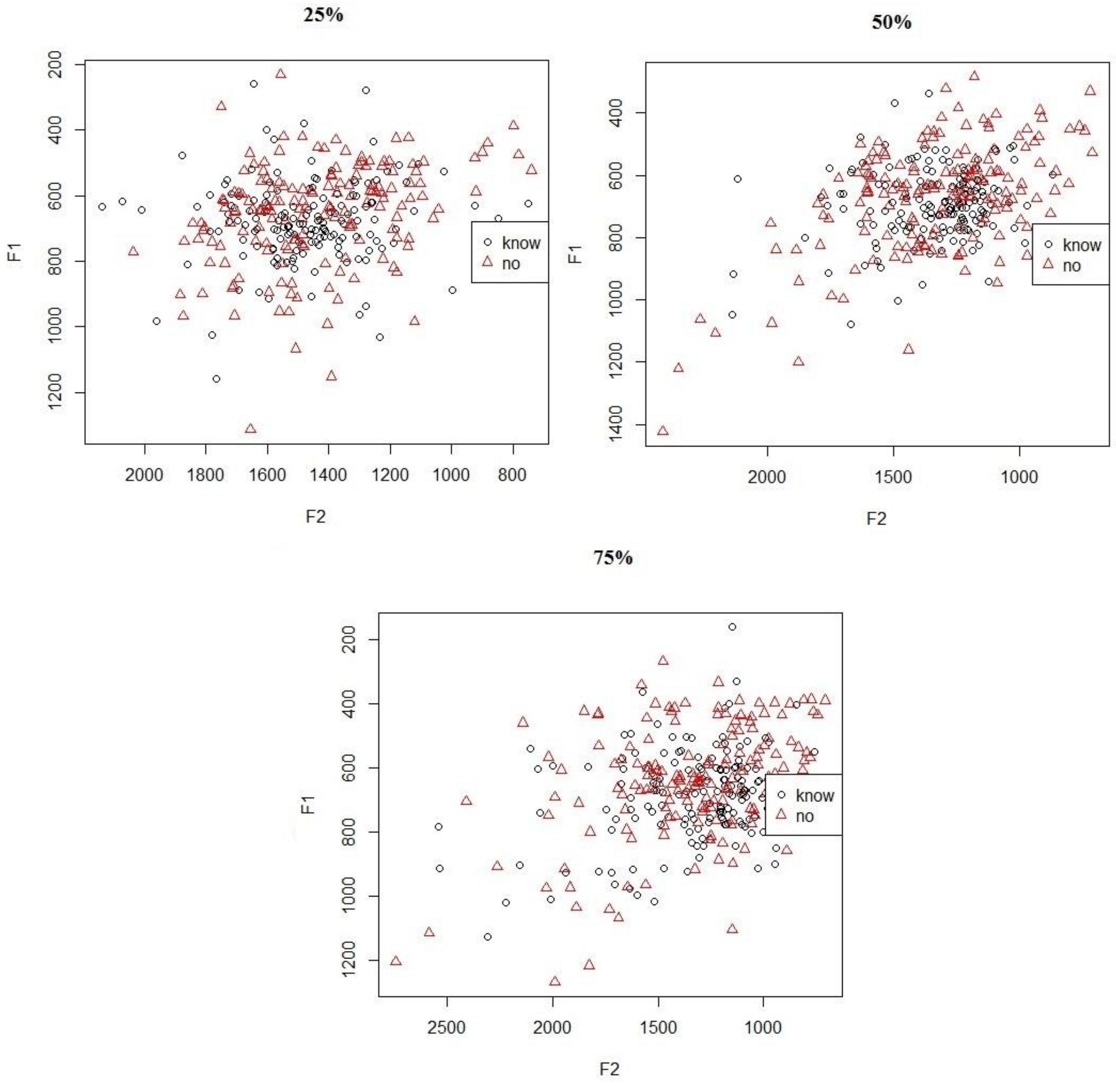

Figure 5.12 – ‘know’ versus ‘no’

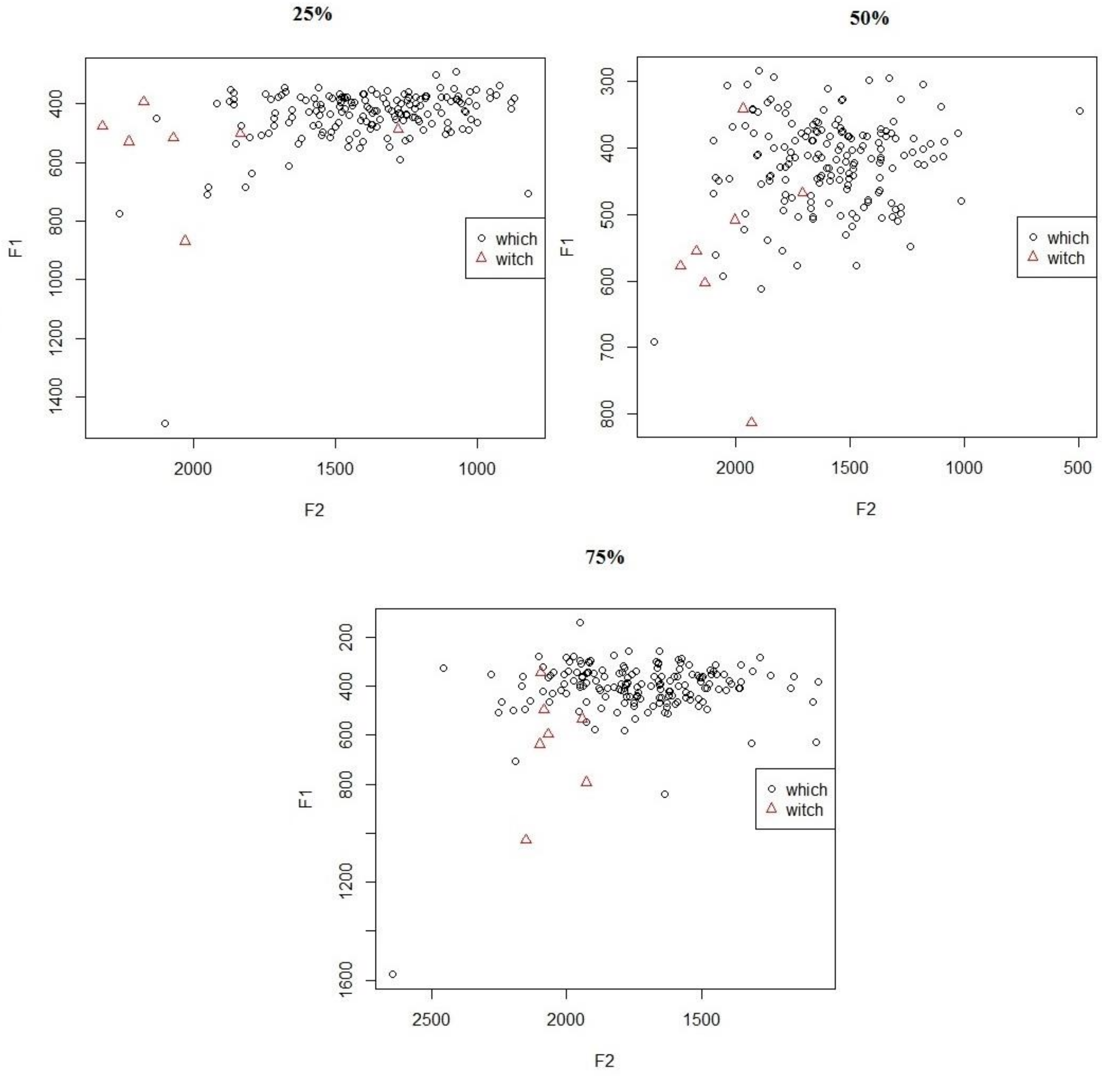

Figure 5.13 – ‘which’ versus ‘witch’