A Training Study using an Artificial Orthography: Effects of Reading Experience, Lexical Quality, and Text Comprehension in L1 and L2

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Text comprehension in adults is correlated with a number of other abilities including working memory span, inference making, and reading experience. There are fewer studies reporting correlations between lexical and sublexical skill and comprehension skill in adults. Comprehension skill in adults may constitute (1) a basic comprehension skill, like lexical skill, that drives the ability to construct representations of text and analyze them; (2) a more sensitive measure of lexical skill, for which it is difficult to measure sufficient variability in competent readers; or (3) a learned skill, derived from an individual's reading experience. Reading a greater quantity and more varied texts increases the size of the knowledge base, the efficiency with which information can be accessed, the likelihood that effective reading strategies will be developed, and with these the enjoyment of reading and the desire to read more. These possibilities are explored in this experiment.

We developed sensitive tests of lexical skill and measured comprehension skill and lexical skill using multiple tests in a large number of college students. In order to determine the effect of lexical skill on comprehension skill we divided participants into groups based on both variables in a two by two design. Using an artificial orthography allowed us to control reading experience.

Patterns of responses to homophones and nonhomophones and to high and low frequency words indicate that differences in lexical skill affect not only the extent and time course of lexical activation but also the direction of the effect. There is some evidence for an interaction with comprehension ability.

Lexical skill affected speed of learning and degree of learning success. Comprehension skill affected the ability to use the artificial orthography in other tasks, including ERP tasks. Effects were not mediated by working memory, inferencing, or lexical skill, suggesting the influence of a basic comprehension skill and an ability to assess the needs of new tasks and adapt their performance appropriately. Both lexical and comprehension skill affected performance on tasks in English, suggesting an influence of reading experience.

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1. INTRODUCTION

Skilled reading depends on the interplay of many skills – sublexical, lexical, sentence and text level, and other basic processes such as working memory. Consider the skills involved in reading this opening sentence. Readers bring to bear their knowledge of the sounds associated with the graphemes, that graphemes (and sounds) can be put together to form words, and that words can be put together in a certain order to form sentences. Readers must know the meanings of the words they read and the rules of syntax that direct the interpretation of sentence meaning. Working memory serves to hold information as the sentence is being read and its overall meaning is being constructed.

While the many stages of reading work in parallel (Sinai & Pratt, 2002), there is an order in which the processes are learned[1]. Researchers often study skills as they are being acquired because of the information this gives on the genesis of the skills, the large variability of performance, and the increased likelihood of identifying strategies for intervention. A basic level of lexical skill is a prerequisite for reading comprehension, and is usually studied as children are learning to read, with pre-reading skills such as phonological awareness studied prior to school age, and word and pseudoword reading studied in early elementary school, especially in kindergarten and first grade. Text level skills are usually studied in mid-elementary school, as task demands increase, and more curriculum material is presented to children in texts. Study of lexical skills generally decreases at this point, as these skills are expected to be fairly automatized by the end of third grade; if they are studied beyond this point, it is often in reference to reading disabilities or to children who are delayed in learning to read for some other reason. In adults, lexical skill is generally studied in people just learning to read, or in second-language learners (e.g. how phonology transfers from one's first language to the second language). Even the study of comprehension begins to become more specialized. Studies focus on how basic skills such as working memory span (Kramer, Knee, & Delis, 2000; Oakhill, Cain, & Yuill, 1998), the ability to make inferences (Long, Oppy, & Seely, 1997), and the capacity to suppress irrelevant information (Gernsbacher, 1990) affect reading

[1] This is not to say that reading skills are learned separately. For example, Perfetti, Beck, Bell & Hughes (1987) showed a reciprocal relationship between children's progress in developing phonological awareness and their progress in word decoding. Parallel processing occurs regardless of the learning stage, but a foundation must be laid of some basic level of achievement in some skills before others can be learned (Juel, Griffith, & Gough, 1986).

comprehension. In addition, some studies focus on how reading experience affects current reading ability (Stanovich & Cunningham, 1993).

While many studies show that lexical and sublexical processes are largely automatized by the middle elementary school years, it is becoming increasingly clear that readers do not universally reach a hard ceiling of ability on lexical processes. Rather, there remains enough variability in lexical performance to predict reading ability on a number of reading tasks, provided the items on lexical tests are difficult enough. This is even true for college students. Our research has begun to show that this variability in lexical performance is unique from any variability due to reading comprehension ability, and lexical performance variability does not appear to be caused by another basic process such as working memory, category inferencing, or suppression ability.

One major difficulty with finding effects of lexical and comprehension skill in college students is their varied reading background. There are differences in the way students are taught to read, with some teachers and school systems focusing on whole word reading and comprehension from context, and others focusing on phonological skills and decoding. There are differences in opportunity to read, as measured by the number of books available at home, at school, and from library access. There are differences in pressures to read from people such as parents, teachers, and peers. Some families hold reading and education in high regard, while others focus on sports, after-school jobs, or television.

There are differences in motivation to read, and consequently, in volume of reading. This is separate from pressure to read from external sources, as it is particularly intertwined with reading ability; the harder it is to read, the less enjoyable an activity it is. And the less reading practice people have (whatever the pressure to practice), the less lexical and comprehension skills will develop, further decreasing motivation to read (Miller-Guron & Lundberg, 2000).

From this information comes the premise on which the current experiment rests: *That basic lexical and comprehension skills remain important contributors to the reading ability of normal adult readers*. Further, *the importance of these basic skills is often masked by variability due to differences in reading experience*. This premise has driven our research program, the goals of which were to decrease the impact of reading experience and to increase the sensitivity of reading tests such that lexical and comprehension variability would become larger and less influenced by potential confounds. Three experiments were developed; the third forms the substance of this dissertation, while the first two provide background.

Previous experiments in our lab included experimental tasks designed to manipulate and/or decrease the effects of reading experience. The experiments were based on the Lexical Quality

Hypothesis (Perfetti & Hart, 2002). The Lexical Quality Hypothesis states that, in order to support efficient comprehension, the activation of a word representation in the lexicon must be fast and of high quality. This occurs when the constituents of the word representation, the phonology (sound), orthography (spelling) and semantics (meaning) are of high quality, and redundantly activate the word representation, leading to a rapid rise in activation of a single word representation (the singularity and the extent of activation forming its quality). Only words efficiently and effortlessly activated are able to free processing resources for building a text representation and comprehending the resulting structure.

1.1. Background Experiment 1

The first experiment (Perfetti & Hart, 2002) utilized two manipulations of lexical quality: homophony and word frequency. Both homophones and low frequency words were included because they result in lower quality lexical representations, homophones because the same phonology activates two competing representations and low frequency words because few learning trials do not build high quality representations.

We presented participants with homophones and controls (non-homophones) of higher frequency or lower frequency, followed by another word related or unrelated to the given word. Participants made a binary decision about the relatedness of the words. The critical trials were the unrelated pairs. Participants who produced a slower response time for homophones versus controls had activated dual meanings of the homophone, and the dual activations of lower quality representations were slowing their responses. In addition to the word manipulations, we varied the stimulus onset asynchrony (SOA), the time between the presentation of the first word and the presentation of the second word.

We divided participants based on their reading comprehension in Experiment one. Participants with good reading comprehension (top third of the distribution of the Nelson-Denny reading comprehension subtest) were faster to activate word representations; they already showed a slower response time to homophones at the shortest SOA. Participants with poor reading comprehension (bottom third of the distribution of the Nelson-Denny reading comprehension subtest) did not show a homophone interference effect until the next SOA. A subset who were also the slowest on the Nelson-Denny comprehension test, never did disambiguate the meanings of the homophones. This subgroup still showed a homophone interference effect at the latest SOA. In addition, the poor readers' interference effects were for the higher frequency words while the good readers' interference effects were for the lower frequency words. Overall, words of high frequency for good comprehenders were of lower frequency for poor comprehenders, most likely due to less reading experience and fewer encounters on average with all words. Words that were of low frequency for good comprehenders were of such low frequency for poor readers that either their word representations were too unstable to be adequately activated, or their representations did not exist at all (participants simply did not have the words in their vocabularies).

While Experiment 1 was designed to show an effect of lexical quality on reading comprehension, it applies to manipulation of reading experience as well. Recall the assertion that lower word frequency is analogous to less experience with a word, and that less experience leads to lower quality word representations. This serves as a basis for understanding some individual differences: people with less reading experience will have lower quality word representations. In Experiment 1, participants with poorer reading comprehension are assumed to have less reading experience.

Experiment 1 provides some evidence that lexical quality and reading experience are related to reading comprehension in college-age people. However, the experiment design has some limitations. First, lexical quality and reading experience are confounded in this experiment. The extent to which each of these variables produces the response time effects is not clear.

Second, reading experience on average is manipulated in this experiment, but individual experience is not controlled. In other words, it is likely that each participant had a different amount of experience with each word in the stimulus set. While one participant might know the homophone pair "hair" and "hare" very well, another participant might not. Similarly, while a single participant might know some of the low frequency words well, he might not know the other half at all.

Third, this experiment did not separate lexical skill and comprehension skill. The object of the experiment was to show the extent to which lexical quality affects reading comprehension, not the extent to which lexical skill and reading comprehension differentially affect reading skill in college students.

Finally, there are aspects of reading experience other than the number of encounters with a word that can affect current readings skill. There is the extent to which learning to read focused on decoding, current reading strategy, motivation, and a host of other similar variables. None of these were controlled by the word frequency/experience manipulation.

1.2. Background Experiment 2

The second experiment in our lab (Balass, in preparation) addressed the first two limitations of Experiment one: reading experience was controlled at the level of individual participants and individual items. This manipulation removed reading experience, at least as measured by differential word encounters, as a source of variance and made the effects of word frequency clearer. Participants were given a homophone orally, and asked to spell and define it two different ways. Then they rated their familiarity with each spelling/meaning on a scale of 0 (never heard of it) to 3 (use it all the time). Twelve homophone pairs for which one word was rated as a 1 or, rarely, a 0 and the other was rated as a 3 or, rarely, a 2 were chosen for each participant. One half of the homophones rated as less familiar were chosen as training words. Participants practiced the meanings of these words in two 45 minute sessions. Testing, in an experiment of the same format as in Experiment one, was conducted before and after training. Results were that all participants, regardless of comprehension skill, showed the same basic pattern of results: early activation, followed by eventual disambiguation, for homophones versus controls. In addition, while the lower frequency homophone showed a slowdown relative to controls prior to training, the higher frequency homophone showed a slowdown after training. The relative frequencies of the words were reversed with increased experience with the trained words. Lexical quality due to word frequency was the same as lexical quality due to word experience. The effects of lexical quality on comprehension skill found in Experiment one could essentially be retitled as the differences in lexical quality based on reading experience

Experiment two did not control all confounds. Individual differences were essentially removed by the individualized word familiarity ratings. While this demonstrates the effects of word experience on comprehension skill, it leaves open the question as to how lexical skill relates to reading experience and to comprehension skill. Experiment two also does not limit the effects of other experience variables such as motivation, method of reading instruction, or reading strategies.

1.3. Rationale for an Artificial Orthography Training Experiment

The participant of this dissertation, or what could be called the third experiment in the series, endeavors to address the limitations of Experiments one and two. The goal of the current experiment was to negate reading experience by teaching participants an artificial alphabetic orthography as different from English as possible. The reasoning was that by making the orthography different from English, participants would not be able to use the strategies that they used to read English. In addition, we manipulated both lexical skill and comprehension skill in a two by two design (high/low comprehension skill by high/low lexical skill) in order to test the independent contribution of these skills as well as their possible interaction.

In general, we expected that lexical skill and comprehension skill would differentially affect participants' responses to the within-participants variables of homophony, frequency, and training (experience). In particular, good lexical skill would increase the rate of learning, conversely leading to earlier homophone interference and greater frequency effects. Because the concepts would be well known to all participants, the vocabulary was new to all participants, and the syntax was easy (short sentences all of the same structure, explicitly taught), reading comprehension was not expected to play much part in learning. However, we expected that reading comprehension would play a role when participants utilized the learned information to carry out other tasks, such as category inferencing and even pseudoword reading in which learned information needed to be applied in new ways.

In the literature review that follows, we address issues that affected our design of the artificial orthography. In particular, we address how training (intervention) can improve reading skill, even in undergraduates, how similarities between English and the artificial orthography might affect learning and proficiency in the artificial orthography, and how evoked potentials can be used to investigate individual differences and effects of training on native and second languages.

1.4. Effects of training on reading skill

One of the goals of reading research is to understand reading processes well enough to predict who is at risk for reading failure, and to develop effective intervention strategies to ensure reading success. In a review of 29 studies with a total of more than 1500 participants, Elbaum and colleagues (Elbaum, Vaughn & Moody, 2000) found a significant effect size of .41, for the improvement in reading due to intervention programs during the elementary school years, regardless of the program specifics. It did not matter whether the intervention was one-on-one or in small groups, how many total hours the intervention lasted, or whether the intervention was a standardized program or an experimental program. What did matter was the education and training of the instructors, the grade level of the students, the length of the intervention, and the type of outcome measure.

The more highly educated the instructors were, the more effective the intervention program. There was a large range of educational level in the instructors, from masters-level teachers trained in learning disabilities to college student volunteers.

The lower the grade level of the participants, the more effective the intervention program. This could be for a number of reasons. As more than two thirds of the studies included in the meta-analysis were of first graders, there may have been a simple statistical advantage rather than a true difference. However, first grade is when students spend much of their class time learning to read. The intervention programs may have supported the classroom instruction, allowing the students to learn more in class. In addition students in higher grades are often included in intervention programs because they have already failed to learn what is expected of them. The expectations of these students, both from themselves and from the adults around them, may be lower than what they could truly achieve, resulting in lower achievement and less improvement. These students may also be more severely impaired than at-risk first graders, many of whom may have learned to read adequately without intervention. On the other hand interventions tend to be more effective with lower-performing students, regardless of grade, precisely because they have more to learn.

The longer the intervention, the more successful it was, even though the total number of training hours did not have an effect on the success of the intervention. The duration effect may be similar to the grade effect in that longer interventions can support broader ranges of classroom activity. Longer interventions also allow time for assimilation of what is being taught.

When the intervention program targeted more skills, it was more effective. Instead of focusing on whole word or phonics approaches, nearly all of the interventions taught with aspects of both. Teaching students how to quickly decode new words and how to read from context, monitor comprehension, etc. resulted in the most successful readers.

Children improved on nearly all outcome measures, regardless of intervention type. They improved most in decoding/oral reading, then in reading comprehension, then in spelling. No significant differences were found for writing and for listening comprehension. The improvement across outcome measures is especially important for the current study. Both lexical and comprehension processes improved with training. Both are modifiable, and with a number of intervention types. The experimental training in the artificial orthography proposed for Dissertation Experiment three is expected to be effective based on these data.

Reading intervention did not improve listening comprehension. Gernsbacher, Varner & Faust (1990) developed a comprehension test in three modalities: oral, written, and pictorial. They found that all three were highly correlated, at .93 for oral and written, .83 for written and pictorial, and .73 for oral and pictorial. Based on these correlations they concluded that comprehension is a general construct, and that comprehension in any modality draws on a basic comprehension process. Gough (Gough, Hoover, & Peterson, 1996; Hoover & Gough, 1990) formulates reading comprehension as decoding plus linguistic comprehension. The argument that logically follows is that the interventions improved decoding since reading comprehension improved but listening comprehension did not, and improvements in comprehension were due to more efficient decoding and more efficient strategies for applying basic comprehension processes to the decoded material. The cross-modal basic comprehension function proposed by Gernsbacher is less likely to have been modified by training.

The meta-analysis showed that children in lower grade levels gained more from training. What is the likelihood that college students, all of whom are expected to decode and comprehend at an adequate level, will show training effects? Guyer & Sabatino (1989) identified 30 learning disabled college students of normal IQ. They came to the attention of their university's LD clinic when they began to fail in their classes. Ten participated in a summer enrichment program that used a phonetic training approach, ten participated in a similar program that used a whole word training approach, and ten participated in neither. Students in the phonetic program gained more in a composite score of word and pseudoword decoding, spelling, and reading comprehension than students in either of the other two groups. They jumped nearly 20 standard score points and two full grade levels.

The intervention study by Guyer and Sabatino complements the meta-analysis of elementary school students and provides evidence that the college students who will be learning the artificial orthography (Zekkish) are likely to show significant training effects. Zekkish has a completely regular orthography, and students are taught using a phonetic approach. The students are a mixed group, with regard to their English reading skill, but all are beginning readers in Zekkish. They have both the most to learn, and the best potential for doing so.

1.5. Reading in a second language

Three themes in the second language literature helped to guide the construction of Zekkish.

1. The structure of the first language (L1) predicts proficiency in a second language (L2).

Fender (2003) tested adults who were native speakers of Arabic or Japanese and who were learning English. Participants with a Japanese L1 were faster and more accurate at word recognition, while participants with an Arabic L1 were better at integrating words into sentence, even though groups were matched on overall English proficiency. The qualities that each L1 shares with English transferred to English. A visual/orthographic strategy leads to efficient Japanese reading, so Japanese speakers were more sensitive to English spelling patterns than to English syntax. Arabic and English share clause patterns (e.g. right-branching sentences), so Arabic speakers could easily apply Arabic sentence-reading strategies to English, but they were slowed down by English's inconsistent orthography.

However, Akamatsu (2002) did not find such a difference. Adults whose first language was Chinese, Japanese or Persian and who were fluent in English as a second language showed the classic frequency by regularity effect in English. Regularity predicted the speed with which participants named words, but only when the words were of low frequency. High frequency words were recognized on sight, while the reading of low frequency words was phonologically mediated. The use of real words instead of pseudowords and the high English proficiency of the participants may have caused the null effect of differences in amount of transfer from L1 to L2 according to language.

2. Some general abilities apply to reading, regardless of language or order of acquisition.

One hundred sixty Finnish first graders were tested as they learned to read and speak English (Dufva & Voeten, 1999). In addition to L1 skill, phonological memory affected English skill in grades two and three. Word recognition, listening/reading comprehension, and phonological memory all contributed to the prediction of English reading and writing (English "communication skills," 73% variance), English listening comprehension (46% variance), and English vocabulary (41% variance). In older Dutch children with an average of two years of English instruction, metacognitive knowledge and vocabulary alone could account for English (L2) proficiency, with no input for grammar knowledge, word recognition, or sentence verification (Van Gelderen, et al., 2004). Background knowledge and language experience affect second language learning as well as first language learning. Pulido (2003) tested beginning, intermediate, and advanced students of

Spanish as L2 in college. Participants were asked to translate nonsense words embedded in paragraphs on familiar and more difficult topics two and 28 days after reading the paragraphs. On day 2, participants remembered and correctly translated more words from familiar passages, and participants with larger Spanish vocabularies translated more words. In this case, it appears that familiarity and experience in Spanish affected the determination of meaning from context.

3. Some specific skills apply to learning any language, if the skills are necessary for proficiency with the language.

A study of children learning to read in Dutch, with Dutch as L1 or L2, found that data from native and non-native Dutch children fit the same structural model of basic reading skills (phonology, decoding, spelling, comprehension, Verhoven, 2000). The non-native children had a slightly higher weight for vocabulary, probably reflecting the fact that their comprehension was slightly poorer than the native Dutch speakers' comprehension performance, although their decoding and phonology were similar. It could also reflect their experience with Dutch, as it is likely that native speakers heard and spoke Dutch at home more than non-native children did.

It is clear that phonological awareness is important for English reading. In a study of second graders with English as L1 or L2, regression analyses showed that both groups' spelling was predicted by pseudoword decoding and phoneme deletion, while oral cloze, syntactic judgment, working memory, and rapid were not predictive (Wade-Woolley & Siegel, 1997). When the children were divided by skill, poor decoders' real word spelling was additionally predicted by rapid naming and their pseudoword spelling was additionally predicted by working memory.

All children learned to spell in the same manner, regardless of L1. Real word spelling draws especially heavily on good lexical access, so when lexical access was compromised as in poor decoders, rapid naming served as a predictor. Pseudoword spelling draws especially heavily on working memory, so when it was compromised as in the poor decoders, working memory served as a predictor. In all cases, either pseudoword decoding or phoneme deletion or both predicted spelling. Unfortunately, children were never divided by both L1 and decoding skill at the same time. It might be predicted that good decoders with English as L1 and L2 show the similar patterns, but poor decoders rely on transfer of other skills from L1. On the other hand, because phonological processing is both a basic skill and necessary for skilled English reading, the regression equations might be the same for all groups. There is one study that shows that phonological processing deficits transfer from L1 to L2 (Miller-Guron & Lundberg, 2000).

Miller-Guron & Lundberg's study explores why some dyslexic Swedish readers actually prefer to read in English (their L2). They compared normal Swedish readers (Norm), dyslexic Swedish readers who preferred to read in English (Dys-E), and dyslexic readers with no preference for English over Swedish (Dys-S). The Norm group outperformed both dyslexic groups on all tasks, eliminating the explanation of a general English reading ability for some readers. The researchers calculated an English Load Score (ELS) – the extent to which English is more difficult than Swedish. All groups had an ELS of zero for phonological tasks. Whatever phonological difficulty participants had with Swedish, they had to the same extent in English. However, only the Dys-S group had an ELS greater than zero for the other skills tested - orthographic, decoding, and text reading. The authors attributed the Dys-E group's success in English to an alternative reading strategy in English's deeper orthography. In addition, there was a leveling effect for the groups because English was new to everyone. The authors note that an early positive experience with English reading could "trigger a greater readiness to approach English texts" compared to Swedish texts. Anecdotal reports from participants provide support for this explanation; some participants reported that reading was more enjoyable in English, and that they were more likely to read in English than in Swedish.

Miller-Guron & Lundberg found that L1 phonological skills transferred to L2, while orthographic skills were revamped for the deeper L2 English orthography, at least for normal participants and dyslexics who preferred to read in English. Nassaji & Geva (1999) found that both phonological and orthographic skills transferred from L1 (Farsi) to L2 (English), but that orthographic skill predicted unique variance while variance explained by phonological skill was shared with other skills. They ran hierarchical regressions predicting reading comprehension, silent reading rate, and word recognition. In each case, rapid naming and working memory were entered first, followed by lexical skills (orthographic and phonological), followed by higher level skills (syntactic and semantic). In this order, both phonological and orthographic skills (among others) predicted a significant amount of variance for all three dependent variables. When the order in which higher-level and lexical skills were reversed, orthographic skill remained predictive of reading comprehension and silent reading rate, but phonological skill dropped out entirely. The relative contributions of phonology and orthography may be due to the fact that Farsi orthography is shallower than English orthography. While one grapheme maps onto many phonemes in English, there is complete one-to-one correspondence in Farsi. Sensitivity to orthographic forms rather than phonological structure may be more helpful when learning English after experience in Farsi.

To summarize, L1 structure influences L2 proficiency, and both general and specific language skills transfer from L1 to L2. When performance is compromised because children are young and learning to read for the first time, because adults proficient in one language are beginning to read and speak in another language, or because of a disability, the contribution of phonological and orthographic skills to reading performance is magnified, general skills such as working memory are tapped, and topic familiarity and reading experience buttress performance. Zekkish was designed to capitalize on these phenomena. Zekkish orthography is shallow, with only one instance when two graphemes map to one phoneme. Therefore, participants were going from a fairly deep English orthography to a shallower one, which would highlight the importance of phonological skill and yet make the influence of orthographic skill necessary and fairly obvious to participants (for distinguishing between the two graphemes with the same sound). The word length and the number of the words in the lexicon were kept small so that more general skills such as working memory would not dilute the expected lexical effects. Experience was completely controlled, and performance was tested at two points, so that the general effects of Zekkish reading experience and Zekkish vocabulary could be determined.

1.6. Event related potentials

We chose to include event related potentials (ERPs) as outcome measures because they have been shown to be sensitive to online processing in a number of studies relevant to training in an artificial orthography.

1. ERPs are sensitive to individual differences in reading ability.

Although there is a long history of ERP amplitude and latency measurement in the description of diseases and illnesses (e.g. eyesight problems with neurological bases, schizophrenia), as well as in learning and memory (e.g. recognition of recently encountered material, Squires, Wickens, Squires & Donchin, 1976) the use of ERPs to measure individual differences in complex cognitive processes such as reading is still fairly new to cognitive psychology[2]. In 1997 Rudell and Hua found a clear dissociation between the correlates of the well-known P300 component and the recognition potential (RP), an early visual component. Participants were asked to detect words in streams of random letters. The same ten target words were presented repeatedly during the

[2] Federico (1973) did measure "Cognitive styles, abilities and aptitudes" and Shucard & Horn (1973) found relationships between visual ERPS and "intelligence," but only for a change in ERP amplitude from one condition to another, and only for a general skill, not for more specific cognitive abilities.

experiment. The P300 is known to be sensitive to stimulus probability and to decision uncertainty. As expected, the P300 latency, not the RP latency, decreased with training (r=.67 across three experimental sessions), as decision uncertainty decreased. The RP latency, not the P300 latency, correlated with participants' response time to identifying the target words (r=.66). Further, the RP predicted participants' reading scores (r=-.74). By expanding their search for ERP components related to individual differences from the routinely studied P300, Rudell and Hua found an electrophysiological component that was related to individual participants' performance *and* to their reading ability. They tied neural response to perception to word reading.

Other recent experiments have found that electrophysiological responses are sensitive to the even higher level processes of metaphor comprehension and inference making during reading (Kazmerski, Blasko, & Banchiamlack, 2003 and St. George, Mannes, & Hoffman, 1997, respectively). The N400 is a component that is sensitive to the expectation that a stimulus will occur. For example, the final word in the sentence "The coffee was too hot to laugh" will produce a larger N400 amplitude than the final word in the sentence "The coffee was too hot to eat," which produces a larger N400 amplitude than "The coffee was too hot to drink." Each study found that the N400 amplitude was related to the measured skill, and that this in turn was related to a measure of individual differences: IQ for metaphor comprehension and working memory for inference making.

In a review paper (Molfese, Molfese, Key, Modglin, Kelley, & Terrell, 2002) Molfese and colleagues describe how individual differences in ERP amplitudes and latencies can be used to predict individual differences in other skills. Molfese and his colleagues first measured ERPs of newborns listening to phonemes with varied voice onset times (VOTs). They measured the reading ability of these infants eight years later, and found that their ERPs at birth discriminated among normal readers (n=24), dyslexic readers (IQ-discrepant, n=17), and poor readers (non-IQ-discrepant, n=7). They correctly classified 81% of the children (19/24 normals, 14/17 dyslexics, and 6/7 poor readers). The control participants had larger amplitude, shorter latency N1s, while poor readers and dyslexics had larger N2 amplitudes and poor readers had larger N2 amplitudes.[3]

From this series of studies, it appears that using electrophysiology to study individual differences in reading ability can be successful. The amplitude and latency of ERP components can be related to specific cognitive processes and to individual differences in related skills, even when

[3] Amazingly, the parents of these children could also be sorted by their ERP waveforms, although none had low enough reading performance to be called dyslexic or a poor reader. While not relevant to the current experiment, it provides evidence that brain activation is, to a certain extent, heritable (along with the skill related to that brain activity).

the skills are measured at a time far removed from the collection of ERP data. The literature is too sparse yet to have identified locations and skills that are related consistently, but as did the studies presented here, the ERP literature identifying the stimulus characteristics to which ERP components are sensitive can be used to direct the search. The Rudell & Hua (1997) study also suggested that ERP components are sensitive to training; although "training" in their case was simple stimulus repetition, other ERP experiments have made training the focus of the project.

2. ERPs change after reading training in both English and in an artificial orthography.

In the same review paper reported above, Molfese and colleagues reported on two training experiments in which nonsense words were associated with nonsense shapes (for college students) or novel objects (14 month old babies). Both training and extent of training produced reliable ERP effects for the college students and for the babies.

One researcher's dissertation work (McCandliss, Posner, & Givon, 1997) focused on ERP responses to training, and trained college students in an artificial orthography called Keki. The words of Keki used the English alphabet, although word structure was unusual for English, with a C(C)VC(C)V form and rare letter combinations. Participants were trained not only on Keki words but also on Keki grammar, although there is no report of the complexity of the grammatical structure nor of its similarity to that of English. Participants spent 50 hours learning Keki, and were tested prior to instruction, after 20 hours of instruction, and after all 50 hours of instruction were completed. An early, negative posterior component was sensitive to the orthography, showing a difference between English and Keki orthography. A slightly later, positive component was sensitive both to task demands and to training, with the amplitude decreasing across testing sessions as participants developed Keki experience; by the second testing session, amplitudes were the same in English and in Keki.

This experiment is important to the interpretation of the current experiment for several reasons.

First, ERP components are sensitive to training in an artificial orthography.

Second, by 20 hours of training, ERP amplitudes were similar in the artificial orthography and in English; the current experiment only includes about 20 hours of experimental time overall. It does not appear that 50 hours of training are necessary to produce ERP effects.

Finally, ERP amplitudes were sensitive to orthography, even when the orthography shared some characteristics with English. The orthography of the current experiment is much more different than English.

ERP components, including amplitude and latency, are sensitive both to individual differences and to training. Training effects can be found regardless of the age of the participant; the important variable is that the information to which the participant is exposed is previously unlearned. The information being learned can be as novel as an artificial language.

3. ERPs are sensitive to individual differences in the response to training.

While the studies reported above discuss ERP responses to individual differences and to training, Perfetti, Wlotko & Hart (under review) used ERPs to study the differences in the way skilled and less skilled comprehenders learned new information – specifically, new vocabulary. They gave skilled and less skilled comprehenders 45 minutes to study the meanings 60 vocabulary words they did not know and tested them on a semantic relatedness task. The vocabulary word was presented followed by a probe word related or unrelated in meaning to a studied word, a previously known word, or an unknown word. More skilled comprehenders were more accurate and produced a stronger effect 600 ms after the onset of the first word and 400 ms after the onset of the second word. The authors suggest that the stronger ERP amplitudes represent a stronger episodic memory trace, and that more-skilled comprehenders produced these stronger episodic memory traces during training, which allowed them to learn more new vocabulary than the less-skilled comprehenders. Based on this study, training skilled and less skilled readers (in comprehension and lexical skill) in an artificial orthography is likely to produce reliable ERP effects both of training and the effect of individual differences on the success of the training.

3. ERPs are different between native and learned languages even for fluent speakers/readers.

As with behavioral data, the results of ERP experiments involving the learning of a second real language can direct research using an artificial orthography. Three experiments of second language learning using ERPs are considered here. Each involves learners with different first and second languages (L1s and L2s): Hebrew learning English (Sinai & Pratt, 2002), Hungarian learning Finnish (Winkler, et al., 1999), and English learning Spanish (Alvarez, Holcomb & Grainger, 2003). The studies vary in the fluency of their participants in the L2, from naïve to fluent, and in the task, from vowel discrimination to semantic categorization. Results vary based on these experiment differences. The less perceptual and more complex the task, the later the component that was sensitive to language differences. More skill in L2 led to more similar performance in L1 and L2 (never with complete overlap). However, each finds differential processing of the two languages, with ERP waveforms diverging very early after stimulus presentation. Even in a semantic categorization task, when the measured component was N400, the waveforms began to separate in much earlier time bins. This indicates that even "preattentive" language processing (Winkler, et al., 1999) is utilized in L2, and that even fluent speakers can retain some language processing differences in L1 and L2. These ERP differences due to language are important to the current study because ERPs will be measured at two points: naïve and experienced. Based on these studies, ERP differences are likely to be found between English (L1) and the artificial orthography ("L2") even at the second testing session. It is also likely that as the task varies, the ERP component at which language and experience differences will be found will change.

1.7. Summary

In sum, both lexical and comprehension skill appear to affect college students' reading ability, provided that lexical skill and comprehension skill are measured with sensitive (difficult) enough instruments. Further, reading experience – from the volume of reading from learning to present – affects the development of lexical and comprehension skills beyond baseline ability. Consequently, the measurement of baseline lexical and comprehension ability is confounded by reading experience.

Our first study examined the relationship between reading comprehension and lexical quality. Lexical quality and experience with words were manipulated by the inclusion of homophones (lower quality because the phonology is not unique) and word frequency (because by definition people have less experience reading lower frequency words). In this study, poorer comprehenders appeared to have lower quality lexical representations. What was unclear was whether these lower quality lexical representations were secondary to comprehension skill, lexical skill which was unmeasured and likely related to comprehension skill, or to reading experience, also likely related to comprehension skill.

Our second study equated word experience for skilled and less skilled comprehenders and showed the effects of building word experience in a training study. When word frequency was equated, comprehension differences disappeared. Training did improve the lexical quality of the representations of the trained words.

Our third study, the artificial orthography training experiment reported here, controlled reading experience at an absolute level instead of on a word by word basis by exposing participants to an artificial language with which no participant had experience. Additionally, both lexical skill and comprehension skill were included as independent variables, motivation to learn was maximized by making the task engaging and paying participants, and by limiting the opportunities for English reading strategies to be applied to reading in the artificial orthography. Thus, we could test not only whether lexical skill and comprehension skill were separate predictors of learning and performance but also whether comprehension skill in English predicted variance separate from reading experience.

The literature supports the ability for training experience to improve the reading ability of college students, in English, in an artificial orthography, and in L2. Evoked potentials can detect group differences even for people fluent in (experienced with) their L2. If such differences were found in our artificial orthography study, they would provide evidence that lexical skill and/or comprehension skill continue to affect reading ability after a language is learned and separately from the effects of experience.

2. OVERVIEW OF STUDY AND HYPOTHESES

The purpose of the present experiment was to control the effects of reading experience in order to examine the separate effects of lexical skill and comprehension skill on college-level reading skill. This experiment addresses the limitations of Experiments 1 and 2 in that lexical skill was measured in addition of comprehension skill and training was carried out using an artificial orthography with which none of the participants had experience. The artificial orthography was as different from English as possible so that participants would not bring their knowledge of English and their resultant English reading strategies to the task. The orthography was simple and alphabetic and the experiment's cover story was engaging.

The reasoning for this experiment design was first, that any reading strategies participants might bring to the experiment would be derailed by (a) changing the order of letters in a word, (b) making the pattern of letters circular rather than linear, (c) changing the order of words in a sentence, (d) making one word hold two different places in the sentence (verb and direct object), (e) using more rare phonemes, (f) using new graphemes, and (g) keeping the structure simple.

Second, by developing our own orthography, we could be sure that participants had not had any practice converting these graphemes to sound.

Third, by keeping the concepts to which the words refer high-frequency, we ensured that all participants were highly familiar with them.

Fourth, we had complete control over participants' experience with the words – frequency of learning and practice trials, and homophony.

Fifth, an artificial language allowed for a great deal of artistic license with the experiment. In addition to the task being unusual and provocative, we made it interesting by creating a cover story around the artificial language. "Ambassadors from the planet Zek are coming to visit, and you have been named the Earth ambassadors. Here is some information about the planet and its people … In order to be dignitaries you must first learn the language…" (See Appendix C for participants' introduction to the cover story.)

Sixth, paying participants turned the onus of multiple training sessions into a motivation advantage; seeing the experiment as a 'job,' increasing the honorarium for each section of the experiment, and saving the payment until the experiment ended (or the rare participant dropped out) increased participants' responsibility and greatly reduced attrition.

Seventh, including an evoked potential portion of the experiment allowed for close monitoring of participants' motivation as well as providing an additional dependent measure. The huge reduction in eye movement artifact compared to participants completing more traditional one-session ERP experiments attested to participants' motivation to do what the experimenter wanted them to do.[4]

A final advantage of the current experiment was that both lexical skill and comprehension skill were manipulated. Half the participants had poor lexical skills and half had good lexical skills, while half the participants had poor comprehension skills and half had good comprehension skills, in a two by two design. Each of the two between-participants variables was measured by four separate tasks, nearly all of which were experimentally designed to have a good deal of variability in college students. The remaining tests, the vocabulary and comprehension subtests of the Nelson-Denny, were standardized for college students.

The manipulations in this dissertation equated as closely as possible the learning and experience of skilled and less skilled readers. As such, as soon as participants had an ability to decode the language, and as soon as they had learned but not practiced the vocabulary, all participants – skilled and less skilled – were expected to perform in testing like less skilled readers. Once they had practiced the vocabulary and their reading skills to the point of overlearning, all participants – skilled and less skilled – were expected to perform in testing like more skilled readers.

In summary, the goal of the current experiment was to control effects of reading experience in order to examine the separate effects of lexical skill and comprehension skill on college-level reading. Experience factors were controlled by utilizing an artificial orthography. Lexical skill and comprehension skill were measured using multiple tests. The hypothesis of the current experiment was that the *between-participants variables of lexical skill and comprehension skill would affect participants' responses to within-participants variables of homophony, frequency, and training (experience).* The implication of this hypotheseis is that *reading comprehension contributes variance to the prediction of participants' performance above the variance it shares with reading experience*. In this case, reading comprehension was assessed in English, but training and testing was carried out using the artificial orthography (Zekkish). Because knowledge of English isn't relevant, and experience is controlled, then *the measured comprehension ability that influences Zekkish performance must be an underlying ability rather than a learned skill*. Finally, lexical skill and comprehension skill are expected to affect different aspects of the experiment. Lexical skill is important in grapheme-phoneme correspondence and assembling words from phonemes. Therefore,

[4] There was also the advantage that participants knew that the experimenter was sitting right outside the door monitoring their performance and their brain waves.

lexical skill should affect the rate in which Zekkish is learned and read. The structure of Zekkish was kept simple enough that comprehension might not play a role in Zekkish learning. Instead, *comprehension skill is expected to affect participant's use of Zekkish* – that is, their ability to apply their knowledge to new tasks and to utilize Zekkish in new ways. Therefore, comprehension skill should affect performance on Zekkish tests such as reading pseudowords, making category inferences about the concepts, and remembering lists of words. These hypotheses were tested four ways: on participants' progress through the training, on participants' performance on tests of various reading tasks in the artificial orthography after partial training and after complete training, on participants' performance on an experimental task designed to be the equivalent to Experiments one and two described above, and on the activation of participants' brain responses and related behavioral responses during a series of evoked potential tasks.

The next chapter includes participant characteristics in detail, while the following four chapters cover each of the four data types: training data from each of the steps in the training process, testing data from two points: when participants had just learned the orthography and its associated vocabulary (partial training) and after participants had practiced the vocabulary words (complete training), ERP data including electrophysiological data and behavioral responses during the ERP tasks, and experimental data on tasks similar in design to those in Experiments 1 and 2. Each of these four data chapters begins with an overview, followed by a detailed methods section, results, and discussion. Chapter 8 includes data from participants' exit interviews. The final chapter is a general discussion of the entire project.

3. PARTICIPANT INFORMATION

3.1. Participant groups

Participants were 45 students from the University of Pittsburgh who participated in a large reading screening to earn credits for their Introductory Psychology class. There were ten participants with poor lexical skill and poor reading comprehension skill, eleven participants with good lexical skill but poor reading comprehension skill, twelve participants with poor lexical skill and good reading comprehension skill, and twelve participants with good lexical skill and good reading comprehension skill.

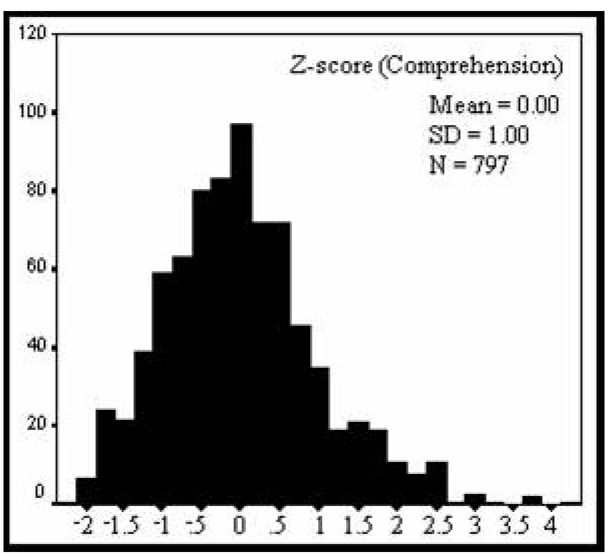
3.2. Pool of eligible participants

Over two years, more than 1600 participants were given a battery of reading tasks, including standardized comprehension and vocabulary tests, a reading experience checklist (the Author Recognition Test, ART), a written test of orthographic and phonological processing, and three checklist tests of University of Pittsburgh design. One taps vocabulary, one taps orthographic knowledge, and one taps phonological knowledge. At the time of participant selection, 797 participants had been given all the screening tasks, had their data entered, and were determined to have scores within a reasonable accuracy range (e.g. not less than four correct answers on the comprehension test, and not more false alarms than hits on the checklist tests).

The first goal in choosing participants to participate was to ensure that less-skilled comprehenders were truly less-skilled, and did not just fail to put in enough effort on one of the screening tasks – after all, these participants were introductory psychology students receiving only credit for participation. Conversely, more-skilled comprehenders had to be truly more skilled, and not just practiced at taking certain reading tasks. In addition, one particularly carefully manipulated variable in this experiment was reading experience. Because of this, a compound variable was created from multiple tasks related to comprehension, to tap a variety of measures of comprehension and experience.

The Nelson-Denny reading comprehension subtest is a standard timed reading comprehension task. Participants read a series of four to eight paragraph texts, each followed by comprehension questions. The Nelson-Denny vocabulary subtest is highly correlated with the comprehension subtest. This is a timed multiple choice test in which participants choose the correct meaning of a given word. Because skilled reading comprehension relies greatly on an extended lexical knowledge base, less-skilled comprehenders are expected to have poorer than average vocabularies, while more-skilled comprehenders are expected to have better than average vocabularies. In addition, participants were asked to indicate their recognition of authors in a list of well-known author names and other names (the Author Recognition Test (ART), Stanovich & Cunningham, 1993). This task assesses the breadth of one's reading experience, and because reading experience is an integral part of the current arguments on the origins of reading comprehension, it is included as a defining quality of the skill groups. Finally, a checklist test of vocabulary was included. Participants are asked to check items that they know to be words. The list contains items participants are expected to recognize (kayak, ladle, lacerate), low-frequency items they are not expected to know (gloaming, jussive, torose), and pseudowords (unmorchise, gilthy, yerkine). Although in one sense it is a lexical decision task, it is included in the definition of comprehension both because it is a vocabulary assessment and because it has a large experience component. With reading experience, participants encounter many words in context that they have not seen before. From the context, they can create a lexical entry that contains semantic content, but the meaning of the word is not likely to be fully fleshed out.

The four measures (comprehension, vocabulary multiple choice, vocabulary checklist, and ART) were standardized and summed. The resulting distribution is reported in Figure 3.2.1.



<u>Figure 3.2.1</u> Histogram of comprehension scores.

Participants were chosen as good and poor comprehenders as follows. Good comprehenders had to be in the top half of the distribution on the composite score as well as not scoring in the bottom 25% on any one of the tests included in the composite. Poor comprehenders had to be in the bottom half of the distribution on the composite score as well as not scoring in the top 25% on any one of the tests included in the composite. Table 3.2.1 gives the descriptive statistics for the skilled and less-skilled comprehenders on the four subtests included in the comprehension composite.

Table 3.2.1 Descriptive statistics for subtests included in comprehension composite. Reported data are Z-scores.

	Less-skilled comp, n = 399			More-skilled comp, n = 398		
	Mean	SEM	Min, Max	Mean	SEM	Min, Max
N-D comprehension	-0.59	.033	-2.22, 1.97	0.59	.042	-1.65, 3.11
N-D vocabulary	-0.63	.032	-2.10, 1.29	0.63	.045	-1.44, 4.02
Author Recognition hit-fa	-0.59	.030	-1.81, 2.24	0.59	.048	-1.33, 5.10
Vocabulary checklist hit-fa	-0.54	.041	-2.96, 2.56	0.54	.043	-1.93, 3.98

The second goal was to select participants who were skilled and less skilled in lexical level tasks. Again, a composite variable helps to increase the reliability of the groups. Four lexical measures were available. A written test of orthographic and phonological processing required participants to subtract and add sounds to words. The sounds did not necessarily correspond to letters (the phonological component), but all answers were required to be real words (the orthographic component). For example, participants might be asked to remove the /w/ sound from "queen," to produce "keen." They might then be asked to replace the sound with the /l/ sound, to produce "clean." The answers were scored for phonological accuracy and for orthographic accuracy. For example, if instead of writing "clean" participants wrote "klean," phonological accuracy would be 1, but orthographic accuracy would be 0. If participants instead wrote "kiln," phonological accuracy would be 0, but orthographic accuracy would be 1.

An orthographic checklist test required participants to indicate, from a list of letter strings, which strings correctly spelled words. Examples of correctly spelled words include mortgage, initiate, and wagon. Examples of incorrectly spelled words include forfit, bouyant, and enemey.
A phonological checklist required participants to indicate, from a list of letter strings, which strings (when sounded out) were words. Here, no letter string formed a correctly spelled word. Examples of

letter strings that sounded like words include pebl (pebble), oquird (awkward), and speschelist (specialist). Examples of letter strings that did not sound like words include filce, colesture, and edepust.

The four measures (written orthography, written phonology, orthographic checklist, and phonological checklist) were standardized and summed. The distribution is reported in Figure 3.2.2 below.

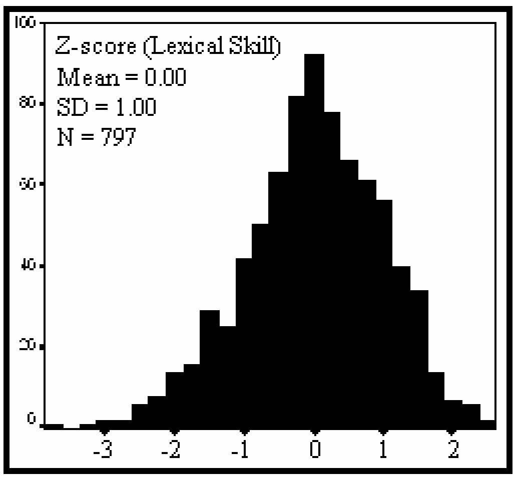


Figure 3.2.2 Histogram of lexical skill scores

Participants were chosen as having good and poor lexical skills as follows. Participants with good lexical skill had to be in the top half of the distribution on the composite score as well as not scoring in the bottom 25% on any one of the tests included in the composite. Participants with poor lexical skill had to be in the bottom half of the distribution on the composite score as well as not scoring in the top 25% on any one of the tests included in the composite. Table 3.2.2 gives the descriptive statistics for participants with greater and less lexical skill on the four subtests included in the lexical skill composite.

Table 3.2.2 Descriptive statistics for subtests included in lexical skill composite. Reported data are Z-scores.

	Less-skilled comp, n = 399			More-skilled comp, n = 398		
	Mean	SEM	Min, Max	Mean	SEM	Min, Max
Phonology checklist hit-fa	-0.55	.047	-3.29, 1.64	0.56	.035	-1.92, 2.25
Orthography checklist hit-fa	-0.55	.040	-2.45, 1.52	0.55	.043	-1.46, 3.17

Phonology – written test	-0.63	.044	-3.61, 1.19	0.63	.033	-1.77, 2.11
Orthography – written test	-0.59	.051	-5.09, 1.26	0.59	.026	-1.09, 1.49

With this division of participants, there were at least 100 participants in each group, as indicated Table 3.2.3. The disproportionate number of participants in the extreme groups – strong or weak on both lexical skill and comprehension – reflects the correlation between comprehension and lexical skill, serving as a reminder as to how important it is to carefully separate these variables when searching for causal factors. Even though the variables have been separated, there remains some regression toward the mean in the diagonal groups – those with one strength and one weakness (see Figure 3.2.3). This regression will need to be considered as an explanation whenever lexical skill and comprehension skill fail to separate in the experimental tasks.

Table 3.2.3 Inclusion of participants into groups

	Not classifiable (Variable performance)	Poor lexical skill	Good lexical skill
Not classifiable (variable performance)	26	61	46
Poor comprehension	53	177	102
Good comprehension	43	101	188

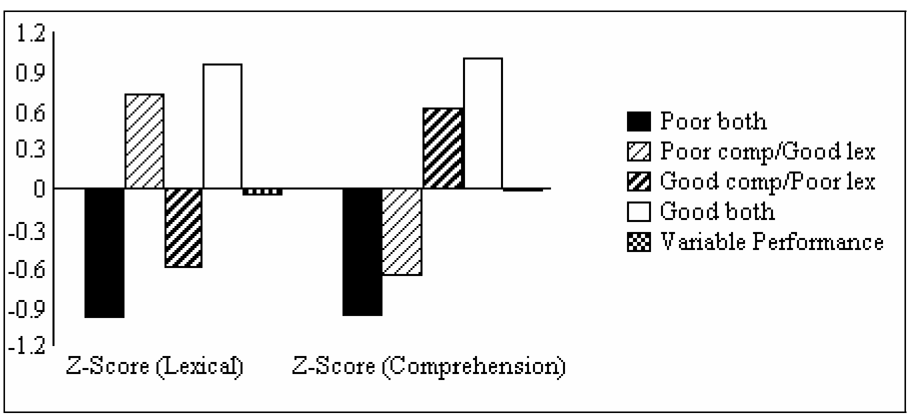


Figure 3.2.3 Lexical and comprehension composite scores for each participant group

3.3. Participant response and participation

Of the 568 participants who qualified for the experiment, response to the initial email invitation (See Appendix A) was fairly good, especially considering that the first invitation went out over the Summer. Initially, the poorest response came from participants with poor comprehension skills but good lexical skills. The initial invitation was resent after the Fall semester began and it was clear that the quota for participants in this group would not be met. No doubt more participants in the other groups would have responded had the initial invitation been resent to them, too.

Table 3.3.1 Number of each participants in each group who responded to the experiment invitation.

	Poor lex	Good lex
Poor comp	36 (20%)	34 (33%)
Good comp	32 (32%)	57 (30%)

These interested participants were sent a follow-up email (see Appendix A) explaining the project in more detail and inviting them to set up an initial invitation. Table shows the response of participants at this time.

Table 3.3.2 Participant response to follow-up information about experiment.

	Poor/poor	Good comp	Good lex	Good/good
Completed experiment	10	11	12	12
Never scheduled appt[5]	11	11	14	38
No-show first appt	6	2	4	1
Dropped out	3	6	0	3
Not interested/can't	5	1	3	3
Other[6]	1	1	1	0

[5] Some participants did not schedule an appointment because of lack of interest, and some (in good lex and good/good groups) were not needed because the quota for participants in their group was met.

[6] The participant in the poor/poor group was run as a pilot participant only, the participant in the good comprehension group was missing data due to experimenter error (he was essentially a second pilot participant, as he was the first real participant run), and the participant in the good lexical group was noncompliant with the experiment instructions. His noncompliance was suspected throughout but not verified until data analysis began.

Here, and throughout this document, statistics are not included in the text. Instead, significant effects are discussed in the text, while the statistics are included in Appendix M to improve text readability. Participants from the poor/poor group were somewhat less likely to indicate initial interest in the experiment than participants in the other groups. Because the good comprehension and good lexical (diagonal) groups had fewer participants than the extreme groups, they were recruited more forcefully and retained in the experiment more often. Participants with better lexical skill and participants with better comprehension skill were more likely to show initial interest and then not schedule an initial appointment than participants with poorer skills. Participants with poor comprehension were more likely to not show up for an initial appointment than participants with good comprehension. Finally, participants with poor lexical skills and participants with good comprehension skills were more likely to drop out of the experiment after they had begun than participants with good lexical skills and participants with poor comprehension skills. Two participants from the good/good group dropped out because they were bored.

3.4. Reading skills of participating participants

Each of the eight tasks that were used to make up the two composite variables contributed significantly to the variance of its composite (See Figure 3.4.1). The largest contributor to the comprehension composite was the vocabulary checklist, followed by the Nelson-Denny comprehension subtest, the Author Recognition Test and the Nelson-Denny vocabulary subtest. None of the variables used to separate lexical skill groups had a significant effect of comprehension skill. The best contributor to the lexical skill composite was the written test phonological score, followed by the written test orthographic score, the phonological checklist and the orthographic checklist. In addition, there was a significant effect of lexical skill for the Nelson-Denny comprehension subtest and a marginal effect of lexical skill for the vocabulary checklist. None of the eight tests had a significant interaction of lexical and comprehension skill.

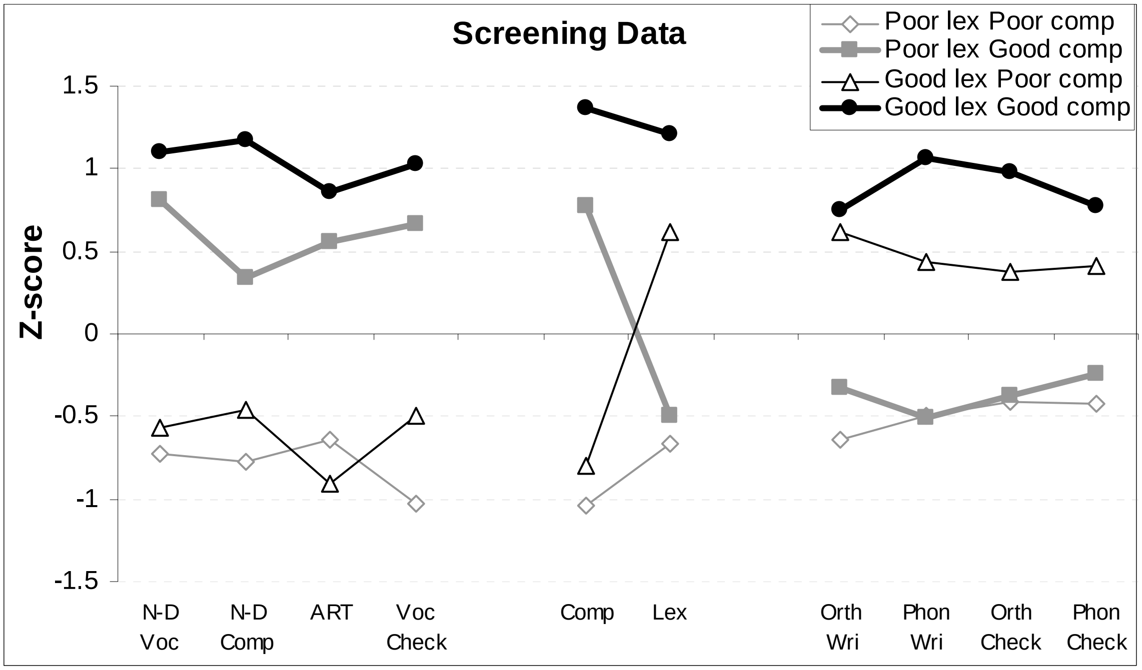


Figure 3.4.1 Screening data and composite scores for each participant group.

There are three reasons to believe that the participant selection is valid. First, the participant selection seems to be representative of the overall population. This is supported by the lack of significant differences between participants who participated in the experiment and those who did not (see Figure 3.4.2). Second, there is a lack of statistical interaction between lexical and comprehension skills. Third, although the differences in scores between the extreme groups and the diagonal groups might indicate a regression to the mean, the diagonal groups are equal to the extreme groups for the low-scoring category. It is only in the high-scoring category that they differ. In other words, participants who are low in lexical skills but high in comprehension skills are just as low as the low/low group in lexical skills; they are just not as high in comprehension skills as the high/high group. The same comparison can be made for the low comprehension skill/high lexical skill group. Nonetheless, there is a possibility that the diagonal groups are actually low-performing participants on one set of tasks who show regression to the mean on the other set of tasks. If results have only main effects of comprehension skill and lexical skill, then regression to the mean is more likely. If there are interactions between comprehension skill and lexical skill, then the diagonal groups are likely more unique categories.

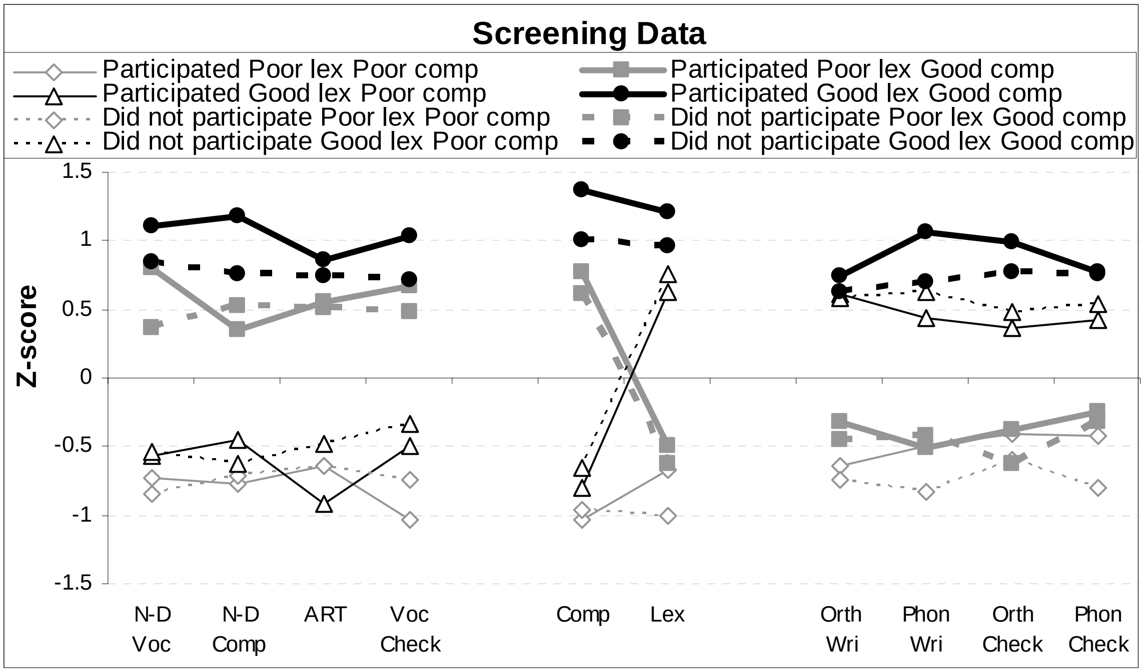


Figure 3.4.2 Screening data and composites for participants and non-participants.

3.5. Language and school histories of participating participants.

During testing after partial training participants filled out a questionnaire regarding their language history, their school performance, their likes and dislikes, and some demographic data. (One participant did not fill out a questionnaire due to experimenter error and participant illness; this participant, in the good lex group, was left out of the analyses.) These data are listed in tables 3.5.1 through 3.5.4.

Table 3.5.1 Second language abilities of participant groups.

Language data: Mean (SEM)	Poor/Poor	Good comp	Good lex	Good/Good
2ond language study (age)	12.10 (.95)	12.80 (.80)	11.92 (1.15)	12.92 (.65)
Highest skill 2ond lang (1-5)^	1.70 (.30)	2.35 (.24)	2.00 (.39)	1.79 (.23)
Average skill 2ond lang (1-5)^	1.60 (.27)	2.30 (.23)	1.80 (.28)	1.61 (.19)
Parents - 2ond lang (0, 1)$^{+}$	0.00 (.00)	0.00 (.00)	0.17 (.00)	0.00 (.00)
Child lang exposure (0, 1)$^{+}$	0.30 (.15)	0.50 (.22)	0.50 (.23)	0.17 (.11)

# high sch 2ond lang classes	1.40 (.16)	1.10 (.10)	1.17 (.11)	1.08 (.08)
# college 2ond lang classes	0.60 (.16)	0.90 (.18)	0.42 (.19)	0.83 (.27)

^ 1 = poor, 5 = good

+ 0 = no, 1 = yes

Participants in this study have remarkably similar language histories. Rarely did a participant study a second language before high school, and only superficially, taking few courses and emerging with a poor proficiency. Only two participants had parents who spoke a second language, and few recalled being exposed to another language during childhood. There was only a marginal interaction of lexical and comprehension skill for average proficiency in a second language. Participants in the extreme groups rated themselves as slightly lower in proficiency than participants in the diagonal groups. This may be due to the groups using different criteria by which to rate their performance; participants in the good/good group would rate themselves more poorly in a second language because their performance would differ more markedly from their performance in their first language.

Table 3.5.2 School histories of participant groups.

School history: Mean (SEM)	Poor/Poor	Good comp	Good lex	Good/Good
Ever told good reader (0, 1)	0.30 (.15)	0.90 (.10)	0.50 (.15)	0.83 (.11)
Ever told bad reader (0, 1)	0.20 (.13)	0.00 (.00)	0.00 (.00)	0.00 (.00)
Ever told good in math (0, 1)	0.60 (.16)	0.60 (.16)	0.67 (.14)	0.50 (.15)
Ever told bad in math (0, 1)	0.10 (.10)	0.00 (.00)	0.17 (.11)	0.33 (.14)
Ever told good in other (0, 1)*	0.50 (.17)	0.80 (.13)	0.75 (.13)	0.67 (.14)
Ever told bad in other (0, 1)	0.30 (.15)	0.50 (.17)	0.33 (.14)	0.42 (.15)

* Other was unspecified, but music and sports were given as examples when requested. Some participants mentioned paying attention and following directions as things with which they were told they had trouble.

Participants who were good comprehenders were more likely to have been told they were good readers than participants who were poor comprehenders. This is remarkable in that both variables of interest are in fact reading variables. “Reading,” as classified by these participants’ teachers or parents, and as recalled by these participants, involves not decoding but comprehension.

Perhaps if they had been asked at age eight or nine, they would have remembered teachers' associating reading with decoding. But as college students, good reading means good comprehension. Participants who were good in lexical skill were marginally more likely to have been told they had a problem with math than participants with poor lexical skill.

Table 3.5.3 Age and year in college averages for participant groups.

Demographics: Mean (SEM)	Poor/Poor	Good comp	Good lex	Good/Good
Age	19.70 (.50)	19.90 (.28)	19.92 (.08)	20.58 (.23)
Year in college	2.10 (.28)	2.80 (.25)	2.83 (.11)	3.08 (.34)

Participants in these four experimental groups did not differ in age, and were only marginally different in years in college. Participants with better lexical skill and with better comprehension skill had been in college for slightly longer (about 1 semester, for each comparison) than participants with poorer skills.

Table 3.5.4 Psychology and language classes of participant groups.

Preferences: Mean (SEM)	Poor/Poor	Good comp	Good lex	Good/Good
Psychology major (0, 1)	0.40 (.16)	0.30 (.15)	0.17 (.11)	0.25 (.13)
Language/related major (0, 1)	0.20 (.13)	0.30 (.15)	0.08 (.08)	0.25 (.13)
Psych as favorite class (0, 1)	0.40 (.16)	0.30 (.15)	0.25 (.13)	0.25 (.13)
Lang as favorite class (0, 1)	0.30 (.15)	0.40 (.16)	0.00 (.00)	0.17 (.11)
Psych as least fav class (0, 1)	0.20 (.13)	0.00 (.00)	0.00 (.00)	0.08 (.08)
Lang as least fav class (0, 1)	0.20 (.13)	0.10 (.10)	0.42 (.15)	0.17 (.11)

Participants with good lexical skills were less likely to have indicated a language class as their favorite class than participants with poor lexical skills. Participants with good lexical skills and poor comprehension skills were more likely to have indicated a psychology class as the one they most disliked than participants in the other three groups. Participants' majors were not related to their experimental group.

3.6. Participants' progress through the experiment

Table 3.6.1 Participants' progress through the experiment.

Exp. Progress: Mean (SEM)	Poor/Poor	Good comp	Good lex	Good/Good
Total days enrolled	23.00 (2.28)	21.09 (1.12)	23.33 (1.08)	18.17 (1.14)
Weekdays skipped	4.00 (1.05)	2.73 (.57)	4.25 (.66)	2.50 (.56)
Weekend days skipped	5.90 (.80)	5.09 (.28)	5.67 (.47)	4.00 (.39)
Multiple sessions/day	0.50 (.31)	0.09 (.09)	0.17 (.11)	0.50 (.19)

Whereas background data did not, for the most part, discriminate groups, their progress through the experiment did. Participants with good comprehension progressed faster through the experiment, skipped fewer weekdays (this means they cancelled and failed to show for fewer appointments), and skipped fewer weekend days (optional days) than participants with poor comprehension. Participants in the extreme groups were more likely to have had multiple sessions scheduled for the same day than participants in the diagonal groups. This is not a participant difference, but an examiner fault; as data collection neared its deadline, a few participants were rushed to finish. Earlier in the more leisurely data collection period, participants were not allowed to schedule more than one session per day. They also were asked to never let more than two consecutive days pass without scheduling an appointment.

3.7. Summary of participant data

In summary, while participants were not completely matched, they were representative of the population as a whole. The slight nonmatching will need to be kept in mind as a possible explanation for any lexical/comprehension interaction effects that may be found. The participants were well matched on age, point in college, and language background. Almost none of the participants spoke another language fluently. Participants with comprehension problems were more likely to report that they had a history of reading problems. Finally, judging by the response rate and the experimental progress, participants were highly motivated to meet the experimental demands. Participants who took longer to get through the experiment also had poorer comprehension. They required extra time to learn the experiment; they were not skipping days when they should have been studying Zekkish.

4. TRAINING

The Zekkish language consists of eight letters, four consonantas and four vowels, but only seven sounds, as one of the vowel sounds is represented by two different letters. Homophones were formed using the phoneme represented by two graphemes. The eight letters were formed into 48 CVC words, none of which was a word in English. Participants spent the first training session learning about the language, learning the letter sounds, and beginning to sound out CVC words not yet paired with meanings (essentially pseudowords).

The 48 words were assigned meanings in a verb/direct object combination. For example, meanings included milking cow, rescuing kitten, and singing karaoke. Participants spent the next two training sessions learning the meanings of the words in 12-word sets to make the task easier. Participants then practiced all 48 words together for 1 to 4 sessions until they were at least 85% correct.

Participants then learned the syntactic structure of Zekkish. There were three alien characters who served as the participant of the sentences (Teb, Dek, and Gep), and each one was assigned 16 words: four low frequency homophones, four high frequency homophones, four low frequency controls, and four high frequency controls. The homophone pairs were always assigned to different characters; this was the basis for homophone interference. Participants learned to read sentences in a verb/DO-Participant structure, and practiced the assignments of characters with words. For example, a sentence might read “Rescuing kitten, Dek” and participants would need to read the sentence right and know that Dek was the one rescuing the kitten.

At this minimal level of proficiency, participants completed the first testing session including written/oral tests and ERPs. They then practiced words in sentences for four more training sessions, and completed the second testing session, again including written/oral tests and ERPs.

The methods section, below, includes the details of the training tasks. The data analysis section describes some of the unique challenges of analyzing these data and the results section includes accuracy and response time data from the training sessions.

4.1. Methods

Training phases were highly regimented.

4.1.1. Phase 0. Comprehension screening.

Over the last three years, more than 1600 Introductory psychology participants have taken a large battery of reading and language screening tests in one or two hour group sessions. From these data, 567 participants were identified as eligible for the Zekkish study. Further information on determination of eligibility is included in the participants section. Participants were recruited via email, and asked to contact the researcher for further information. A first appointment was then scheduled by email or by phone.

4.1.2. Phase 1. Introduction and pretraining.

Six events happened during phase one, all in a single one hour session.

1. Participants read and signed a detailed consent form.
2. Participants listened to the examiner explain the experiment in detail, with emphasis on the time commitment, scheduling, and payment issues.
3. Participants read a computerized introduction to the experiment's cover story, which introduced them to the three Zek characters and the Zekkish language. This information is included in Appendix B.
4. Participants were introduced to the eight Zekkish letters and their sounds by the examiner. The examiner emphasized the differences in shape and size of consonants (small and curly) and vowels (long and straight), and pointed out that two vowels made the same sound. They were also give two examples of mnemonics for remembering the sounds. (The letter that makes the /z/ sound looks like a bumble bee, and the letter that makes the /m/ sound looks like the steam rising from a cup of soup.) In the computer letter training, the computer presented each letter to the participants and played a .wav file with its sound. Participants were then presented with a 1000 ms fixation point, followed by a randomly chosen letter. Response time was presented and the correct sound was played to the participant after a response was given or after two seconds had passed. Participants were then given the prompt "Did you get it right?" and asked to enter 1 for yes and 2 for no. Participants saw "Good Job!" or "Oops! That's okay." for 1000 ms following their response. Trials were repeated until all eight letters had been presented. Participants were then given their average accuracy and response time for the round of trials. Rounds were repeated until participants had completed 12 rounds or had reached 85% accuracy. A minimum of 8 rounds was set to ensure adequate exposure to the letters and their sounds.
5. Participants were introduced to the structure of the Zekkish words by the examiner. The examiner emphasized the cvc structure of the words, the stacked formation of the consonants, and the need to read in a clockwise direction. In the computer decoding training, participants were presented with a 1000 ms fixation point, followed by a randomly chosen word. Response

time was presented and the correct word pronunciation was played to the participant after a response was given or after six seconds had passed. Participants were then given the prompt "Did you get it right?" and asked to enter 1 for yes and 2 for no. Participants saw "Good Job!" or "Oops! That's okay." for 1000 ms following their response. Trials were repeated until 16 of the total 48 words had been presented. Participants were then given their average accuracy and response time for the round of trials. Rounds were repeated until participants had completed 20 rounds or had reached 85% accuracy. A minimum of 12 rounds was set to ensure adequate exposure to the decoding process. At this time frequency levels and meanings had not yet been applied to the words.

6. Participants made an appointment for the next training session. A great deal of effort was made to keep the time between appointments constant. Participants were asked not to schedule more than one session in a day (and ideally to skip a day in between sessions), and to not let more than two days pass between sessions. This was usually possible. Scheduling data are presented in the participants section.

4.1.3. Phase 2. Introduction to Vocabulary.

Three events happened during each of two 1.5 hour sessions in phase two.

1. During computer vocabulary training, the computer presented twelve new vocabulary words to the participant (3 high frequency homophones, 3 low frequency homophones – the counterparts to the high frequency homophones, 3 high frequency controls, 3 low frequency controls) and played a .wav file with its sound. The computer then displayed a picture representing the meaning of that word, and played a .wav file of its two-word meaning (verb, direct object). Words (in sentences), their translations and the associated pictures are shown in Appendix C. Participants were then presented with a 1000 ms fixation point, followed by a randomly chosen word from the set of twelve. Response time was presented and the correct sound was played to the participant after a response was given or after two seconds had passed. A line appeared on the screen prompting participants to respond with the word's meaning. The picture representing the meaning was then presented along with the .wav file. Participants were then given two prompts: "Did you read the word right?" and "Did you get the meaning right?" and asked to enter 1 for yes and 2 for no for each. Participants saw "Good Job!" or "Oops! That's okay." for 1000 ms following each response. Trials were repeated until all twelve words had been presented. Participants were then given their average accuracy and response time for the round of trials. Rounds were repeated until participants had completed 12 rounds or had reached 85% accuracy. A minimum of 8 rounds was set to ensure adequate exposure to the vocabulary words.

2. The procedure outlined in event 1 was repeated with a new set of twelve vocabulary words. The four sets of vocabulary words were presented within reading groups in a Latin Square design.
3. Participants made an appointment for the next testing session.

4.1.4. Phase 3. Vocabulary Competence.

Two events happened during each of one to four 1.5 hour sessions in phase three.

1. Participants repeated the vocabulary training as in Phase 2, with three alterations. First, the meanings of the words were not reviewed at the beginning of the computer program. Second, all 48 words (96 trials, accounting for frequency differences) were presented during each round. Third, participants completed three rounds regardless of accuracy. If participants reached 85% accuracy on any of the three rounds, they proceeded to phase 4. If not, they repeated phase three until they reached a maximum of four sessions. Only two participants had difficulty reaching the 85% cutoff by session 4; both had poor lexical skill and poor comprehension skill. With both, it was obvious by the end of session 3 that they would not reach the 85% cutoff. They were given printouts of the words and their meaning pictures to review overnight, and both subsequently reached the 85% cutoff.
2. Participants made an appointment for the next training session.

4.1.5. Phase 4. Grammar Training.

Three events happened during this 1.5 hour session.

1. Participants received information on the grammatical structure of Zekkish from the examiner. The examiner emphasized the two-word format of Zekkish sentences, the verb-direct object-participant structure of the sentences, and the need to associate the Zek character with the verb/object. The association was necessary in order to read the sentences right, and to perform at an adequate level on subsequent testing (which relied heavily on this association). Note that this is not their first association of word and character. In each picture representing word meaning, there is one and only one character who acts out each verb. For example, in the picture "rescuing kitten," Dek (the yellow Zek with glasses) is doing the rescuing each time.
2. Participants repeated the vocabulary training as in Phase 3, with two alterations. Instead of being asked "Did you read the word right?" participants were asked "Did you get the character name right?" And participants completed only one grammar training session.
3. Participants made an appointment for the first testing session.

By this time, participants had encountered each low frequency word and its meaning a minimum of 14 times, and a maximum of 27 times. They had encountered each high frequency word and its meaning a minimum of 56 times and a maximum of 108 times.

4.1.6. Phase 5. Testing after partial training.

These testing sessions were three hours long. Often, participants scheduled two 1.5 hour blocks, completing behavioral tasks at one session and ERP tasks at another session. Three events happened during this phase.

1. Participants completed a battery of computerized and paper-and-pencil reading tasks in Zekkish and English. Included was a questionnaire about the participants' experience with languages.
2. Participants completed six reading, visual, and interference ERP tasks in Zekkish and English.
3. Participants made an appointment for the next training session.

4.1.7. Phase 6. Acquisition of Experience.

Two events happened at each of four one hour sessions.

1. Participants repeated vocabulary training as in phases three and four, completing two rounds from phase 3 (vocabulary competence, without the grammatical requirements) and one round from phase 4 (grammar training, ensuring knowledge of character-word associations).
2. Participants made an appointment for the next testing session.

By this time, participants had encountered each low frequency word and its meaning a minimum of 26 times, and a maximum of 39 times. They had encountered each high frequency word and its meaning a minimum of 104 times and a maximum of 156 times.

4.1.8. Phase 7. Testing after experience.

These sessions were three hours long and often split into two 1.5 hour sessions. Three events happened during this phase.

1. Participants completed a batter of computerized and paper-and-pencil reading tasks in Zekkish and English. Included was a questionnaire about the participants' experience during the Zekkish experiment. Email or home addresses were collected so participants could be sent a summary of experimental findings if they desired.
2. Participants completed six reading, visual, and interference ERP tasks in Zekkish and English.
3. Participants were paid for their participation (If phase 8 was already completed).

4.1.9. Phase 8. Modern Language Aptitude Test (MLAT).

The MLAT was given in a one hour session, scheduled at any time during the training period. Many participants opted to postpone the MLAT until after the test point after complete training; these participants were paid after completing the MLAT.

4.2. Data analysis

There were many challenges to analyzing the training data. Because these data span the period from when participants were completely inexperienced to when they were completely experienced, there is a large variability in response time, as well as many trials for which there is no response at all. Some of the "no" response data are due to participants' difficulties with the use of the microphones. For example, during one week of data collection, three microphones got increasingly less sensitive and finally quit working all together. It was not until the end of the week that one participant pointed out that none of her responses were being recorded. Another mentioned it at a later testing period. Thus care had to be taken to be sure that response time data were accurate representations of participants' performance. This was accomplished by routinely looking for outliers, and for participants who had few to no acceptable RTs in several conditions. In cases for which lack of RTs was traceable to inaccuracy, data were replaced by cell means. When there was clearly a microphone error, participants were dropped from the analysis. The dropped data did not appear to be related to lexical skill or comprehension skill. Details of data trimming are reported in Appendix L.

In addition to microphone difficulties and "no response" trials, participants were on the honor system to indicate the accuracy of their answers. There were a variety of ways the honor system was enforced. Participants were informed at the beginning of the experiment that payment was not based on performance, and that honesty was valued above high scores. Participants .were led to believe that all responses were being recorded by the computer. Routinely, a tape recorder was placed in the room during testing, as a "quality control backup." And finally, the examiner occasionally listened in to ensure that participants were actually participating and accurately recording responses. Response time and accuracy patterns indicate that participants were complying with the instructions. Participants occasionally even checked in with the examiner to ensure that they were correctly recording their responses, and even commented on the examiner's likely lack of sleep after reviewing all those tapes and computer files.

Finally, the training data are extremely complex, involving homophony, frequency, training time, letter, word, meaning, and sentence information, accuracy and response time, lexical skill and comprehension skill, two arrangements of word-meaning pairings, and four orders of word presentations. To deal with the complexity of the data, analyses were done in stages. Data from each phase were analyzed in full, while data across the course of the training phases were analyzed using averages across lexical information. The results section discusses significant effects, while statistics are reported in Appendix M.

4.3. Results

4.3.1. Phase 1a: Letter learning.

The purpose of the letter learning task was to familiarize participants with the letter sounds before they were introduced to the letters within words. During the computerized letter learning task, participants were presented with letters in isolation and asked to say the letter sound into the microphone. The computer then played the correct sound and participants recorded their accuracy. Letter sets were repeated a minimum of eight times or until participants reached 85% accuracy for a maximum of 12 times. Data are shown in Table 4.3.1 and in Figure 4.3.1. Participants with good lexical skill took 8.5 rounds to reach 85% accuracy, while participants with poor lexical skill took 9.1 rounds. The effect was larger for participants who also had poor comprehension (although the interaction is not significant). Participants became faster and more accurate across the eight rounds. Participants with good lexical skill were more accurate (with poor/poor participants being the least accurate) than participants with poor lexical skill, while participants with good comprehension skill were faster than participants with poor comprehension skill.

Table 4.3.1 Number of cycles to 85% accuracy criterion during letter learning.

Mean (SE)	Poor comprehension	Good comprehension
Poor lexical skill	9.40 (.60)	8.91 (.39)
Good lexical skill	8.33 (.14)	8.64 (.35)

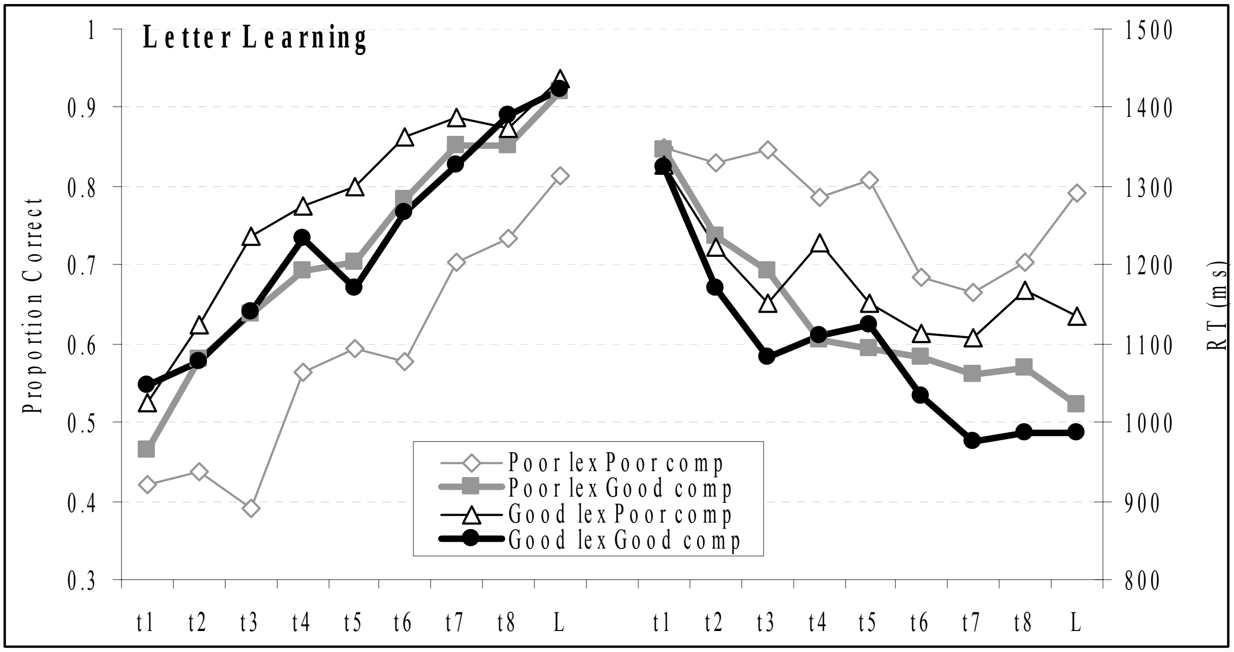


Figure 4.3.1 Accuracy and Response Time across the eight rounds of letter learning. L indicates the last round completed by the participant.

4.3.2. Phase 1b: Decoding.

The purpose of the decoding session was to provide participants with practice sounding out words before they were also required to complete the simultaneous task of comprehending the words' meanings. During the computerized decoding task, participants were presented with words (as yet unassociated with meanings) and asked to read them into the microphone. The computer then played the correct word and participants recorded their accuracy. Sets of twelve words were repeated a minimum of twelve times or until participants reached 85% accuracy for a maximum of 20 times. Data are shown in Table 4.3.2 and in Figure 4.3.2. Participants with poor comprehension skill and poor lexical skill take 14.2 rounds to reach 85% accuracy, while participants in other groups take about 12.4 rounds. Participants got faster and more accurate over rounds. Participants in the poor/poor group took slightly longer to reach an accuracy asymptote than other groups; this significant accuracy effect is echoed in the marginal effect of rounds to 85% accuracy criterion. Participants with good lexical skill tended to be faster and more accurate overall than participants with poor lexical skill, while participants with good comprehension skill were faster for rounds after the first set of four than participants with poor comprehension skill.

Table 4.3.2 Number of cycles to 85% accuracy criterion during decoding.

Mean (SE)	Poor comprehension	Good comprehension
Poor lexical skill	14.20 (1.02)	12.27 (0.14)
Good lexical skill	12.33 (0.22)	12.58 (0.58)

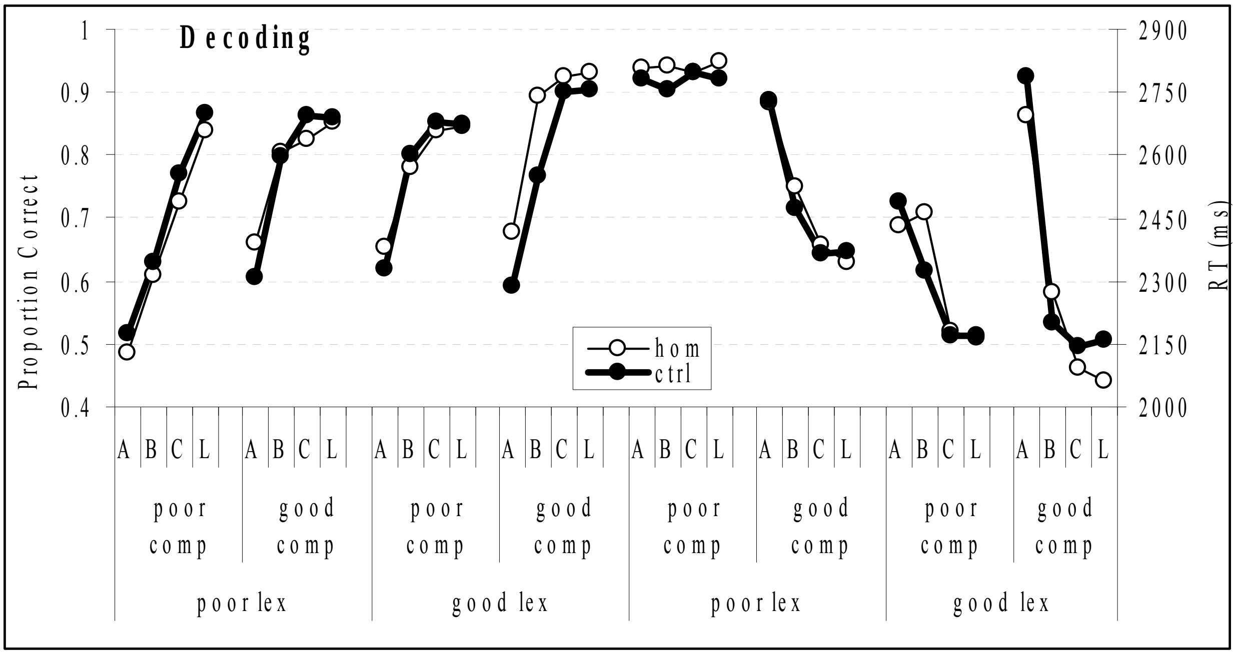


Figure 4.3.2 Accuracy and response time for the decoding task. Times A, B, and C represent rounds 1-4, 5-8, and 9-12, while L represents the last round completed.

4.3.3. Phase 2: Vocabulary Learning.

The purpose of the vocabulary learning task was to introduce vocabulary words to participants slowly, so as to not overwhelm them. During the computerized vocabulary learning task, participants were presented with words and asked to read them into the microphone, and then a second prompt to speak the word's meaning into the microphone. The computer then played the correct word and showed the picture representing its meaning. Participants recorded their accuracy for spoken and meaning responses separately. Sets of twelve words were repeated a minimum of eight times or until participants reached 85% accuracy for a maximum of 12 times. Data are shown in Figures 4.3.3 and 4.3.4.

Spoken responses: Participants grew faster and more accurate with training, and were more accurate for high frequency words than for low frequency words (although more accurate only in the first two sets of rounds). Participants were more accurate for low frequency controls than for low frequency homophones. For response time, the frequency/homophony interaction was more pronounced: while there was a frequency difference only for controls, participants were slower for controls than for homophones for low frequency words, and were faster for controls than for homophones for high frequency words. Participants with good lexical skill were faster than participants with poor lexical skill, and the difference between the groups became greater across the training period.

Meaning responses: Participants grew faster and more accurate with training, and were faster and more accurate for controls than for homophones (this effect increased with training, and was larger for low frequency words than for high frequency words) and for high frequency words than for low frequency words (this effect decreased with training, especially for high frequency words). Participants with good lexical skill were more accurate than participants with poor lexical skill. Good comprehenders were more accurate than poor comprehenders for low frequency words, but not for high frequency words. Participants with good lexical skill were faster than participants with poor lexical skill.

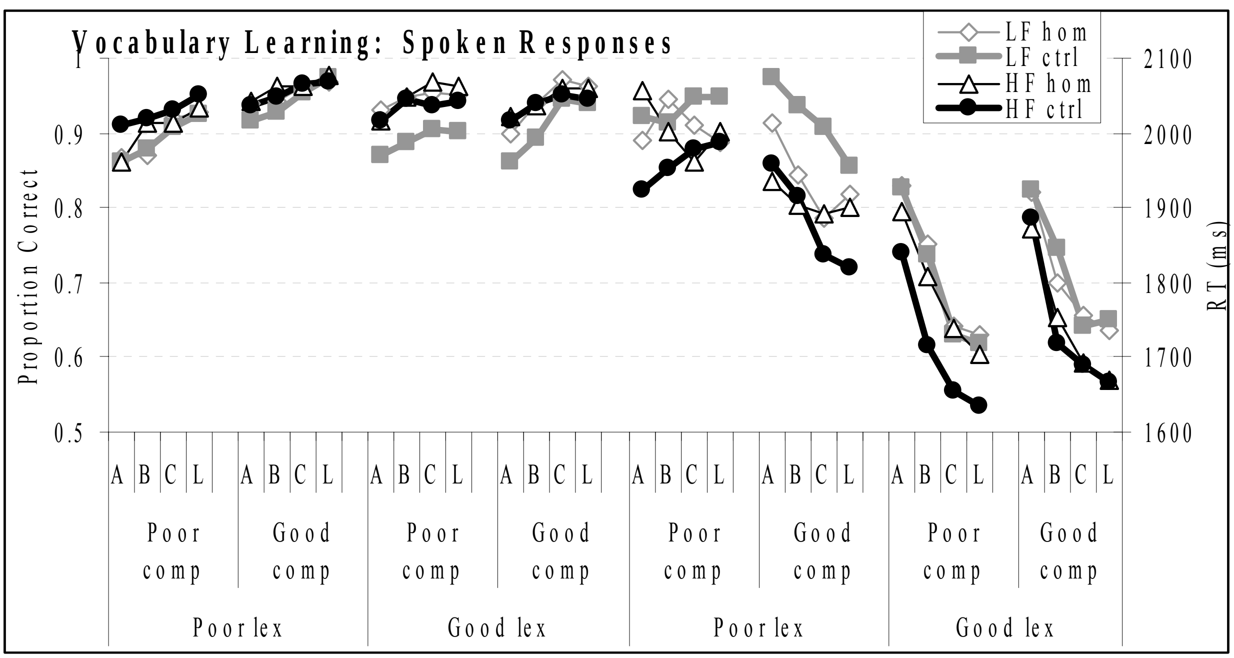


Figure 4.3.3Accuracy and RT of spoken responses during vocabulary learning. Times A, B, C, and L represent rounds 1-2, 3-4, 5-6, and the last two rounds.

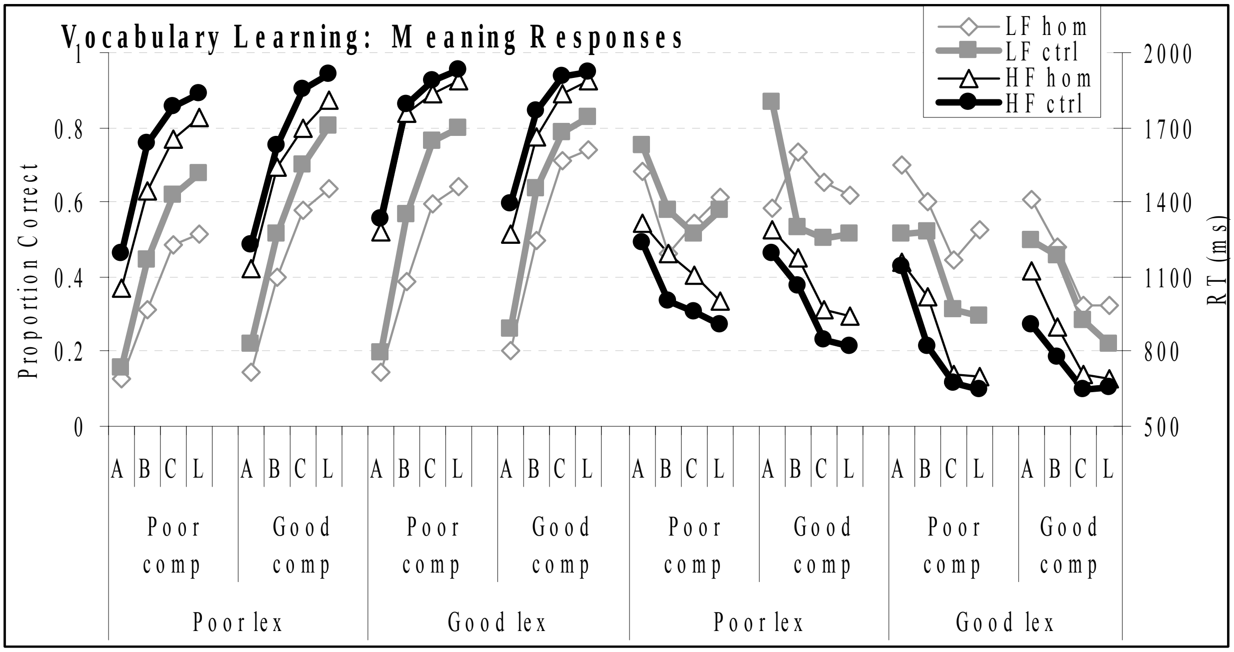


Figure 4.3.4 Accuracy and RT of meaning responses during vocabulary learning. Times A, B, C, and L represent rounds 1-2, 3-4, 5-6, and the last two rounds.

4.3.4. Phase 3: Vocabulary Competence.

The purpose of the vocabulary competence task was to increase participants' accuracy of vocabulary knowledge, but only to a minimum requirement so that participants would still be considered novices and performance would likely still be fairly effortful. During the computerized vocabulary competence task, participants were presented with words and asked to read them into the microphone, and then at a second prompt to speak the word's meaning into the microphone. The computer then played the correct word and showed the picture representing its meaning. Participants recorded their accuracy for spoken and meaning responses separately. Participants saw all 48 words in each of three rounds. This session was repeated until participants reached 85% accuracy for a maximum of four sessions. Data are shown in Figures 4.3.5 and 4.3.6.

Spoken responses: participants generally had very high levels of accuracy for spoken word identification. This is because by this phase of training they have had a great deal of practice simply reading the words. The diagonal groups (high on one skill and low on the other) continued to be more accurate for high frequency words than for low frequency words. All participants continued to get faster with training. While all participants were faster to high frequency words than low frequency words initially, participants with good lexical skill managed to overcome much of their low frequency disadvantage with repeated training sessions while participants with poor lexical skill did not. Participants with good lexical and comprehension skill showed sensitivity to homophones than did other groups, with their response time to homophones faster (and more accurate, for low frequency items) than their response time to controls.

Meaning responses: Because this was the first time participants saw all 48 words together, their accuracy for meaning responses was initially much lower. Because they had some lead time (during the time of the spoken response), their meaning response times were actually faster than their spoken response times. However, the experimental effects were still very large, and effects of reading group actually only show up in response time, and not in accuracy. Participants became faster and more accurate with training. They were faster and more accurate for high frequency words than for low frequency words, and more accurate for controls but faster for homophones, especially low frequency controls and homophones.

Participants with good lexical skill were faster than participants with poor lexical skill. There was a tendency for poor comprehenders to have larger homophone-control differences for response time than good comprehenders. A marginal interaction of training and comprehension skill showed that at time A, poor comprehenders were faster than good comprehenders; at all other time points, good comprehenders were faster than poor comprehenders

There is a marginal three-way interaction that shows that while there was always a homophone-control difference for low frequency words and that it builds with training, there is initially a difference for high frequency words that quickly disappears with training. This interaction is shown in Figure 4.3.7.

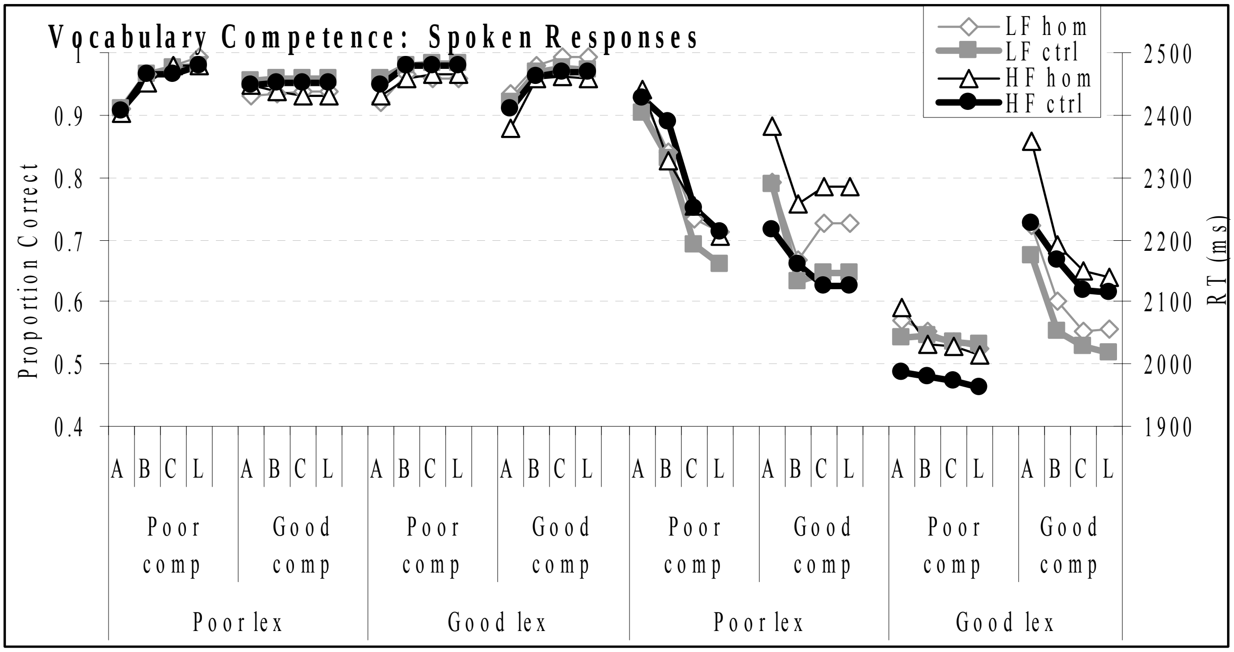


Figure 4.3.5 Accuracy and RT of spoken responses during vocabulary competence. Times A, B, C, and L represent days 1, 2, 3, and 4.

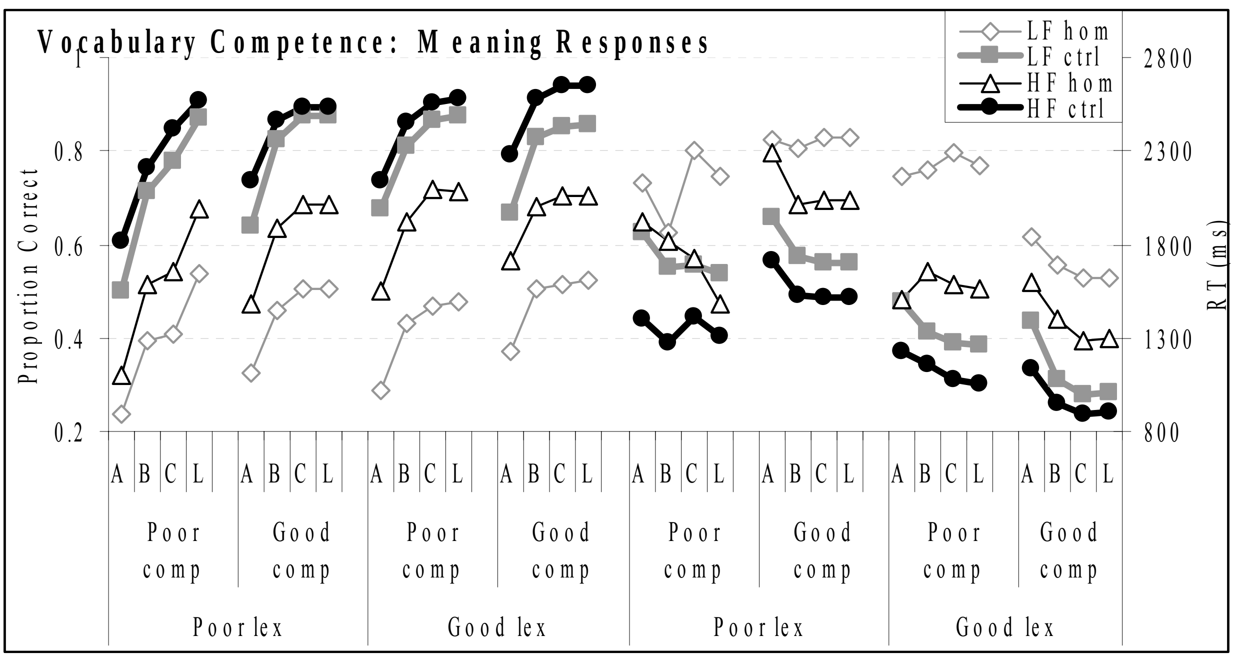


Figure 4.3.6 Accuracy and RT of meaning responses during vocabulary competence. Times A, B, C, and L represent days 1, 2, 3, and 4.

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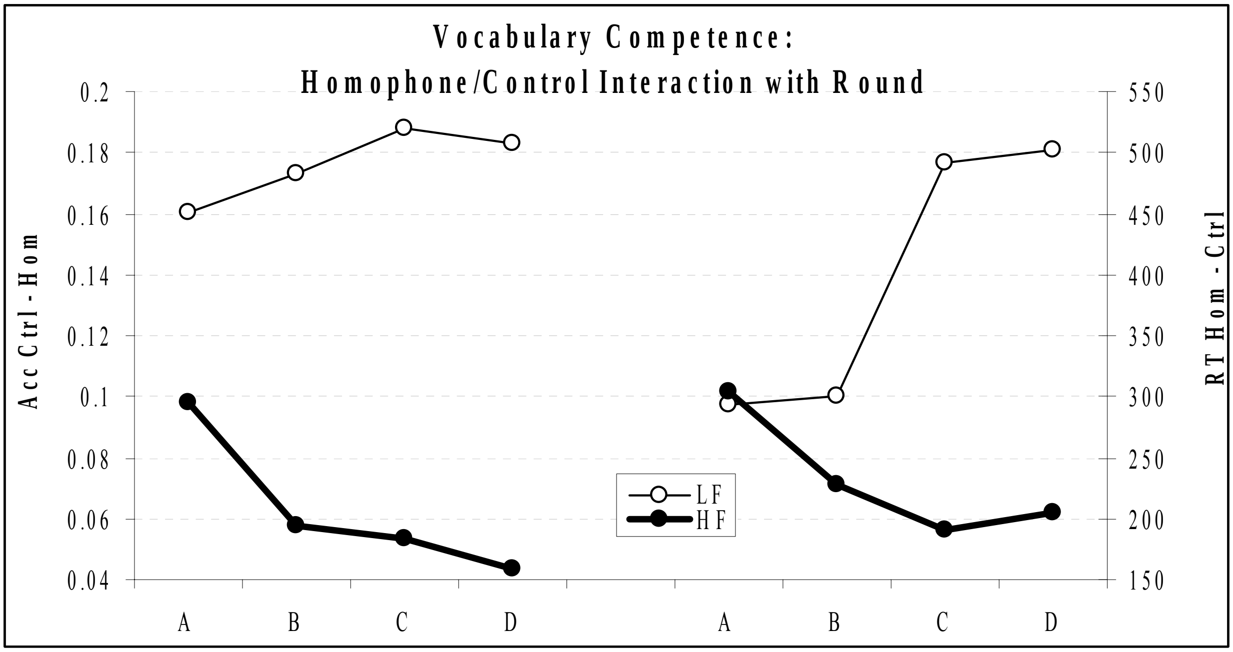


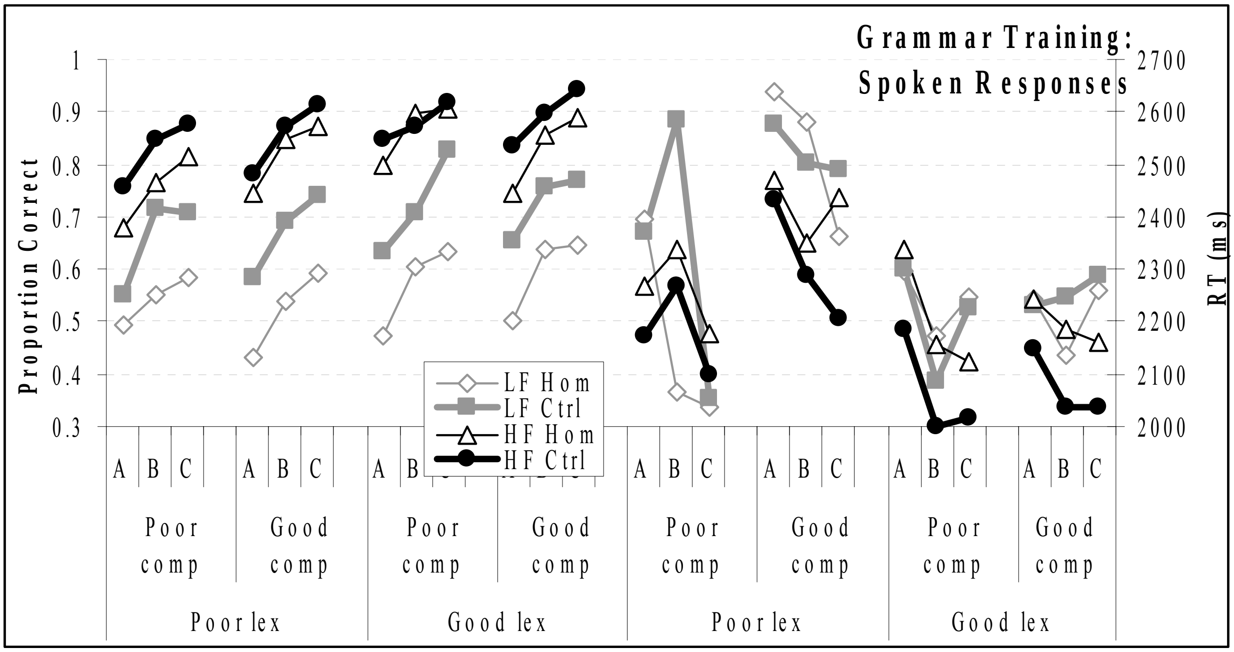
Figure 4.3.7 The interaction of homophony, frequency, and time for meaning responses during vocabulary competence training.

4.3.5. Phase 4. Grammar Training.

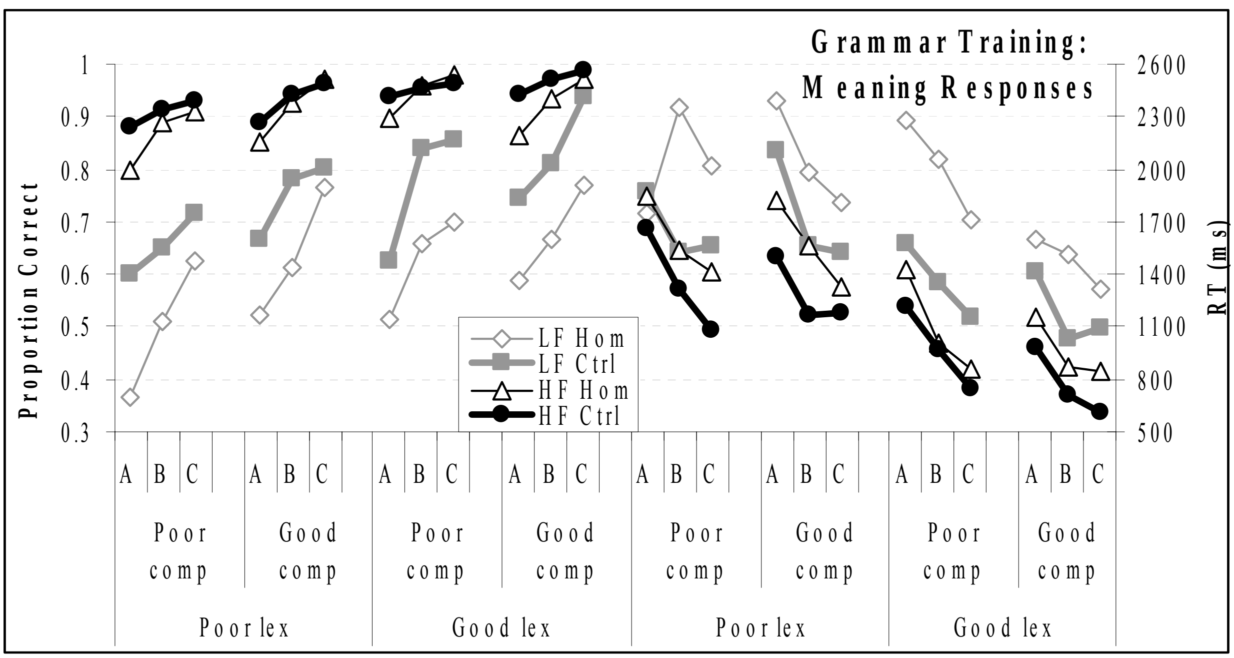
The purpose of the grammar training session was to introduce participants to the grammatical structure of the sentences and to more adequately relate the Zekkish character (sentence participant) to the Zekkish word (sentence verb/direct object). Data are shown in Figures 4.3.8 and 4.3.9.

Spoken responses: participants became more accurate with training. They were faster for high frequency words than for low frequency words. They were more accurate for controls than for homophones when the words were of low frequency, but faster for controls than for homophones when the words were of high frequency. Participants with good lexical skill show a homophone-control difference by round 1, while participants with poor lexical skill do not show the difference until round 2.

Meaning responses: participants became faster and more accurate with training, especially for low frequency words versus high frequency word sand marginally for homophones versus controls. They were faster and more accurate for high frequency words than for low frequency words and for controls than for homophones. Homophone-control differences were bigger for low frequency words than for high frequency words. Participants with better lexical skill and participants with better comprehension skill were more accurate than less skilled participants. The poor/poor group was late to show homophony and frequency effects in response time; the other groups showed effects during round one, while the poor/poor group did not until round two.



<u>Figure 4.3.8</u> Accuracy and RT of spoken responses during grammar training. Times A, B and C represent rounds 1, 2 and 3.



<u>Figure 4.3.9</u> Accuracy and RT of meaning responses during grammar training. Times A, B and C represent rounds 1, 2 and 3.

4.3.6. Phase 6. Acquisition of Experience.

The purpose of the acquisition of experience session was to increase the number of exposures participants had to the vocabulary words and their Zek pairings to automatize as much as possible the activation of the Zekkish lexical item. Data are shown in Figures 4.3.10 and 4.3.11.

Spoken responses: participants became faster and more accurate with training. They were faster and more accurate for high frequency words than for low frequency words, and for homophones than for controls, especially when the words were of low frequency. Participants with good lexical skill were faster than participants with poor lexical skill, but less and less so from day one to day four. Participants with good lexical skill show sensitivity to frequency earlier than participants with poor lexical skill.

Meaning responses: participants became faster and more accurate with training. They were faster and more accurate for high frequency words than for low frequency words and for controls than for homophones, especially for low frequency words. Participants with better lexical skill and participants with better comprehension skill were more accurate, especially for low frequency words (with participants less-skilled in both being the least accurate overall). Participants with good lexical skill were faster than participants with poor lexical skill. Participants with poor lexical skill showed bigger homophone-control differences in speed for high frequency words, while participants with good lexical skill showed bigger homophone-control differences in speed for low frequency words. Differences were greater on day 1 than they were on subsequent days.

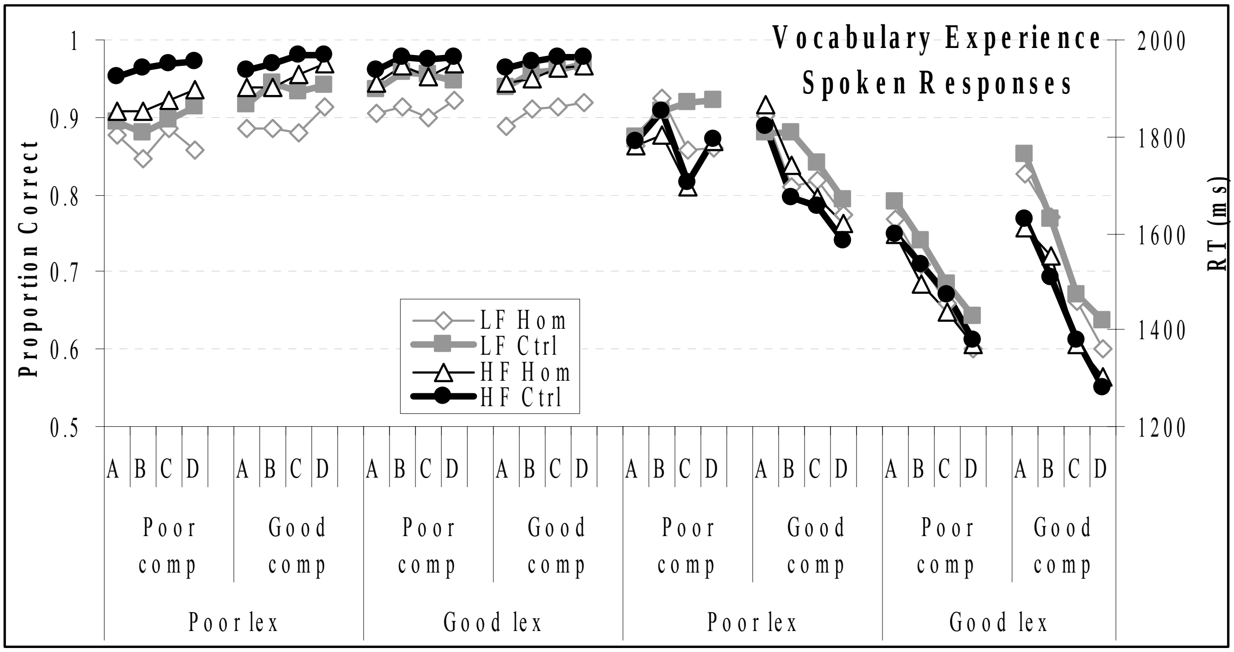


Figure 4.3.10 Accuracy and RT of spoken responses across the training period during acquisition of experience. Letters A, B, C, and D are days 1, 2, 3, and 4, respectively.

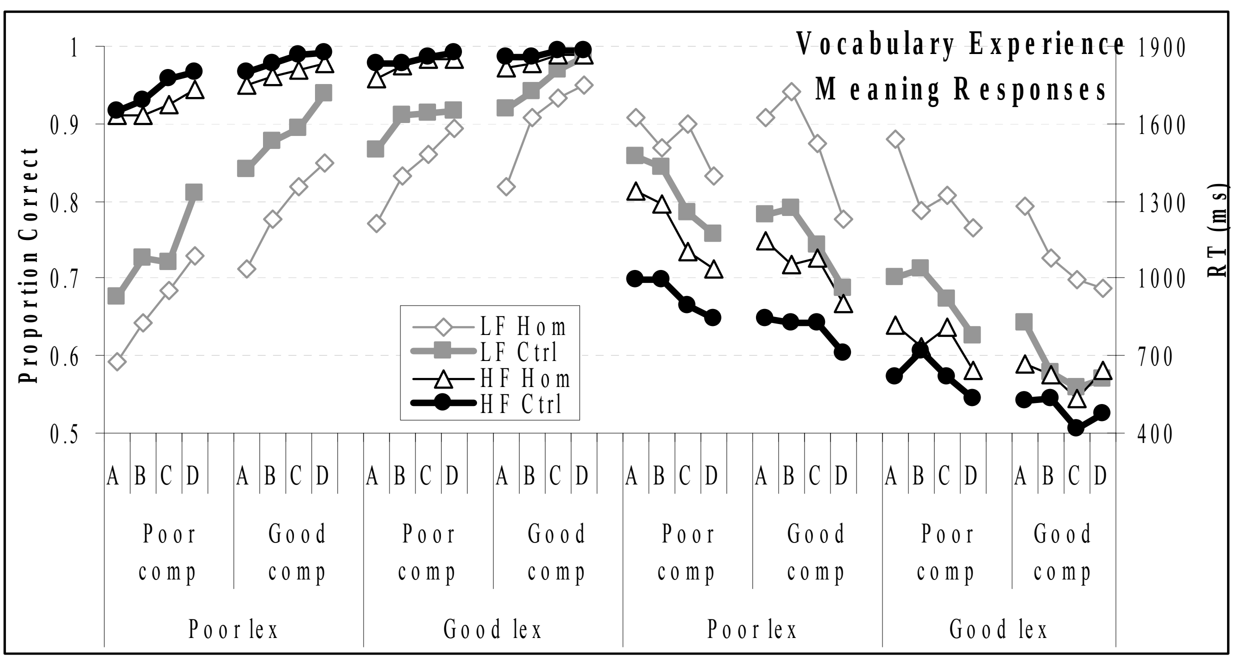


Figure 4.3.11 Accuracy and RT of meaning responses across the training period during acquisition of experience. Letters A, B, C, and D are days 1, 2, 3, and 4, respectively.

4.3.7. Behavioral patterns across phases.

In order to examine participants' general success during the training phase of the experiment, data from each training phase were reduced to two points representing the beginning and the end of the training phase. For letter learning, the first three rounds and the last three rounds were averaged. For decoding, the first four rounds and the last four rounds were averaged. For vocabulary learning, the first two rounds and the last two rounds were averaged. For vocabulary consolidation, the first day and the last day were compared. For grammar training, the first round and the last round were compared. For vocabulary experience, the first day and the last day were compared. Accuracy and response time variables were standardized, and the distribution was inverted for response time. Response time and accuracy were then summed and the resulting variable was restandardized. The distribution of the final variables are shown in Figures 4.3.12. Higher scores indicate better performance.

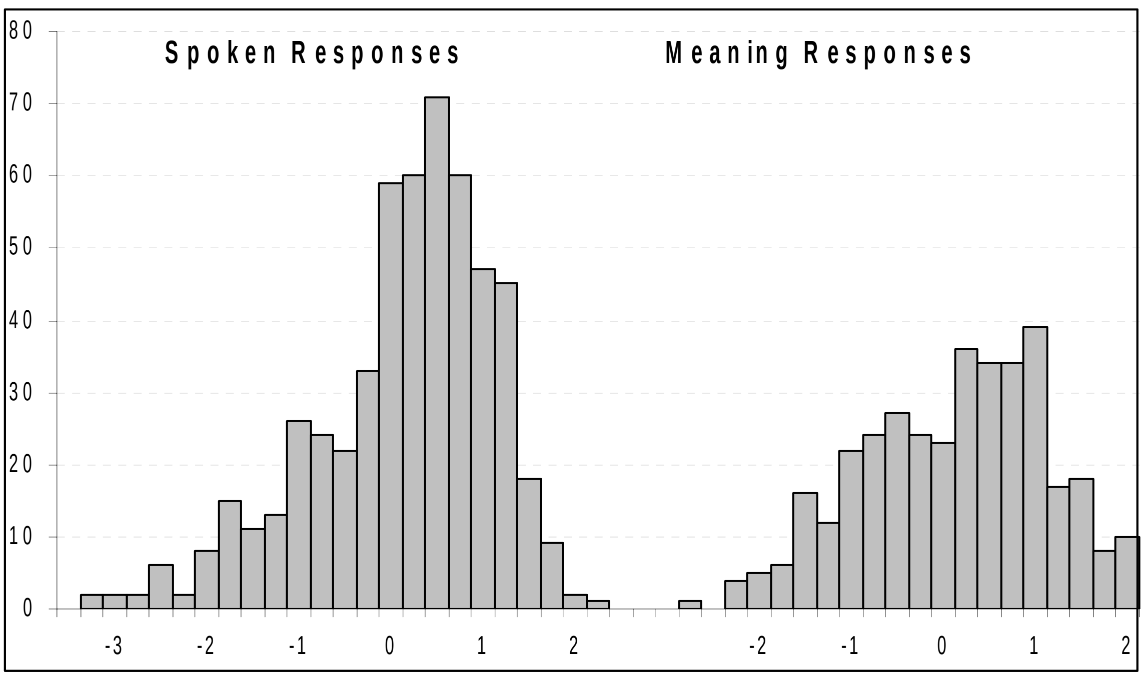


Figure 4.3.12 Distribution of spoken responses and meaning responses across the training procedure.

Recall that some phases of the experiment involved two steps – word identification and meaning identification. These two steps were handled as separate variables. Two ANOVAs were run on the resulting data set. For letter-word identification, the ANOVA included the within participants variables of test point (beginning and end) and training phase (six levels), and the between participants variables of lexical skill and comprehension skill. For meaning identification, the ANOVA was identical except that the training phase only included four levels. Data for participants with completely missing data were replaced by cell means for this analysis.

Data are shown in Figures 4.3.13 and 4.3.14.

Spoken responses: Changes in phase scores indicate that as participants were challenged by new and harder tasks, their performance varied accordingly. New tasks were introduced during letter, decode, and grammar (critter) stages; each time, performance showed a large increase from the first time point to the last. That there was a main effect of test point indicates that they did learn the skill being taught. Only lexical skill in English affected participants' learning of Zekkish word identification. English comprehension skill did not transfer.

Meaning responses: Changes in phase scores indicate that participants were challenged by new and harder tasks. Unlike the word identification part of the tasks, the knowledge being measured by vocabulary identification is the same across tasks. The conjunction of increasing phase scores and significant time point scores indicates that participants applied the knowledge gained from one phase to the next phase they began. The reason participants improved so much from beginning to end during vocabulary learning is because participants only studied 12 words at a time. In the other phases, they had all 48 words. Thus, performance did not reach a ceiling until the end of the experience phase, and there was room for participants to continue to improve throughout the course of their practice with 48 words. Only lexical skill in English affected participants' learning of Zekkish vocabulary. English comprehension skill did not transfer.

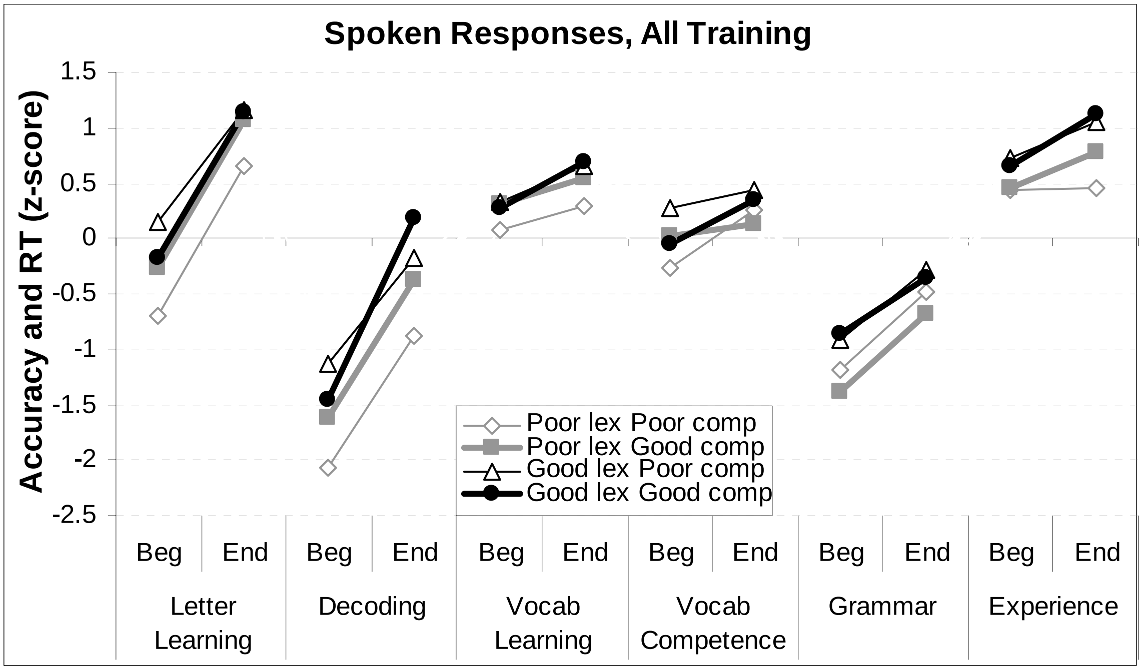


Figure 4.3.13 Summary data of spoken responses across the training procedure.

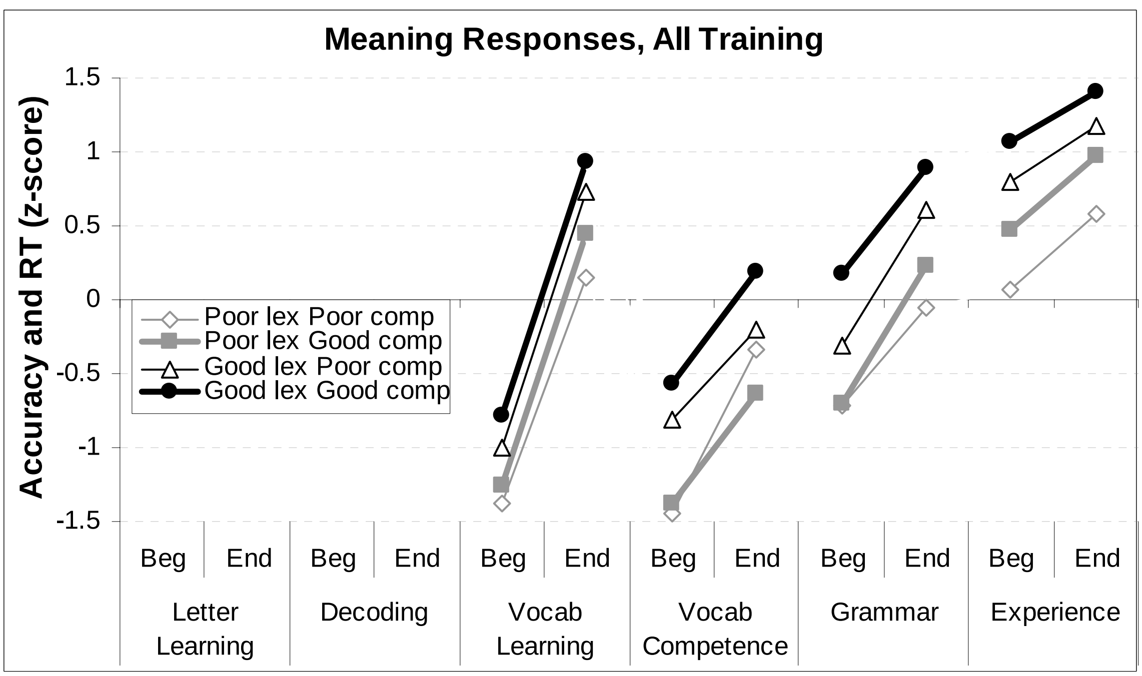


Figure 4.3.14 Summary data of meaning responses across the training procedure.

4.4. Discussion

1. Participants grew faster and more accurate with training. The main effect of training was significant for speed and/or accuracy (and usually both) at each stage of training, for both spoken and meaning responses. When it was not significant, it was because the skill carried over from the previous phase. During vocabulary competence, participants were highly skilled in spoken responses, and were faster with training, but no more accurate. During grammar training, participants were highly skilled at both spoken responses and meaning responses. Their learning at this phase was for the ends of spoken sentences (the character name was added to make a sentence); they began to speak as quickly as they had in the previous phase. Only accuracy improved with training, as the participants learned the word-character pairings. In all other phases both speed and accuracy improved with training. Final accuracy levels were very high, and final speeds were very fast, indicating some degree of automaticity to reading and understanding the Zekkish language.

2. Lexical skill affected participants' learning curve and performance. Participants with good lexical skill required fewer cycles to reach criterion in the initial exercise of letter learning than participants with poor lexical skill. Participants with good lexical skill were faster and/or more accurate in all phases of training, for both spoken and meaning responses, than participants with poor lexical skill. In addition, lexical skill was the source of three very important interactions.

First, the effects of lexical skill decreased across the training period during the experience phase of training; that is, when provided with enough practice, participants with poor lexical skill had time to catch up to those with good lexical skill. It is particularly of note that they did not begin to catch up until after test data were collected after partial training.

Second, participants with poor lexical skill caught up more rapidly for high frequency words than for low frequency words.

Third, participants with poor lexical skill showed a homophone effect for high frequency words, and participants with good lexical skill showed a homophone effect for low frequency words.

The reasoning behind lexical effects is thus. Lexical quality is built from experiencing words, building the efficiency with which they can be activated and the strength of the activation. Low frequency words, because they are encountered less often during reading, have lower quality lexical representations. Participants with poorer lexical skill build up lexical quality more slowly.[7]

[7] Why? Probably due to many reasons, all causing problems with the contingency of activation of the constituents of a lexical representation: orthography, phonology, and semantics. The strength of a connection between neurons is increased when the neurons are coactivated. This is Hebb's rule (Kandel, Schwartx & Jessell, 1991). Participants with poorer lexical skill may have a poorer grasp of grapheme-phoneme correspondences, leading to

As a result, participants with poorer lexical skill have too much variability in activation (and response times subsequent to the activation) of low frequency words for homophone effects to show up. The lexical quality of high frequency words for participants with poor lexical skill and the lexical quality of low frequency words for participants with good lexical skill are at the correct intermediate level for homophone interference to occur. High frequency words for participants with good lexical skill are protected from interference because of their very high lexical quality. There is no time for interference to occur before a lexical entry reaches sufficient unique activation on which a response can be based.

The interaction of skill and frequency replicates the effect reported in Perfetti & Hart (2000). The inclusion of lexical skill as a between participants variable in the current experiment was instrumental in explaining the interaction of skill and word frequency found in Perfetti & Hart (2000). That experiment divided participants on comprehension skill but not lexical skill, and the inference was made that comprehension skill was derived from lexical skill. While true, dividing participants by lexical skill is more direct, and dividing participants by both lexical skill and comprehension skill allows the effect to be isolated. In the Perfetti & Hart experiment, it is likely the shared variance of lexical and comprehension skill that led to the interaction with frequency, and not the unique variance of comprehension skill. The unique variance of comprehension skill is explained below.

3. Comprehension skill affected participants' performance less than lexical skill. In letter learning and decoding, participants with good comprehension were faster than participants with poor comprehension. In the four phases involving meaning responses, participants with good comprehension skill were more accurate than participants with poor comprehension skill, on meaning judgments only. These effects were greater for low frequency words.

While not as broad as the effects of lexical skill, comprehension skill was important at some stages of training. Early in training, comprehension effects could be due to a faster orientation to the expectations of the experimenter and the response needs of the experiment, and to a better grasp of experiment instructions. (This explanation could also explain why participants with poor lexical skill were particularly likely to require more training to reach criterion if they also had poor comprehension skill.) Later in training, the additional effect of a basic skill in incorporating new

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slower word reading overall. Participants may have a particular difficulty with one of the constituents. Changing the coactivation of the neurons responsible for coding the constituents will lead to lower activation strengths, less redundancy in how a lexical representation can be activated, and lower and slower lexical activation overall. This explanation is partially based on Breznitz' (2003) mistiming explanation of reading disorders.

information into a knowledge base may have increased accuracy of meaning responses. The alternative explanation is that participants were incorporating the information into a better existing knowledge base, something that this experiment was designed to avoid. The high familiarity with all the vocabulary concepts makes this explanation less likely to be correct.

4. Word frequency improved performance. Participants were nearly always faster and more accurate for high frequency words than for low frequency words. Only when participants became extremely fast and accurate overall did frequency differences not reach significance. The frequency differences decreased with training. The frequency effects appear to be due to absolute word frequencies, and not relative word frequencies. That is, the difference between having seen a word 3 times and having seen a word 9 times was very important, while the difference between having seen a word 30 times and having seen a word 90 times was less important, even though the ratio of low-frequency to high-frequency word encounters is 1:3 in both cases. It could be that some minimum number of encounters is necessary to reach a minimum lexical quality criterion, or that the effects of frequency are just not linear. Mazur & Hastie (1978) explain the shape of a negative exponential growth curve as being created by the increase in number of trials which correctly enhance the strength of a memory trace (here, lexical entry). By this logic, increasing from 3 to 9 correct trials still has the ability to greatly improve the strength of the lexical entry, but by 30 trials, the strength increments are not as large, and by 90 trials, they are smaller still. Further, the first trials may actually be incorrect – that is, not properly forming or updating the lexical entry, further increasing the relative advantages of additional successful trials.

5. Homophony reduced performance, especially for low frequency words. Participants were slower and less accurate for homophones than for controls, as soon as word meanings were introduced and participants needed to discriminate between the homophones. Participants were much less accurate for homophones than for controls when the words were of low frequency, and the homophone effects actually grew with training, while the homophone effects for high frequency words decreased with training. This nice interaction is probably due to the relative lexical quality increase with training. The relative lexical quality difference between high frequency and low frequency words increased, leading both to more interference from the high frequency homophone on the low frequency homophone, and to more protection from interference for the high frequency homophone. In both cases, though, initially the lexical quality of the homophones was lower than the lexical quality of the controls. Over the training period, the lexical quality of the low frequency homophones deviated more and more from their frequency-matched controls, while the lexical quality of the high frequency homophones became more and more similar to their frequency-matched

controls. Replicating the effects of Perfetti & Hart (2000) with the definition of frequency as a simple difference in the number of encounters participants had with words provides strong evidence that the frequency differences in Perfetti & Hart (2000) were explainable by differences in reading experience of the participants.

In summary, participants successfully learned the Zekkish language with practice, and became fairly skilled at its use. While some effects of a basic comprehension skill were noted, it is participants' lexical skill that drove both their rate of learning and their pattern of interactions with homophony and frequency. The artificial orthography of Zekkish successfully duplicated the lexical effects of frequency and homophony in English, with frequency entirely manipulated by number of occurrences with a word and homophony manipulated by a single grapheme-to-phoneme correspondence duplication. The simplicity of the lexical manipulations and the dual division of participants by lexical and comprehension skill help explain the results of the Perfetti & Hart (2000) experiment.

5. TESTING

The testing occurred after grammar training and after acquisition of experience. In general, the testing took about 1.5 hours. Many tasks needed to be done one-on-one with the examiner. The category inferencing task, the interview (language interview after partial training, exit interview after complete training), and the tasks modeled after Experiments 1 and 2 described in the introduction (completed during behavioral testing) could be done by the participant working independently. The examiner generally ran one ERP session and one testing session simultaneously. In general, the order of tests was kept standard; occasionally, the tasks were reordered so that the participant taking the tests could continue to work while the examiner was busy with the ERP setup. The needs of the ERP participant always came first. Some test order rules were always maintained: (a) Zekkish tests were grouped together, so participants would not need to switch from Zekkish to English more often than necessary, (b) the phonological awareness tests were separated by at least one half hour, because the item structures were similar (see explanation in the next section), (c) working memory tasks in the two languages were separated by at least one half hour because participants found them particularly taxing, and (d) Category inferencing from words was always done before category inferencing from pictures, according to test rules.

The MLAT was also taken independently by the participant listening to a cassette tape. Most of the time the MLAT was completed by the participant in a different session after everything else was completed. Reading tasks were completed on a computer in the examiner's office or in the behavioral lab. The one-on-one dictated tasks like working memory and spelling were completed in these locations or in the ERP lab where the examiner could monitor the ERP computers.

Administration and scoring information for each test are included in the methods section. Statistically significant results are discussed in the results section while details on data trimming are included in Appendix L and statistics are included in Appendix M. Test items, with translations for Zekkish, are included in Appendix E.

5.1. Methods

5.1.1. Zekkish word identification.

Participants read each of the 48 Zekkish words as quickly and accurately as possible. A 500 ms. fixation cross preceded each word, and a prompt for the examiner to enter accuracy followed each word. Words for which the microphone was triggered too soon were not scored for accuracy or response time. Words that the participant had to repeat because the microphone did not pick up the first response were scored for accuracy but not response time. All 48 words were given at both testing sessions. Data were analyzed separately for test time, homophony, and frequency.

5.1.2. English word identification.

Participants read 53 English words as quickly and accurately as possible. A 500 ms. fixation cross preceded each word, and a prompt for the examiner to enter accuracy followed each word. Words for which the microphone was triggered too soon were not scored for accuracy or response time. Words that the participant had to repeat because the microphone did not pick up the first response were scored for accuracy but not response time. Items were taken from the Woodcock-Johnson Psychoeducational Battery, Word Identification subtest. Odd numbered items were included in one version, and even numbered items were included in another version. Different versions were given at the two test sessions, with the order counterbalanced across participants. One typo was removed from version 2, and a word corresponding in accuracy was removed from version 1 before analysis. In addition, the first five words (very easy) and the last five words (very hard) were not included in response time calculations.

5.1.3. Zekkish pseudoword identification.

Participants were presented with 27 pseudowords created using the following rules: (a) two-letter words with a consonant and a vowel (cv or vc) in the standard clockwise Zekkish orthography, (b) three-letter words in which both consonants are the same, or (c) four or more letter words created by concatenating letter units left to right. A 500 ms fixation cross preceded each pseudoword, and a prompt for the examiner to enter accuracy followed each pseudoword. Pseudowords for which the microphone was triggered too soon were not scored for accuracy or response time. Pseudowords that the participant had to repeat because the microphone did not pick up the first response were scored for accuracy but not response time. However, only pseudowords for which average accuracy was 85% or greater were used to calculate response time. This is because more skilled participants tended to get more of the longer pseudowords correct, and these took longer to decode. Had these been included in the response time calculations, more skilled participants would have had artificially inflated response times. Participants were reminded that their first response would trigger the microphone, and that they should assemble the phonology for the whole word in their head before saying it aloud. Two separate lists of 27 pseudowords were used, one given at each testing session, and the order of the lists was counterbalanced across participants. Both lists had the same consonant/vowel patterns in the same list position. The lists were arranged in the expected order of difficulty.

5.1.4. English pseudoword identification.

Participants read 24 English pseudowords as quickly and accurately as possible. A 500 ms. fixation cross preceded each word, and a prompt for the examiner to enter accuracy followed each word. Words for which the microphone was triggered too soon were not scored for accuracy or response time. Words that the participant had to repeat because the microphone did not pick up the first response were scored for accuracy but not response time. Items were taken from the Woodcock-Johnson Psychoeducational Battery, Word Attack subtest. Odd numbered items were included in one version, and even numbered items were included in another version. Different versions were given at each testing session, with the order counterbalanced across participants. Several of the easier pseudowords are either English words or names. These words were removed from the list before scoring. Since more words needed to be removed from version A than from version B, equivalent words were removed from version B in order to equate the number and difficulty of items.

5.1.5. Zekkish phonological awareness.

A modified version of the Lindamood Auditory Conceptualization (LAC) test, part III was given. This test asks participants to manipulate colored blocks (this experiment used cards) to represent patterns of sounds. The sounds of the standard LAC were substituted with sounds from the Zekkish language. The score was recorded as the total correct out of twelve. In the LAC, two versions of the test are provided, each with different sets of sounds but the same sound patterns. Each item builds on the previous item, and having two versions makes it possible to switch to a new set of stimuli each time a participant makes a mistake (going back and forth between versions). In the current experiment, rare mistakes were corrected if the mistake resulted in an insufficient sound pattern on which to build the next sound pattern. Mistakes that provided a correct base for the next item were scored as incorrect, but testing continued without correction. One version was given at each testing session, counterbalanced between participants. In retrospect, there are two problems with this test. One is that, between the Zekkish and English versions, at the two test points, participants saw the same sound sequences four times (even though specific sounds varied). Some implicit or explicit learning could have taken place, and gains in performance from Zekkish to

English or from first testing session to second testing session may be due to test exposure. The other is that, as pointed out by a couple of participants, sounds in the Zekkish LAC were represented left to right instead of in the standard clockwise pattern. This may have resulted in a loss of some information about Zekkish phonology or some interference from English.

5.1.6. English phonological awareness.

A modified version of the Lindamood Auditory Conceptualization (LAC) test, part III was given. This test asks participants to manipulate colored blocks (this experiment used cards) to represent patterns of sounds. The sounds of the standard LAC were substituted with sounds that were not from the Zekkish language. In addition, sounds that were generally written with more than one letter (ch, th, oo) were included in order to increase the difficulty of the test. The score was recorded as the total correct out of twelve. In the LAC, two versions of the test are provided, each with different sets of sounds but the same sound patterns. Each item builds on the previous item, and having two versions makes it possible to switch to a new set of stimuli each time a participant makes a mistake (going back and forth between versions). In the current experiment, rare mistakes were corrected if the mistake resulted in an insufficient sound pattern on which to build the next sound pattern. Mistakes that provided a correct base for the next item were scored as incorrect, but testing continued without correction. One version was given at each testing session, with the order counterbalanced between participants.

5.1.7. Zekkish working memory.

This working memory test was based on the Wechsler Digit Span task. Four alternate sets of Zekkish word lists were created. Word lists were two to seven items long, and there were two lists of each length in each set of Zekkish words. One set was presented for participants to repeat in the same order as the examiner read them, and another set was presented for participants to repeat in reverse order. Word lists were presented until participants missed both lists of a given length. The ceiling level of performance was never reached, as the Zekkish alphabet is limited to only 8 letters and the potential for phonological confusion was high. Once, there was even a floor effect. Participants completed one forward and one backward set at each testing session with the order counterbalanced between participants. Two scores were recorded for each word set: number of lists correctly repeated, and highest list length correctly repeated.

5.1.8. English working memory - words.

Two tasks of English working memory were given. The first was an English analog to the Zekkish task. A set of English words was chosen to have the same phonological characteristics as the Zekkish words. All words in the set were formed from only four consonant sounds and four vowel sounds.[8] With this word set, four alternate sets of English word lists were created. Word lists were two to seven items long, and there were two lists of each length in each set of English words. One set was presented for participants to repeat in the same order as the examiner read them, and another set was presented for participants to repeat in reverse order. Word lists were presented until participants missed both lists of a given length. The ceiling level of performance was never reached, as the potential for phonological confusion was high. Participants completed one forward and one backward set at each testing session with order counterbalanced between participants. Two scores were recorded for each word set: number of lists correctly repeated, and highest list length correctly repeated.

5.1.9. English working memory - digits.

The second English working memory task was a digit span task. Digits from one to nine were used to create four alternate sets of digit lists. Digit lists were two to nine items long, and there were two lists of each length in each set of digits. One set was presented for participants to repeat in the same order as the examiner read them, and another set was presented for participants to repeat in reverse order. Digit lists were presented until participants missed both lists of a given length. The ceiling level of performance was occasionally reached, but limiting the lists to nine items shortened test time, and allowed for lists in which no digit was ever repeated. Participants completed one forward and one backward set at each testing session with the order counterbalanced between participants. Two scores were recorded for each word set: number of lists correctly repeated, and highest list length correctly repeated.

5.1.10. Zekkish word spelling.

Participants were asked to use letter cards to spell each of ten dictated Zekkish words. A different set of ten was given at each testing session with the order counterbalanced. The outcome variable was total correct. In order to get an answer correct, participants had to arrange the letters in the typical, Zekkish stacked-consonant form. If participants did not do this on the first item, they were reminded once to use Zekkish format.

5.1.11. English word spelling.

Participants were asked to spell 21 dictated words, taken from the Wide Range Achievement Test, Third Edition, Tan version. Odd numbered items were placed in one list, and even numbered items were placed in another list. List order was counterbalanced across testing sessions. The outcome variable was total correct.

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[8] The lists were still more variable than the Zekkish lists, though, because the four vowel sounds were spelled with more than four orthographic patterns. The lists also included fewer homophones.

5.1.12. Zekkish pseudoword spelling.

Participants were asked to use letter cards to spell each of ten dictated Zekkish pseudowords. Words were created using the following rules: (a) two-letter words consisted of a consonant and a vowel (cv or vc) in the standard clockwise Zekkish orthography, (b) three-letter words in which both consonants are the same, or (c) four or more letter words created by concatenating letter units left to right. Two lists were created, using the same consonant-vowel patterns for each. List order was counterbalanced across testing sessions. The outcome variable was total correct. There was one additional Zekkish spelling outcome variable, that measured an underlying sensitivity to and understanding of spelling patterns. This variable is described in more detail in the results section.

5.1.13. English pseudoword spelling.

Participants were asked to spell 23 dictated English pseudowords, taken from the Woodcock-Johnson Psychoeducational Achievement Test (an older version of the test than that used as a source of items for pseudoword identification), with some additional items created by the examiner. Items overlapping in spelling and pseudoword identification were removed from the list before testing. Two versions of the test were developed, and list order was counterbalanced across testing sessions. The outcome variable was total correct, scored using two different measures of increasing sensitivity to orthographic structure. Both measures used grapheme-phoneme correspondence (GPC) percentages from Hanna, Hanna, Hodges & Rudorf (1966). GPC percentages were tabulated from a 17,310 word list taken mostly from the then-current Merriam-Webster dictionary, and were separated according to syllable stress and position in syllable. In the first measure, each word was scored according to whether phonemes were ever represented in the corpus as they were spelled by participants. If all phonemes in the word were spelled in ways found in the corpus at least once, the word was scored as correct. In the second measure, accent, position, and spelling frequency were taken into account. In order to be correct, all phonemes had to be spelled in ways represented in the corpus in the same position, with the same stress, at least 20% of the time. Greater detail on the scoring of pseudoword spelling is described in Appendix F.

5.1.14. Zekkish Inferencing.

Participants were provided with four Zekkish words, and told that three of the words shared some component of their meaning. They were asked to circle the fourth word and provide an explanation of the shared meaning component of the other three. For example, participants might read the words for feeding chickens, milking cow, building snowman, and watching fish. The correct word to circle would be building snowman, and the correct explanation would be that all the other items contain animals. After participants completed eight sets of words, they were given the same items with pictorial representations. They were told that they were to retake the test with the pictures to see if they could get any additional correct answers. They were not to go back and change their answers to the items with word stimuli. Two versions of this test were made, and the versions were presented counterbalanced across testing sessions. Only the explanations of their answers were scored. Any explanations that reasonably fit the pattern of concepts, even if the correct explanations did not all correspond to the same three concepts, were accepted. The frequency of given explanations for each item, and their scores, are tallied in Appendix G. The number of different levels upon which three concepts can share semantic information made this task fairly difficult to develop and score. A multi-level scoring system in which some answers were given a higher score because they corresponded to a deeper level of meaning was considered and rejected. Pilot data rating possible answers for the pictures would be necessary to make this scoring work, rather than the opinions of just one examiner.

5.1.15. English Inferencing.

Participants were provided with four English phrases corresponding roughly to the phrase pattern represented by Zekkish words, and told that three of the phrases shared some component of their meaning. They were asked to circle the fourth phrase and provide an explanation of the shared component. For example, participants might read the phrases “falling from skis,” “snowboarding down hill,” “painting sled,” and “blowing out candles.” The correct phrase to circle would be “blowing out candles” and the correct explanation would be that all the other phrases involve snow sports. After participants completed eight sets of phrases, they were given the same items with pictorial representations. They were told that they were to retake the test with the pictures to see if they could get any additional correct answers. They were not to go back and change their answers to the items with phrase stimuli. Two versions of this test were made, and the versions were presented counterbalanced across testing sessions. Only the explanations of their answers were scored. Any explanations that reasonably fit the pattern of concepts, even if the correct explanations did not all correspond to the same three concepts, were accepted. The frequency of given explanations for each item, and their scores, are tallied in Appendix G. The number of different levels upon which three concepts can share semantic information made this task fairly difficult to develop and score. A multi-level scoring system in which some answers were given a higher score because they corresponded to a deeper level of meaning was considered and rejected. Pilot data rating possible answers for the pictures would be necessary to make this scoring work, rather than the opinions of just one examiner.

5.1.16. Modern Language Aptitude Test (MLAT).

Participants took the one-hour-long, tape-administered MLAT to measure their ability to acquire skill in a new language. The MLAT is composed of five sections. Raw scores for each section as well as a total score were recorded.

A. Number learning teaches participants new words for the numbers one through five and endings for the number words to place them in the tens column and hundreds column. For example, emlaki nola em might be 121 whereas nolaki no might be 202. B. Phonetic script measures sound-symbol association ability and memory for speech sounds. Participants are read the pronunciation for three-phoneme words, then read a single word and asked to pick the phonetic script for the dictated word. C. Spelling clues measures sound-symbol association ability and English vocabulary. For example, participants could be asked to choose the English word that corresponds most nearly in meaning to "Ernst" – shelter, ***sincere***, slanted, free, or impatient. D. Words in sentences measures knowledge of grammatical structure, as well as formal English grammar training. Participants are asked to choose the part of a sentence that plays the same role as an underlined word in a key sentence. For example, participants might be given "Money is his only object." They would then be asked to choose a section from the following sentence: "Not so many years ago, most ***farming*** was done by hand." E. Paired associates measures rote memory. Participants are given 24 foreign words and their English translations, and two minutes to study them. They are then asked to choose the appropriate meaning for each word from five choices.

Parts A, B, and E require memory skills. Parts B and C require sound-symbol association ability. Parts C and D require knowledge of English (vocabulary and grammar, respectively). All parts have a time factor, but C, D, and E are especially speeded.

5.2. Results

5.2.1. Zekkish word identification.

Accuracy and response time data are shown in Table 5.2.1. All participants improved with experience, becoming both faster and more accurate from test point 1 (after partial training) to test point 2 (after complete training). Participants responded more quickly for high frequency words than for low frequency words, and for homophones than for controls. Participants were more accurate for high frequency words, but only when the word was a control. Participants with good comprehension skill were more accurate than participants with poor comprehension skill, while participants with good lexical skill were faster than participants with poor lexical skill (especially for homophones). Skilled comprehenders were faster for homophones than controls when the words were of low frequency, and less-skilled comprehenders were faster for homophones than controls when the words were of high frequency. This three-way interaction is shown in Figure 5.2.1.

Table 5.2.1 Means and standard errors for percent accuracy and response time, Zekkish word identification.

Mean (SE)	Freq	H/C	Time	Poor/Poor	Good comp	Good lex	Good/Good
Accuracy	Low	Hom	Partial	0.82 (.09)	0.95 (.03)	0.90 (.02)	0.97 (.01)
			Complete	0.86 (.08)	0.99 (.01)	0.99 (.01)	0.99 (.01)
		Ctrl	Partial	0.85 (.09)	0.95 (.02)	0.85 (.08)	0.97 (.02)
			Complete	0.91 (.05)	0.97 (.02)	0.96 (.02)	0.97 (.02)
	High	Hom	Partial	0.82 (.09)	0.93 (.04)	0.92 (.03)	0.97 (.02)
			Complete	0.84 (.07)	0.98 (.02)	0.98 (.02)	0.99 (.01)
		Ctrl	Partial	0.85 (.08)	0.96 (.03)	0.89 (.07)	0.99 (.01)
			Complete	0.96 (.03)	0.98 (.01)	0.96 (.01)	0.99 (.01)
RT	Low	Hom	Partial	1880 (131)	1687 (93)	1518 (103)	1440 (36)
			Complete	1547 (136)	1408 (72)	1350 (111)	1177 (56)
		Ctrl	Partial	1860 (152)	1732 (99)	1610 (79)	1494 (40)
			Complete	1535 (128)	1460 (78)	1307 (118)	1288 (53)
	High	Hom	Partial	1820 (144)	1672 (102)	1526 (102)	1401 (36)
			Complete	1487 (90)	1413 (75)	1257 (96)	1166 (47)
		Ctrl	Partial	1941 (139)	1647 (90)	1498 (102)	1444 (44)
			Complete	1575 (135)	1498 (102)	1327 (115)	1218 (42)

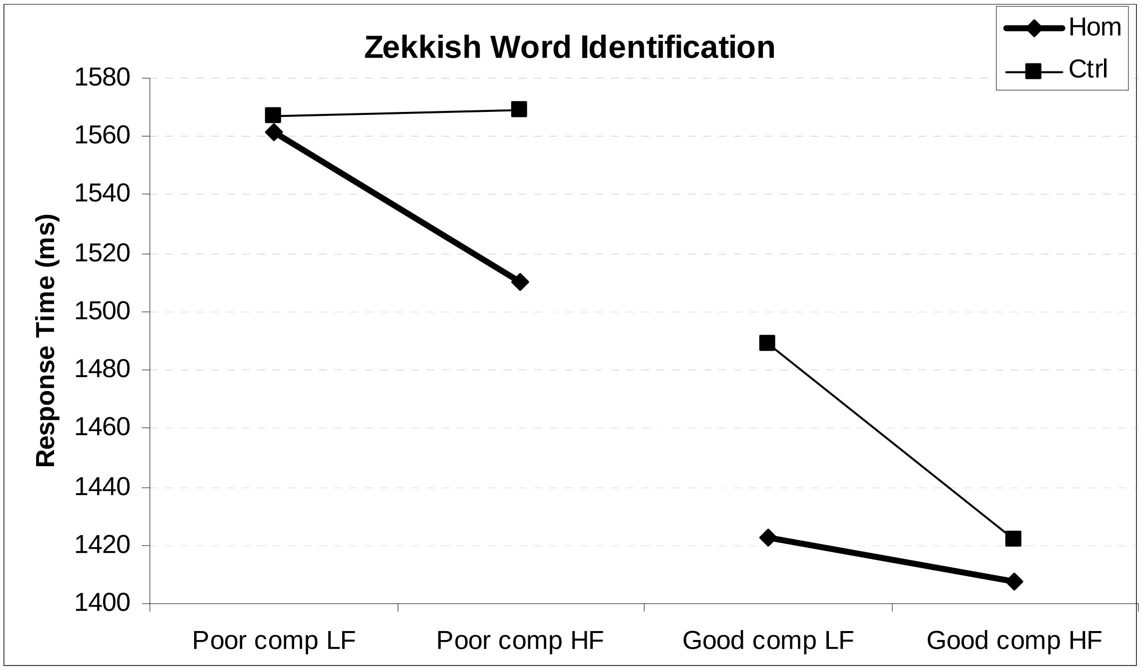

Figure 5.2.1 Three-way interaction of comprehension, homophony and frequency for Zekkish word identification response time.

5.2.2. English word identification.

Accuracy and response time data are shown in Table 5.2.2. Participants with good lexical skill were more accurate than participants with poor lexical skill, and participants with good comprehension skill were both faster and more accurate than participantswith poor comprehension skill. Neither Zekkish experience nor test version mattered, except for one three-way interaction. Participants who were both poor in lexical skill and in comprehension were faster after partial training than after complete training than any other group.

Table 5.2.2. Means and standard errors for percent accuracy and response time (ms.) for English word identification.

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Accuracy	Partial	0.92 (.01)	0.96 (.01)	0.95 (.01)	0.98 (.01)
	Complete	0.93 (.01)	0.96 (.01)	0.95 (.01)	0.98 (.00)
RT	Partial	661 (28)	619 (23)	662 (24)	580 (24)
	Complete	689 (32)	614 (18)	662 (35)	580 (27)

5.2.3. Zekkish pseudoword identification.

Accuracy and response time data are shown in Table 5.2.3. All participants improved with experience, becoming both faster and more accurate. Skilled comprehenders were more accurate than less skilled comprehenders, especially after partial training.

Table 5.2.3. Means and standard errors for percent accuracy and response time (ms) for Zekkish pseudoword identification.

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Accuracy	Partial	0.54 (.07)	0.77 (.03)	0.65 (.055)	0.75 (.04)
	Complete	0.74 (.06)	0.87 (.02)	0.84 (.04)	0.86 (.03)
RT	Partial	5621 (611)	5027 (246)	5046 (302)	5106 (444)
	Complete	4491 (534)	4178 (280)	3805 (424)	3703 (293)

5.2.4. English pseudoword identification.

Accuracy and response time data are shown in Table 5.2.4. Participants with good comprehension skill were faster than participants with poor comprehension skill, and participants with good lexical skill were both faster and more accurate than participants with poor lexical skill. Participants with poor comprehension actually became less accurate from partial to complete training, but participants with good comprehension became more accurate from partial to complete training.

Table 5.2.4. Means and standard errors for percent accuracy and response time (ms) for English pseudoword identification.

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Accuracy	Partial	0.77 (.04)	0.79 (.03)	0.83 (.04)	0.81 (.03)
	Complete	0.71 (.04)	0.79 (.04)	0.79 (.02)	0.87 (.02)
RT	Partial	1010 (57)	871 (40)	858 (60)	743 (59)
	Complete	980 (78)	836 (49)	884 (55)	748 (58)

5.2.5. Zekkish phonological awareness.

Data are shown in Table 5.2.5. Participants with good comprehension skill and participants with good lexical skill had higher scores than participants with poor skills. Overall, participants did better after complete training than after partial training.

Table 5.2.5. Means and standard errors for phonological awareness in Zekkish

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Phon Aware	Partial	10.5 (.43)	11.4 (.31)	10.9 (.43)	11.8 (.11)
	Complete	11.1 (.28)	11.8 (.20)	11.8 (.10)	11.9 (.08)

5.2.6. English phonological awareness.

Data are shown in Table 5.2.6. Participants with good comprehension skill had higher scores than participants with poor comprehension skill.

Table 5.2.6. Means and standard errors for phonological awareness in English

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Phon Aware	Partial	10.4 (.48)	11.6 (.16)	10.8 (.39)	11.5 (.29)
	Complete	10.9 (.35)	11.2 (.33)	11.5 (.22)	11.9 (.08)

5.2.7. Zekkish working memory.

Data are shown in Table 5.2.7. "Total" is the number of items participants correctly repeated, "length" is the longest list participants correctly repeated, "z-score" is the average of standard scores of forward and back, for both total and length. Participants with good comprehension skill had higher scores than participants with poor comprehension skill. The participants in the extreme groups (good comprehension/good lexical skill and poor comprehension/poor lexical skill) improved from the test point after partial training to the test point after complete training, while the marginal groups actually slightly declined. Although the three-way interaction is significant, none of the test time differences are significant by paired t-tests within reading groups.

Table 5.2.7. Means and standard errors for working memory in Zekkish. .

Mean (SE)	Direc.	Time	Poor/Poor	Good comp	Good lex	Good/Good
Total	Forw	Partial	3.3 (.26)	3.9 (.38)	3.5 (.29)	4.3 (.41)
		Complete	3.7 (.37)	4.1 (.43)	3.5 (.24)	4.8 (.49)
	Back	Partial	2.0 (.33)	3.1 (.18)	2.5 (.22)	2.7 (.22)
		Complete	2.4 (.37)	2.8 (.25)	2.2 (.26)	3.0 (.27)
Length	Forw	Partial	3.0 (.21)	3.3 (.21)	3.1 (.21)	3.6 (.26)
		Complete	3.2 (.25)	3.4 (.27)	3.0 (.16)	3.8 (.30)
	Back	Partial	2.2 (.29)	3.0 (.15)	2.8 (.12)	2.8 (.17)
		Complete	2.4 (.31)	2.6 (.16)	2.4 (.14)	2.8 (.18)
Z-score	Avg	Partial	-0.5 (.29)	0.3 (.20)	-0.1 (.17)	0.3 (.23)
		Complete	-0.2 (.29)	0.1 (.26)	-0.4 (.16)	0.5 (.27)

5.2.8. English working memory – words.

Data are shown in Table 5.2.8. "Total" is the number of items participants correctly repeated, "length" is the longest list participants correctly repeated, "z-score" is the average of standard scores of forward and back, for both total and length. Participants with good comprehension skill had higher scores than participants with poor comprehension skill.

Table 5.2.8. Means and standard errors for working memory (words) in English

Mean (SE)	Direc.	Time	Poor/Poor	Good comp	Good lex	Good/Good
Total	Forw	Partial	4.3 (.30)	5.2 (.39)	4.5 (.24)	5.8 (.41)
		Complete	4.7 (.37)	5.6 (.50)	4.8 (.36)	5.6 (.53)
	Back	Partial	3.1 (.18)	4.4 (.48)	3.5 (.33)	4.6 (.23)
		Complete	4.1 (.23)	3.8 (.44)	3.5 (.31)	3.8 (.32)
Length	Forw	Partial	3.4 (.16)	4.0 (.26)	3.9 (.18)	4.2 (.21)
		Complete	3.9 (.23)	4.4 (.34)	3.8 (.22)	4.5 (.29)
	Back	Partial	3.0 (.01)	3.7 (.26)	3.3 (.21)	3.7 (.14)
		Complete	3.3 (.15)	3.2 (.33)	3.1 (.18)	3.3 (.19)

Z-score	Avg	Partial	-0.6 (.11)	0.3 (.30)	-0.3 (.19)	0.5 (.16)
		Complete	-0.1 (.22)	0.2 (.33)	-0.3 (.22)	0.2 (.27

5.2.9. English working memory – digits.

Data are shown in Table 5.2.9. "Total" is the number of items participants correctly repeated, "length" is the longest list participants correctly repeated, "z-score" is the average of standard scores of forward and back, for both total and length. Participants with good comprehension skill had higher scores than participants with poor comprehension skill.

Table 5.2.9. Means and standard errors for working memory (digits) in English

Mean (SE)	Direc.	Time	Poor/Poor	Good comp	Good lex	Good/Good
Total	Forw	Partial	11.6 (.65)	11.3 (.56)	10.9 (.54)	12.7 (.61)
		Complete	11.3 (.65)	11.7 (.82)	10.9 (.45)	12.8 (.59)
	Back	Partial	7.4 (.43)	8.2 (.55)	8.2 (.61)	9.6 (.60)
		Complete	7.7 (.61)	9.7 (.82)	9.2 (.62)	10.0 (.46)
Length	Forw	Partial	7.2 (.36)	7.1 (.31)	6.9 (.29)	7.8 (.34)
		Complete	7.2 (.36)	7.5 (.37)	7.0 (.30)	7.8 (.33)
	Back	Partial	5.1 (.23)	5.8 (.36)	5.9 (.37)	6.5 (.38)
		Complete	5.1 (.28)	6.2 (.44)	6.6 (.33)	6.8 (.25)
Z-score	Avg	Partial	-0.4 (.17)	0.2 (.24)	0.3 (.23)	0.4 (.24)
		Complete	-0.4 (.24)	0.2 (.34)	0.0 (.23)	0.5 (.22)

5.2.10. Zekkish word spelling.

Data are shown in Table 5.2.10. Participants with good comprehension skill had higher scores than participants with poor comprehension skill, especially after partial training.

Table 5.2.10. Means and standard errors for word spelling in Zekkish

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Word Spell	Partial	9.6 (.22)	9.9 (.10)	9.5 (.39)	9.8 (.11)

	Complete	9.1 (.41)	9.8 (.13)	9.6 (.18)	9.8 (.11)

5.2.11. English word spelling.

Data are shown in Table 5.2.11. Participants with better good lexical skill and participants with good comprehension skill scored higher than their less-skilled counterparts.

Table 5.2.11. Means and standard errors for word spelling in English

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Word Spell	Partial	14.2 (.68)	15.6 (.56)	14.7 (.65)	17.3 (.56)
	Complete	14.1 (.41)	15.6 (.48)	15.2 (.46)	17.4 (.51)

5.2.12. Zekkish pseudoword spelling.

Data are shown in Table 5.2.12. Participants with good comprehension skill received higher scores than participants with poor comprehension skill, especially after partial training. Participants with good lexical skill received slightly higher scores than participants with poor lexical skill.

Table 5.2.12. Means and standard errors for pseudoword spelling in Zekkish

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Pseudo Spell	Partial	6.5 (.52)	8.5 (.52)	7.6 (.60)	8.9 (.26)
	Complete	7.9 (.48)	9.0 (.30)	8.8 (.30)	9.3 (.22)

5.2.13. Zekkish spelling – ease.

In addition to total correct for Zekkish spelling of words and pseudowords, some other markers of spelling ease were collected. Each measures some ability to maneuver through the testing efficiently and with a sensitivity to and understanding of the underlying spelling-sound structure. Each variable alone had little variance, so they were standardized and averaged for a single stable variable of spelling ease. The variables were: (a) frequency with which the /u/ sound was represented by the same letter in words, (b) frequency with which the /u/ sound was represented by the same letter in pseudowords, (c) repetition of same letter for /u/ sound for homophones presented one after another, (d) frequency of three-letter units constructed in pseudowords (some pseudowords could be correctly spelled more than one way), (e) whether letters were always in canonical orientation, and (f) whether one sound, which would probably be a schwa in English was represented with the correct (and emphasized by the examiner) /u/ sound in Zekkish.

Data are shown in Table 5.2.13. Participants with good lexical skill scored higher than participants with poor lexical skill, participants with good comprehension skill scored higher than participants with poor comprehension skill, and participants with both poor comprehension skill and poor lexical skill scored lower than all the other groups.

Table 5.2.13. Means and standard errors for spelling ease in Zekkish

Mean (SE)	Time	Poor/Poor	Good comp	Good lex	Good/Good
Spell Ease Z	Partial	-.5 (.23)	0.1 (.08)	0.1 (.18)	0.1 (.15)
	Complete	0.2 (.16)	0.1 (.08)	0.1 (.09)	0.2 (.12)

5.2.14. English pseudoword spelling.

English pseudoword spelling was scored two ways: by the proportion of items that had all phonemes spelled in ways represented in English, and by the proportion of words that had all phonemes spelled in ways that English spells those phonemes at least 20% of the time. See Appendix F for a fuller explanation. Data are shown in Table 5.2.14. Good comprehenders were more accurate than poor comprehenders, and were also more sensitive to aspects of grapheme-phoneme correspondence including phoneme position in syllable, syllable stress, and relative frequency of grapheme spellings

Table 5.2.14. Means and standard errors for pseudoword spelling, English

Mean (SE)	Direc.	Time	Poor/Poor	Good comp	Good lex	Good/Good
Pseudo Spell	Total	Partial	0.9 (.04)	0.9 (.02)	0.8 (.04)	0.9 (.02)
		Complete	0.9 (.03)	0.9 (.02)	0.8 (.03)	0.9 (.01)
	Common	Partial	0.5 (.04)	0.6 (.04)	0.5 (.04)	0.6 (.03)
		Complete	0.5 (.02)	0.5 (.04)	0.5 (.02)	0.6 (.01)

5.2.15. Zekkish Category Inferencing.

Data are shown in Figure 5.2.2. Participants scored higher after complete training than after partial training for word stimuli but not for picture stimuli. They scored higher on picture stimuli than on word stimuli, and the effect was greater after partial training than after complete training.

Participants with good lexical skill and participants with good comprehension skill scored higher than their less skilled counterparts. The lowest scorers were those who had both poor lexical skill and poor comprehension skill; this effect was greater for word stimuli than for picture stimuli and after complete training than after partial training.

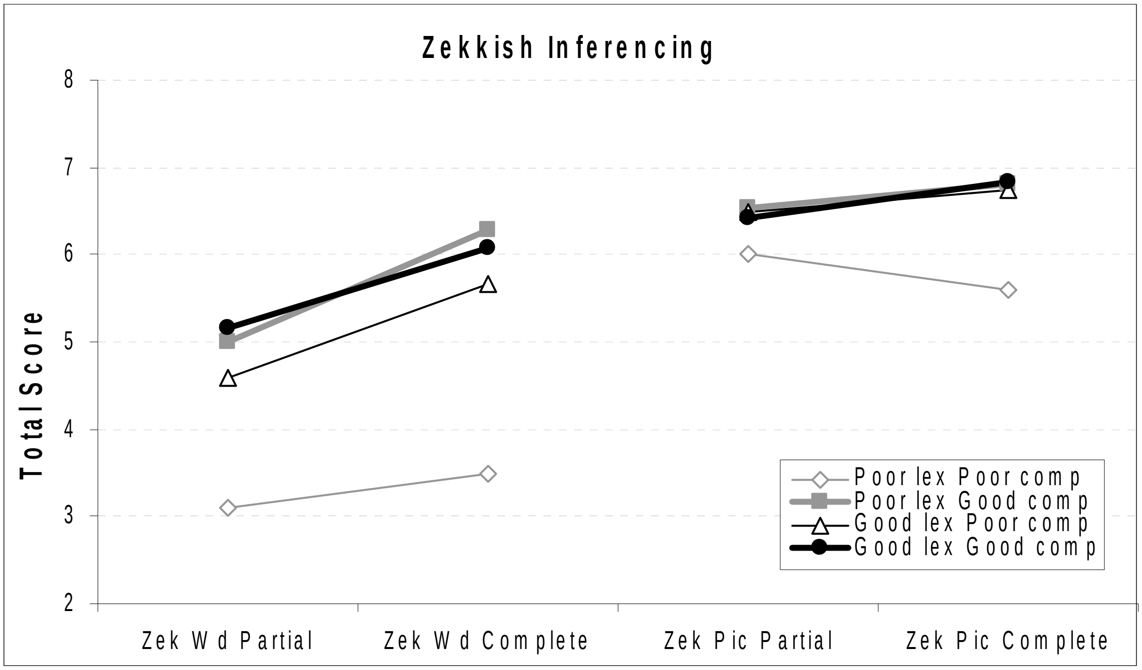

Figure 5.2.2. Total scores on Zekkish category inferencing, word and picture versions

5.2.16. English Category Inferencing.

Data are shown in Figure 5.2.3. Participants scored higher for picture stimuli than for word stimuli. Participants with good comprehension scored higher than participants with poor comprehension, regardless of time or mode of testing.

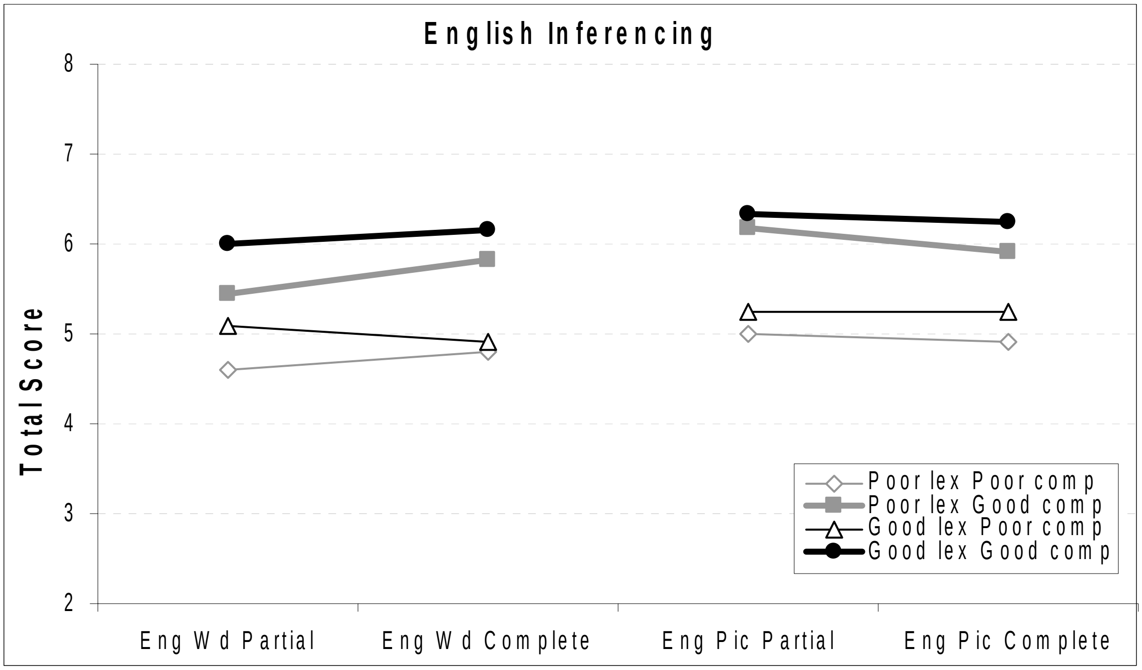

Figure 5.2.3. Total scores on English category inferencing, word and picture versions

5.2.17. Modern Language Aptitude Test (MLAT).

Data are shown in Table 5.2.15. Participants with good comprehension skill and participants with good lexical skill receive higher scores than their less skilled counterparts. Comprehension skill and lexical skill do not interact. Comprehension skill is related to sound-symbol association ability, whereas lexical skill is related to rote memory skill. Both are related to language structure, at the levels of word and syntax. Neither knowledge of English nor speed was specifically associated with lexical skill or comprehension skill.

Table 5.2.15. Means and standard errors for the Modern Language Aptitude Test (MLAT)

Mean (SE)	Poor/Poor	Good comp	Good lex	Good/Good
Subtest 1	38.40 (1.91)	40.40 (1.92)	40.23 (1.03)	43.67 (.58)
Subtest 2	23.00 (1.10)	27.00 (.77)	26.15 (.82)	26.75 (.77)
Subtest 3	19.10 (2.04)	28.80 (3.87)	23.23 (2.42)	26.83 (3.12)
Subtest 4	20.00 (1.66)	23.60 (1.32)	23.54 (1.32)	26.42 (2.12)
Subtest 5	15.50 (1.45)	18.20 (1.26)	22.08 (.59)	20.42 (1.64)
Total	116.00 (4.91)	138.00 (6.20)	135.31 (3.38)	144.08 (4.80)

5.3. Discussion

1. Participants in this study improved on almost all the Zekkish tests from the test point after partial training to the test point after complete training. On the two timed tests of word identification and pseudoword decoding, they improved both their speed and their accuracy. They even improved on the fairly easy phonological awareness test, despite its use of left-to-right letter placement. There was only a trend toward improvement on the spelling test, and only for words. This is most likely because Zekkish is completely decodable. On the category inferencing test, there is a nice division between words and pictures; they improved their performance when taking the test with words, but not with pictures. This indicates that the lexical information was feeding into the comprehension system; when the need for the lexical information was bypassed, comprehension (of the picture stimuli) was good, even after partial training.

2. On none of the English tests did participants improve from the test point after partial training to the test point after complete training. This speaks to the reliability of the English tests and indicates that the improvement on the Zekkish tests was probably due to an increase in facility with the Zekkish language and not merely to test repetition or an improvement in test-taking ability. Although in some experiments English performance might improve because of an increased sensitivity to word and language structure from the process of learning a new language, this experiment was not set up to capitalize on this change. The first testing point occurred after participants were exposed to all the aspects of Zekkish – letters, word structure, vocabulary, and grammar. If participants were going to show an increase in sensitivity to English as a result of Zekkish learning, the first testing would have had to take place before Zekkish learning began.

3. Lexical skill affected performance on some of the behavioral tasks. Participants with better lexical skill received higher scores on four Zekkish tests: word identification (response time), phonological awareness, pseudoword spelling (a trend), and category inferencing, and on three English tests: word identification (accuracy), pseudoword reading (response time and accuracy), and word spelling. In addition, participants with better lexical skill scored higher on the MLAT total score and on sections involving rote memory and language structure. The hypothesis was that lexical skill in English would transfer to Zekkish, and there is behavioral evidence that it has. Participants perform, on a variety of reading tasks in English and Zekkish, as their English lexical skill predicts that they will. In addition, several skills necessary for learning a new language, as measured on the MLAT, are associated with English lexical skill.

4. <u>Comprehension skill affects performance on nearly all the behavioral tasks.</u> Participants with better English comprehension score higher on both the English and Zekkish versions of working memory, phonological awareness, pseudoword reading, word reading, pseudoword spelling, word spelling, and category inferencing. In addition, they score higher on the MLAT total score and on sections involving sound-symbol association and language structure. The hypothesis was that comprehension skill in English would not transfer to Zekkish. Instead, comprehension skill in English plays a large role in participants' performance on the Zekkish behavioral tests, as well as on their English counterparts.

Given that English comprehension appears to affect performance on Zekkish tests, the next goal is to discover the reason. Is comprehension really a basic skill that transfers to performance in new language, or is there some other explanation? It does not transfer much to language acquisition, as the training data showed. If it is really a basic skill, then it should affect scores after both partial training and complete training; perhaps even more after complete training, because experience could compound the effects. While the ANOVAs showed main effects of comprehension skill, indicating that comprehension was related to performance at both the test point after partial training and the test point after complete training, more sensitive measures of lexical skill and comprehension skill were available; these tell a more complex story. Table 4.4.1 shows the correlation of the scores after partial training and after complete training with the continuous variables of lexical and comprehension skill that were used to define the dichotomous groups. Only two tests with significant correlations increase from the test point after partial training to the test point after complete training, and one of these is category inferencing with words. Two tests with significant correlations have only a slight drop in correlation from the test point after partial training to the test point after complete training, and one of these is working memory. Four tests with significant correlations with comprehension skill show a large drop from the test point after partial training to the test point after complete training. The correlation of comprehension skill with these four may be due to more complete understanding of the test demands. Of the four tests that don't show a significant drop, two – category inferencing and working memory – are prominent in the comprehension literature. Both are proposed to be causal in producing comprehension deficits. It was therefore considered that either working memory or category inferencing (or both) could be driving the correlations seen between Zekkish tests and English comprehension. Working memory seemed to be the more likely candidate because of the higher correlations after partial training than after complete training. However, neither working memory (Zekkish word strings or digit strings) nor category inferencing explained a significant proportion of variance between the Zekkish tests and English comprehension (See Table 4.4.2).

Three further explanations beyond category inferencing and working memory capacity were considered. The next (third) explanation was that the comprehension effects in testing were due solely to experience with Zekkish, in the same manner that comprehension is proposed to affect English. To test this, Zekkish tests were correlated with their English equivalents. If experience, rather than a basic skill, were driving the correlations, then it would be likely that test scores after complete training would be more highly correlated with the English equivalents. While this was true for some tests, it was not true often enough to call it a pattern (See Table 5.3.1).

The fourth explanation was that while the number of participants was too low to find significant interactions between lexical skill and comprehension skill in the ANOVAs, it was the correlation between lexical skill and comprehension skill that was driving the significant comprehension results. To test this, variance due to lexical skill was removed (partialled out) of the correlations between comprehension skill and the Zekkish tests See Table 5.3.2). If lexical skill was driving the comprehension skill results, the correlations should drop to zero. Most of the correlations did not decrease appreciably.

The fifth explanation returns to the experiment on which the current series of three was based: the experiment by Gernsbacher & Faust (1991). These researchers found that poor comprehenders showed homophone interference at 450 and 1350 ms SOAs, while good comprehenders only showed homophone interference at 450ms SOA. Their explanation was that good comprehenders were good suppressors of irrelevant information; in this case, the additional homophone representation activated by the presentation of its homophone mate. While our (Perfetti & Hart, 2000) experiment showed that the proposition of a suppression mechanism wasn't strictly necessary (as a simple shift in activation/deactivation time would suffice), the amount of homophone interference might explain some of the comprehension variance. Correlations between comprehension and the Zekkish tests, partialled by several different suppression/activation variables, were run, and none of the partials reduced any of the correlations. Attempted were English homophone interference by 150 ms, Zekkish homophone interference by 450 and 1000 ms after partial training and the test point after complete training, English homophone interference during the ERP task, and Zekkish homophone interference during the ERP task after partial training and after complete training.

Table 5.3.1 Correlations of Zekkish tests with lexical skill as a continuous variable, comprehension skill as a continuous variable, and English test equivalents.

	Lexical		Comp		English	
	Partial	Complete	Partial	Complete	Partial	Complete
Lindamood	0.30*	0.26	0.28	0.34*	0.51^^	0.52^^
Working Memory	0.18	0.32*	0.39**	0.35*	0.62^^	0.73^^
Word Spelling	0.22	-0.11	0.39**	0.07	0.19	0.08
Pseudo Spelling	0.28	0.31*	0.53***	0.26	0.26	0.30*
Spelling Sensitivity	0.43***	0.37*	0.39**	0.30*	0.21	0.22
Word Ident Acc	0.17	0.25	0.26	0.25	0.26	0.22
Word Ident RT	-0.52^^	-0.45***	-0.38**	-0.34*	0.24	0.37*
Pseudo Rdg Acc	0.20	0.18	0.43**	0.22	0.50^^	0.46
Pseudo Rdg RT	-0.31*	-0.39**	-0.18	-0.23	0.24	0.34*
Category Inf- words	-0.10	0.25	0.24	0.36*	0.27	0.33*
Category Inf- pics	-0.02	0.11	0.13	0.22	0.08	0.18

Note: All n = 45, * $p < .05$, ** $p < .01$, *** $p < .005$, ^ $p < .001$, ^^ $p < .0005$

Table 5.3.2 Correlations of Zekkish tests with comprehension skill as a continuous variable, partialled for possible sources of variance.

	Part Dig Span		Part Inf (Eng wd)		Part Lex	
	Partial	Complete	Partial	Complete	Partial	Complete
Lindamood	0.26	0.27	0.25	0.32*	0.18	0.26
Working Memory	0.21	0.16	0.38*	0.29	0.35*	0.25
Word Spelling	0.34*	-0.02	0.39**	0.07	0.34*	0.13
Pseudo Spelling	0.43***	0.14	0.51^^	0.14	0.18	0.26
Spelling Sensitivity	0.35*	0.32*	0.33*	0.11	0.35*	0.25
Word Ident Acc	0.27	0.2	0.12	0.18	0.34*	0.13
Word Ident RT	-0.33*	-0.32*	-0.42***	-0.32*	-0.22	-0.2
Pseudo Rdg Acc	0.35*	0.08	0.35*	0.12	0.39**	0.16
Pseudo Rdg RT	-0.27	-0.27	-0.13	-0.22	-0.06	-0.08

Category Inf- wds	0.24	0.29	0.14	0.25	0.22	0.30
Category Inf- pics	0.20	0.21	0.03	0.12	0.15	0.19

Note: All n = 45, * $p < .05$, ** $p < .01$, *** $p < .005$, ^ $p < .001$, ^^ $p < .0005$

There were some tasks for which participants with both poor lexical skill and poor comprehension skill had the lowest scores. These were Zekkish spelling ease and Zekkish inferencing. One description of Zekkish spelling ease is that it is the inference of sublexical patterns. For the inferencing, the effects were found primarily for word stimuli. Further, the poor/poor group did not gain as much from experience. This indicates that lexical knowledge feeds up into the comprehension system. When lexical knowledge is available, or when its need is bypassed as in the case of the picture stimuli, comprehension can proceed more smoothly.

In conclusion, performance on the Zekkish tests indicated that participants' scores conformed to their level of experience. No effects of Zekkish (or lab performance) experience were found for the English tests. Lexical skill was related to performance in both Zekkish and English. English comprehension was related to performance in both Zekkish and English. While some of the relationship to Zekkish does appear to be due to a basic comprehension skill, links through other basic skills as well as to experience were identifiable though minimal in their influence. There was some evidence of a feed-forward mechanism from lexical information to comprehension.

6. ERP DATA

We measured event related potentials to tasks utilizing the Zekkish and English languages because ERPs have been shown to be sensitive to the characteristics of interest in this study. We and other researchers have used ERPs to study individual differences in reading ability, effects of training in both English and an artificial orthography, and the electrophysiological changes associated with learning a second language. The location and strength of brain activation has been shown to change with reading skill, extent of training, language of the experiment (L1 or L2) ass well as to word characteristics such as the need to make an inference and the sufficiency of a word in context. In our Zekkish experiment we expect to find ERP amplitude and location differences to be associated with reading skill (lexical and comprehension), training status (partial and complete), language (English and Zekkish) and word characteristics (homophony and frequency). We also expect to find ERP differences to be related to the difficulty of the task. For this reason we included simple tasks such as identification of the three Zek characters as well as difficult tasks such as the pairing of Zek characters to Zekkish words.

6.1. ERP Methods

The six ERP tasks generally required 1.5 hours to complete, from cap application to cleanup. The first task, Zekkish word classification, was the longest, taking approximately 30 minutes. Zekkish pictures and English words took about 15 minutes each. The remaining three tasks took only about eight minutes, total. Participants viewed the stimuli on a 15-inch CRT monitor with a 60Hz refresh rate. Stimuli presentation and data collection was managed by commercial software, EPrime (Psychology Software Incorporation, Pittsburgh, Pennsylvania). Event information from EPrime was sent to the EEG recording system (NetStation, Electrical Geodesics Inc., Eugene, Oregon). A 128 channel Geodesic Sensor Net (EGI, Eugene, Oregon) was used to collect the EEG data. All impedances were kept below 40KOhms (Ferree, Luu, Russell, & Tucker, 2001). A vertex reference was used in the recording and the data were recomputed off-line against the average reference (Lehmann & Skrandies, 1980). Six eye channels were recorded to allow rejection of trials with eye movements and blinks. The signals were recorded continuously at 1000 Hz by EGI net station. Hardware filter setting was between 0.1 and 200 Hz. The EGI net station also recorded all event onset times, response times, and accuracy for later use in data analysis. The experiment took place in a dedicated ERP lab, located in an isolated, quiet room. The participant viewed the trials on a

CRT screen in the testing room, while the experimenter monitored the ERP recordings in an adjacent room.

Event related potentials were averaged off-line over the conditions in each task after eliminating eye-movements and other movement artifacts on a trial-by-trial basis. After a baseline correction, a 30Hz software low pass filter and bad channel replacement (also done by trial), data were downloaded into SPSS for analysis.

6.2. ERP Task Descriptions

We chose a series of tasks to elucidate comparisons of interest. Three of the tasks included word types expected to produce different ERP responses: homophones and controls, low frequency and high frequency words. The stimuli in these tasks were Zekkish words, Zekkish pictures, and English words. This allowed us to compare responses based on language (Zekkish and English) and modality (words and pictures). The picture task tested knowledge of Zekkish vocabulary while the word task tested knowledge of the vocabulary with the additional requirement of decoding. Another task measured the extent to which participants saw Zekkish decoding as reading. Finally, a nonlinguistic interference task was included as a comparison for homophone interference.

6.2.1. Zekkish word classification.

Participants read a Zekkish word and indicated which of the three Zek characters was associated with that word. At the beginning of a trial participants saw ~*****~ appear on the computer screen. This prompt stayed on the screen until participants hit the space bar to begin the trial. Having this "ready" signal ensured that participants were focused on the task and looking at the screen. A fixation cross appeared for 1000 ms before the word appeared centered on the screen. Participants used the index, middle and ring fingers of their right hands to indicate that the word was associated with Teb, Dek, or Gep, respectively. The 1, 2, and 3 keys on the keyboard's number pad were color coded with the Zeks' body colors to aid in mapping. The Zekkish word remained on the screen for four seconds or until a response was made. No feedback was provided. Each of the 48 Zekkish words were presented five times, for a total of 240 trials. Homophones and controls, low frequency and high frequency words were presented with equal frequency.

Even at chance performance, the expected number of correct trials per bin (not accounting for movement artifact) was 20. The rate of movement artifact was high, especially after partial training. Participants often looked away from the screen while thinking or moved their eyes clockwise, following the letters as they decoded the word. Often the first several trials were spent coaching the participant on how to avoid movement artifact. However, participants in this experiment were supremely motivated to follow the examiner's instructions and to perform well. Participants nearly always corrected their performance.

6.2.2. Zekkish picture classification.

Participants saw pictures representing meanings of the Zekkish words. The pictures were the same ones they had used to learn the meanings of the words, except that the Zek characters were removed from the pictures and the pictures were black and white. Stimuli are shown in Appendix H. The task and the experiment design were the same as for the Zekkish word classification. The pictures were large, and participants were asked to focus on the center of the screen. The low rate of movement artifact attests to their motivation and skill in doing this. Each picture was presented four times, for a total of 192 trials.

6.2.3. Zekkish name recognition.

Participants saw the names of the Zekkish characters. The task and the experiment design were the same as for the previous experiments, except that the maximum time for stimulus presentation was two seconds. Each name was presented 15 times, for a total of 45 trials.

6.2.4. Zekkish character recognition.

Participants saw pictures of the Zekkish characters, in color. The task and the experiment design were the same as for the Zekkish name classification. Each character was presented 15 times, for a total of 45 trials.

6.2.5. Zekkish character color interference.

Participants saw pictures of the Zekkish characters, in color. Half the time the Zeks were presented in the appropriate colors, and half the time they were presented in the color associated with one of the other Zeks. This task was described to the participants as an indication of the Zeks' sense of humor. The Zeks were wearing costumes to try to trick them into making an incorrect response. The task and the experiment design were the same as for the Zekkish character classification. Each character was presented in the appropriate color 16 times, and in an interfering color 16 times (eight times in each other color) for a total of 96 trials.

6.2.6. English word classification.

Participants saw English words that could be placed into one of three categories: people/groups of people, animals, and objects. Like the Zekkish words, there were equal numbers of homophones and controls, and of low frequency and high frequency words. There were not equal numbers of words in each category. The task and experiment design were the same as for the

Zekkish word classification, except that the maximum time for stimulus presentation was two seconds. There were 48 unique words of each type, and each word was presented only once, for a total of 192 trials. The words in this task were not repeated in the experimental task involving English homophones and controls. Stimuli are listed in Appendix H.

6.3. Behavioral Results of ERP tasks

As in other sections, details of data trimming are included in Appendix L and statistics are included in Appendix M.

6.3.1. Zekkish word classification.

Data are shown in Figure 6.3.1. Participants were faster and more accurate after complete training than after partial training, for high frequency words than for low frequency words, and for controls than for homophones (especially for low frequency words). Good comprehenders were more accurate than poor comprehenders, especially for low frequency words, and especially after complete training. Participants with good lexical skill were more accurate than participants with poor lexical skill, and faster for high frequency words as well.

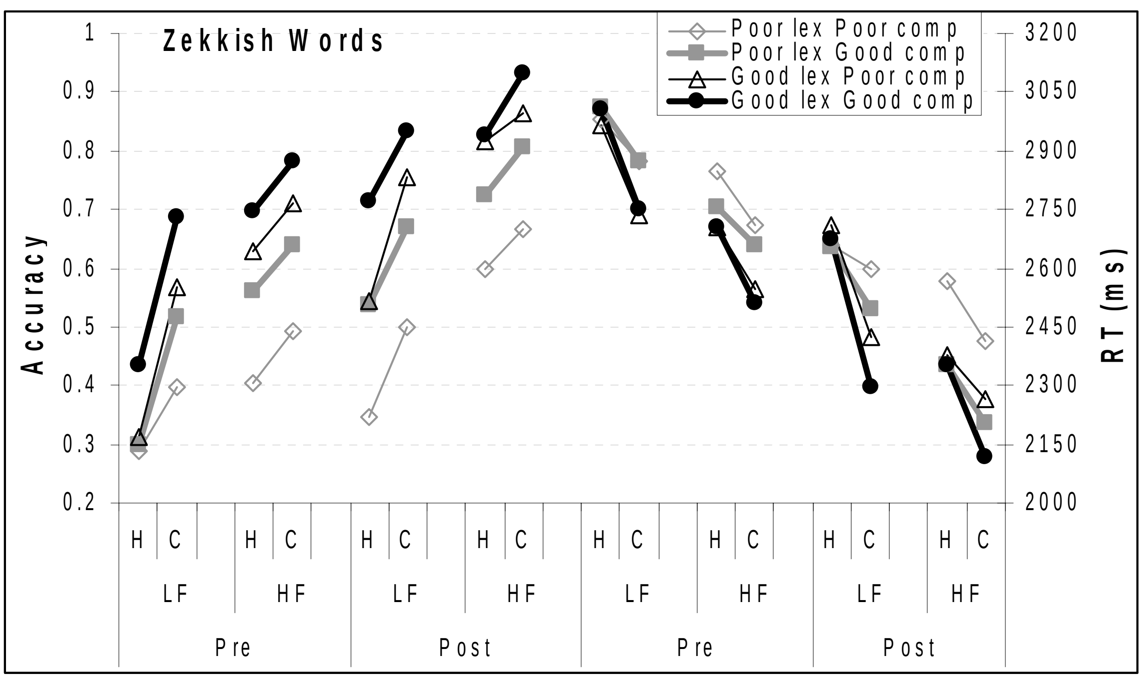

Figure 6.3.1. Response time and accuracy data for Zekkish word classification

6.3.2. Zekkish picture classification.

Data are shown in Figure 6.3.2. Participants were more accurate for high frequency words than for low frequency words after partial training. They were faster overall after complete training than after partial training, for homophones than for controls when the words were of high frequency, and for high frequency words than for low frequency words after partial training. Participants with good lexical skill were faster than participants with poor lexical skill. Participants with good comprehension skill were faster than participants with poor comprehension skill for low frequency words.

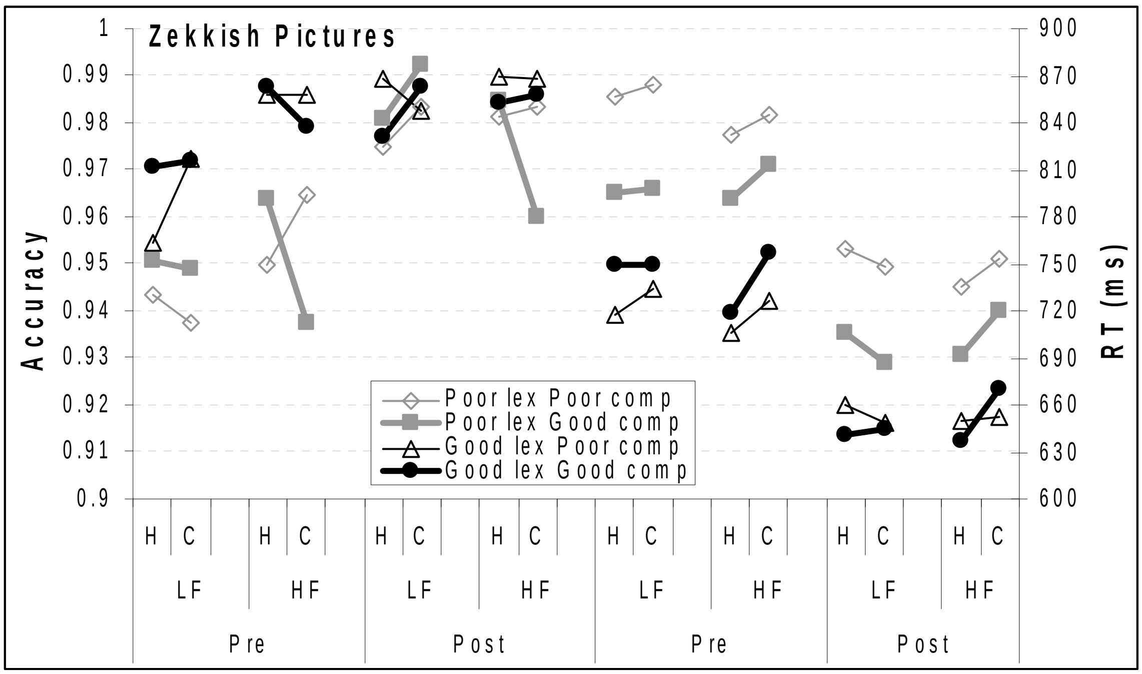

Figure 6.3.2. Response time and accuracy data for Zekkish picture classification

6.3.3. Written language sensitivity (Name and Character Recognition).

Data are shown in Figure 6.3.3. Accuracy on these tasks was very high; greater than 98% overall. Participants were faster for pictures than for written names and faster after complete training than after partial training. Participants increased their speed from the test point after partial training to the test point after complete training much more for names than for pictures. Participants with good lexical skill were faster than participants with poor lexical skill.

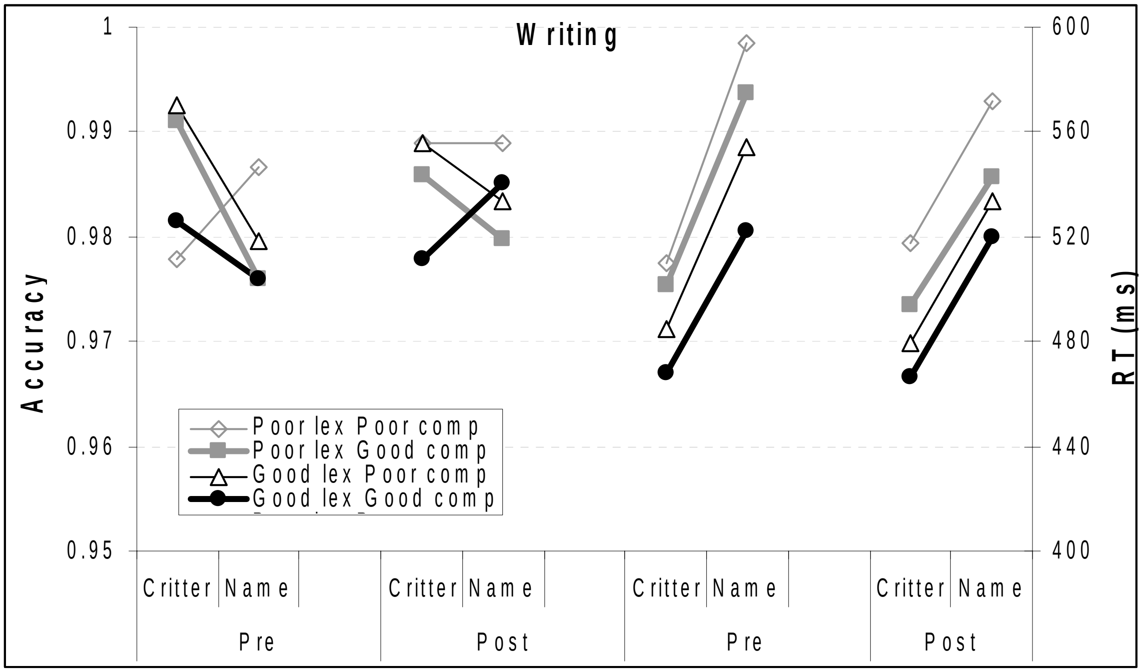

Figure 6.3.3. Accuracy and response time data for written language sensitivity

6.3.4. Nonlinguistic interference effects.

Data are shown in Figure 6.3.4. Participants were faster and more accurate when the trials presented no interference, and faster after complete training than after partial training. Participants with good lexical skill were faster than participants with poor lexical skill.

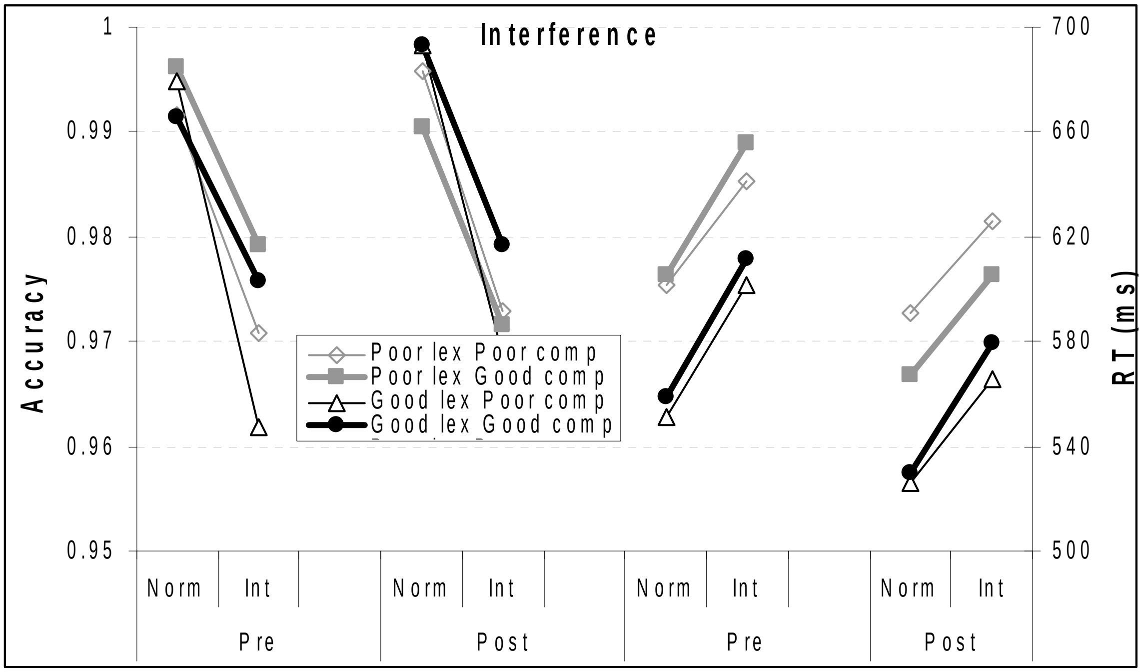

Figure 6.3.4. Accuracy and response time data for nonlinguistic interference effects

6.3.5. English word classification.

Data are shown in Figure 6.3.5. Participants were faster and more accurate for controls than for homophones (especially after complete training), and for high frequency words than for low frequency words. Poor comprehenders had a greater decrement in accuracy due to homophony and low frequency, but good comprehenders had a greater decrement in speed due to homophony.

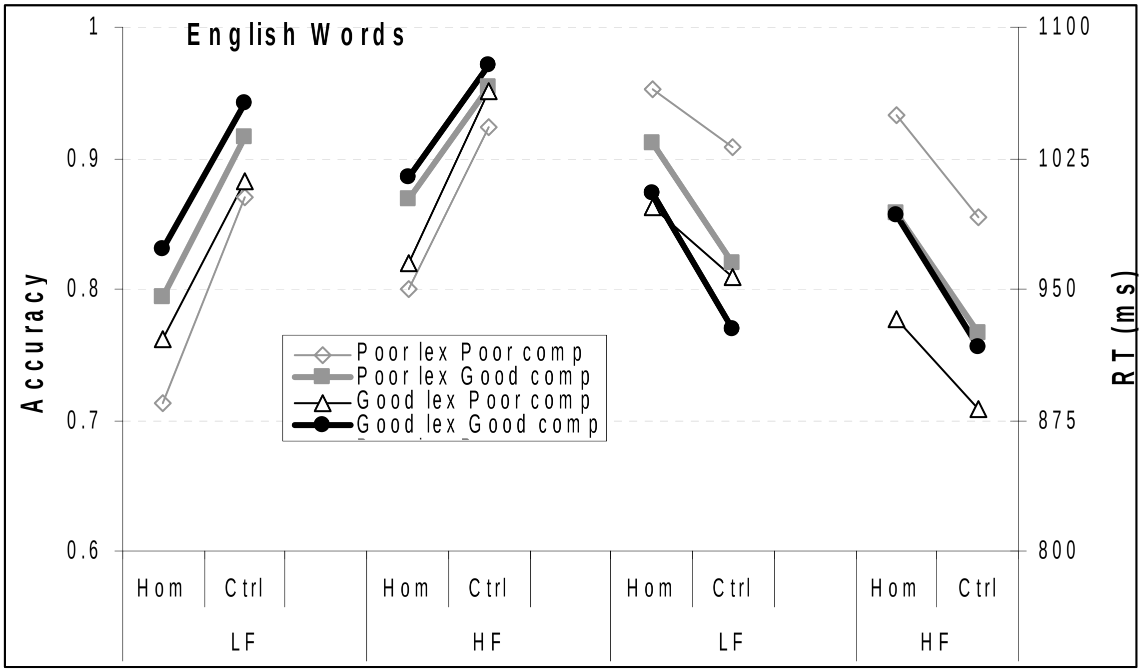

Figure 6.3.5. Response time data for English word classification

6.3.6. Summary of ERP Behavioral data

On the Zekkish reading task, the stimulus manipulations were effective; that is, participants were faster and more accurate for controls than for homophones, and for high frequency words than for low frequency words. Overall, participants with better lexical skill were faster and more accurate. Participants with better comprehension skill were more accurate, conditional upon condition; they were more accurate after complete training, and when the words were of low frequency. While lexical skill always had an effect, comprehension skill interacted with experience, via word frequency and test time.

The Zekkish picture task was included to make sure participants knew the vocabulary word-Zek associations, and to separate vocabulary knowledge effects from reading effects. On the Zekkish picture task, participants were almost universally highly accurate. They only showed a slight decline in accuracy for low frequency words after partial training, and all groups showed this effect. This indicates that knowledge of word meanings, and the associated Zek characters, was quite high, and that any effects found on the Zekkish word task were likely due to reading, and not knowledge of Zekkish vocabulary. As on the Zekkish reading task, lexical skill had an overall effect, whereas effects of comprehension skill were conditional upon experience. One surprising result was that participants were faster for high frequency homophones than for high frequency controls. Perhaps this indicates participants' attention to homophone discrimination, which was necessary since the two words in a homophone pair were associated with two different Zek characters.

The writing task was included as an indicator of a reading approach to the task. It was conceivable that participants could complete the Zekkish reading task without really reading. There were only 48 words to learn, and participants could have simply memorized the shapes of the words; the overall "pictures." However, participants were faster to indicate which Zek picture they saw than which Zek name they saw, and their speed improved more for names than pictures. This indicates that participants were approaching the name task as a reading task more than a picture identification task. In addition, the overall advantage for participants with better lexical skill is seen in this task, as well.

The nonlexical interference task was included as an indicator of specificity of interference effects. Any interference effects found in the Zekkish or English reading tasks that are not found in this Stroop-like task can be considered to be linguistically based. All participants showed interference on this task, in that they were slower and less accurate on interference trials than on control trials. Again, participants with better lexical skill were faster overall. No effects of comprehension skill were found on this task. The comprehension effects found in the Zekkish word and picture task appear to be linguistically based, whereas the lexical effects appear to be a due to a basic function that affects performance regardless of the specific task demands.

The English word task was included to examine the similarity of performance of participants in Zekkish and English. As for Zekkish, the stimulus manipulations were effective; participants were more accurate for high frequency words than for low frequency words, and for controls than for homophones. There were also conditional effects of comprehension skill; good comprehenders were more accurate overall, were less affected by homophony, and were less affected by frequency. However, they were more affected by homophony for speed; good comprehenders were more slowed for homophones relative to controls than poor comprehenders. To some extent, the different comprehension groups traded off speed and comprehension differently. There were no effects of lexical skill.

In summary, regardless of the language, homophone effects and word frequency effects were evident. Comprehension skill affected performance on linguistic and experience-related tasks, while lexical skill affected overall performance on all tasks but English.

6.4. ERP Amplitude Data Analysis

There are a multitude of techniques for analyzing ERP data. All have the same primary goal: to limit the data to be analyzed. The number of variables is staggering, with 800 time points and 129 electrodes per condition, or 103,200 variables. Multiplied by the 28 stimulus types across the tasks in this experiment, there are 2,889,600 numbers per participant, and 130,032,000 numbers in all. The temporal and spatial densities of these data are large. In addition, there are many within-participants variables, as well as two between-participants variables, in each experimental task. Third, even though a direct comparison (i.e. in the same analysis) of the tasks is not desired, the conclusions that are drawn from one analysis depend on the conclusions drawn in other analyses, so the analyses need to be parallel. Finally, the hypotheses regarding the ERP data are based on differences between conditions, not on specific locations or times. For all these reasons, we chose a bottom-up, data-driven analytic technique that reduced the data to a maximum extent. The following steps were undertaken for the analysis of each experimental task.

1. Data were truncated at 800 ms, and reduced from 1000 Hz to 200 Hz. That is, every fifth data point was included in the analysis.
2. The data were participanted to a temporal factor analysis with 161 variables (0-800ms), and 45 participants x # conditions (4 or 8) x 129 electrodes as records. A covariance matrix was used, and factors with eigenvalues above one were rotated orthogonally via varimax rotation. All factors with loadings above .4 except for the first factor (invariably the one involving the latest time points) were retained for further analysis.
3. The factors (two for Zekkish words, three for the other tasks) were participanted to a spatial factor analysis with 129 variables (the electrodes) and 45 participants x 3 conditions (4 or 8) x factors (2 or 3) as records. Again a covariance matrix was used, and factors with eigenvalues above 1 were rotated orthogonally. All factors with loadings above .4 were retained for further analysis. The factor structures at this point were remarkably similar across the tasks.
4. An ANOVA was run with within-participants variables of stimulus types, temporal factors, and spatial factors, and between-participants variables of lexical skill and comprehension skill.

   Because participants were expected to be fairly inaccurate on some of the tasks, especially Zekkish words at partial training, no participant's data were excluded because of low numbers of trials. Reported in Table 6.4.1 are the mean number of trials included in each average; complete statistics are included in Appendix N.

Table 6.4.1 Number of trials included in each ERP average.

		Zek (Corr)	Zek (Incorr)	Zek Pict	Eng		Wri	Interfer
Partial	LF Hom	16.49	30.49	40.69	32.07	Names	39.30	
	HF Hom	28.80	18.44	41.13	33.49	Critters	38.89	
	LF Ctrl	26.80	20.33	40.69	37.09	Normal		42.09
	HF Ctrl	32.62	15.44	41.31	38.09	Interference		41.68
Complete	LF Hom	27.49	23.31	41.62	34.42	Names	40.16	
	HF Hom	37.67	12.62	41.82	36.89	Critters	40.11	
	LF Ctrl	36.36	15.38	41.58	38.11	Normal		44.31
	HF Ctrl	42.24	9.04	42.56	40.89	Interference		44.38

6.5. ERP Amplitude Data

We report in this text only overall representations of the factor structures, total variance explained, peaks of each temporal factor, and locations of each spatial factor. Tables of variance explained by each factor, graphs of temporal factors, representations of spatial factors, and statistics from ANOVAs are reported in Appendix N. The data are too complex to discuss in their entirety here. Instead, we report significant results in a summary table, and discuss specific patterns of results that provide insight into the experimental hypotheses and to the interpretation of the training and behavioral data.

6.5.1. ERP Amplitude Data Summary

The factor structures themselves provide some insight into the similarities between tasks. Figure 6.5.1 shows the temporal factors, overlaid for the five ERP tasks.

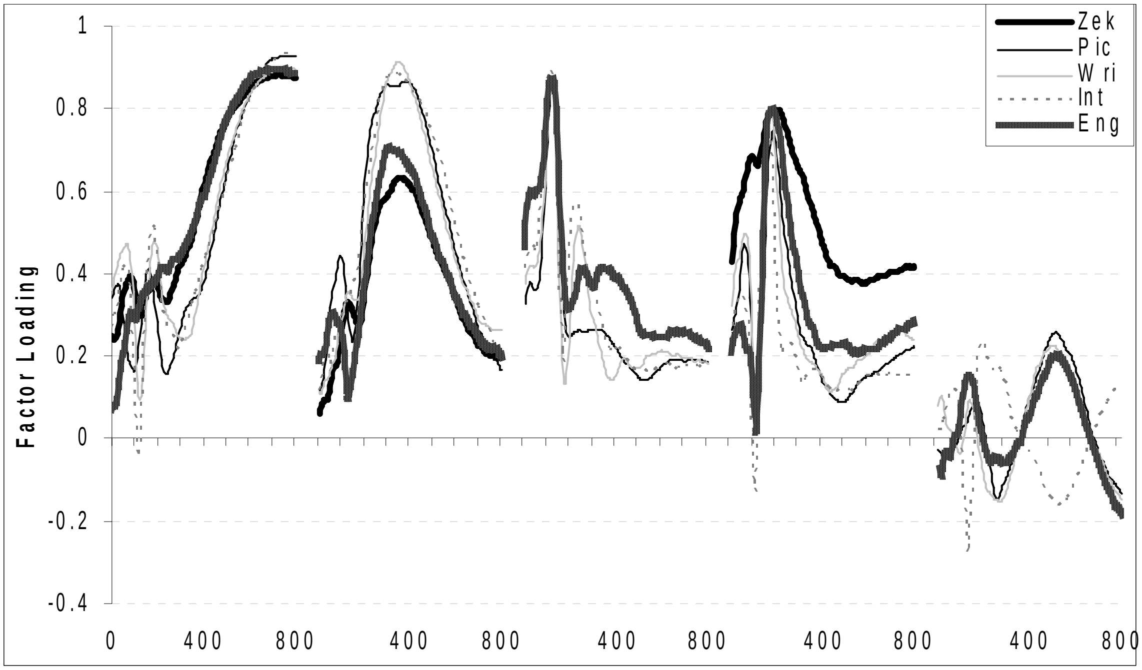

Figure 6.5.1. Temporal factor structures for the five ERP tasks.

There are several properties of this graph that are striking. First, the factors are neatly overlaid upon one another. This is despite the fact that the tasks were blocked, and very different; some were in Zekkish, some were pictorial, and one was in English; some were very easy, others were very difficult. Second, the tasks cluster according to modality. Reading tasks (Zekkish word and English word) look similar for the latest two factors, rising earlier for the latest factor and peaking lower for the 300 ms factor. The tasks that included pictures formed a second cluster. Third, most likely due to its difficulty, Zekkish words had a different factor structure for the earlier factors. Whereas the other four tasks had one factor at about 120 ms and another factor at about 200 ms, one Zekkish factor accounts for both of these. It is likely that the processes that are automatized in English and picture tasks are not yet automatized in Zekkish. This makes them take longer, have more variance, and depend more on processes that are nearby in time. In other words, processes that are usually separate in skilled word and picture processing are still intertwined for Zekkish reading. Nonetheless, the temporal factor structure provides evidence that Zekkish words is indeed a reading task, and that despite their high accuracy after complete training, reading is still fairly labor-intensive. It is possible that if factor analyses had been done on data after partial training and after complete training separately, the data after complete training would have separate factors.

Figure 6.5.2 shows the electrodes at which all five factor structures had loadings above .5. White electrodes were inconsistent or nonsignificant for one or more factor structures.

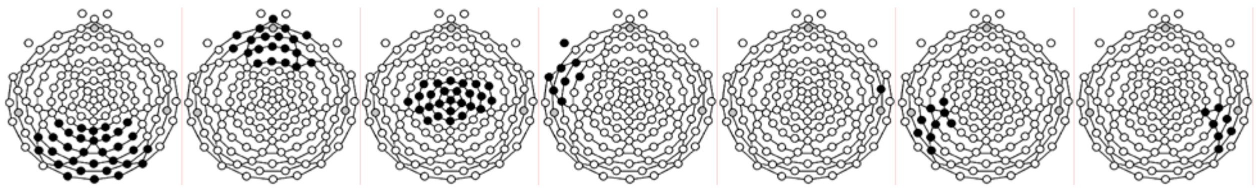

Figure 6.5.2 Electrodes common to factor structures in all five ERP tasks.

Like the temporal factors, the spatial factors were remarkably consistent. The factor order differed slightly, but all had three midline factors (frontal, vertex, and occipital), two parietal factors (right and left), and one or two temporal factors. The right temporal factors were least consistent. Also like the temporal factors, comparisons among the spatial factor structures provide some evidence about processing in the tasks. First, the two tasks that had only one temporal factor instead of two were the easiest tasks. Second, there was a great deal of overlap in the electrodes that loaded on each factor for the English word task. Whereas joined factors, such as the Zekkish 100-200 ms temporal factor, may indicate processing interconnectedness, overlapping factors are more likely to have a different explanation. Whether temporal or spatial, the size of a factor (and thus its overlap with adjacent factors) may indicate its strength. English spatial factors encompass a broader area than factors from the other tasks. This may be due to larger or stronger neural generators, and decreased variability in response, leading to more electrodes responsive to the same electrical source.

6.5.2. Zekkish words

The temporal factor analysis for Zekkish words produced two factors for further analysis: one that peaked at 200 ms and one that peaked at 350 ms. Three factors (including the first, late factor) explained 88.33% of the variance.

The spatial factor analysis for Zekkish words produced seven factors for further analysis, loading electrodes at occipital, vertex, frontal, left temporal, right temporal, left parietal, and right parietal locations. These factors explained 78.83% of the variance.

6.5.3. Zek Pictures

The temporal factor analysis for Zek pictures produced three factors for further analysis: one that peaked at 120 ms, one that peaked at 200 ms and one that peaked at 350 ms. Four factors (including the first, late factor) explained 88.97% of the variance.

The spatial factor analysis for Zek pictures produced seven factors for further analysis, loading electrodes at occipital, vertex, frontal, left temporal, right temporal, left parietal, and right parietal locations. These factors explained 85.51% of the variance.

6.5.4. Writing

The temporal factor analysis for writing produced three factors for further analysis: one that peaked at 120 ms, one that peaked at 175 ms and one that peaked at 350 ms. Four factors (including the first, late factor) explained 90.01% of the variance.

The spatial factor analysis for writing produced six factors for further analysis, loading electrodes at occipital, vertex, frontal, bilateral temporal, left parietal, and right parietal locations. These six factors explained 84.02% of the variance.

6.5.5. Nonlinguistic interference

The temporal factor analysis for nonlinguistic interference produced three factors for further analysis: one that peaked at 110 ms, one that peaked at 160 ms and one that peaked at 325 ms. Four factors (including the first, late factor) explained 89.42% of the variance.

The spatial factor analysis for nonlinguistic interference produced six factors for further analysis, loading electrodes at occipital, vertex, frontal, bilateral temporal, left parietal, and right parietal locations. These six factors explained 84.71% of the variance.

6.5.6. English words

The temporal factor analysis for English words produced three factors for further analysis: one that peaked at 120 ms, one that peaked at 175 ms and one that peaked at 325 ms. Four factors (including the first, late factor) explained 89.53% of the variance.

The spatial factor analysis for English words produced six factors for further analysis, loading electrodes at occipital, vertex, frontal, bilateral temporal, left parietal, and right parietal locations. These six factors explained 74.34% of the variance.

6.5.7. Data Summary

Table 6.5.1 summarizes the significant effects in the ERP tasks. Stimulus and test time effects form the columns, individual differences effects form the rows, and interactions with time and space are included in the cells. M indicates a main effect (no interaction with time or space), t indicates an interaction with time, s indicates an interaction with space, and ts indicates an interaction with both time and space. The letters Z, E, P, I, and W stand for the tasks: Zekkish word, English word, Zek picture, Interference, and Writing tasks, respectively. Grey boxes are cells that were not included in the ANOVAs. That is, Interference and writing tasks had no frequency variable, and the English task had no test time variable.

Table 6.5.1. Significant effects across all five ERP tasks.

	Task	*Main Effect*	*Inter-ference*	*Frequency*	*Int x Freq*	*Test Time*	*Int x TT*	*Freq x TT*	*Int x Freq x TT*
Main Effect	Z	ts				ms			
	E	ts							
	P	t, ts	ts	t, s, ts	t, s, ts	m			
	I	t, ts	ts						
	W	t, ts	t, s, ts						
By Comp	Z								
	E				m				
	P	t, ts	m, ts						
	I					t, s	ts		
	W	t					m		
By Lex	Z				s				
	E								
	P		s		s, ts				ts
	I					t			
	W					s			
By Comp x Lex	Z					s	m	s	m
	E			t					
	P	s		s		m			
	I	s							
	W								

Results are summarized by category.

1. Main effects of time and space. As expected, there are nearly always main effects of time, space, and/or time by space. The amount of brain activation across time and across the scalp

varied, such that different ERP components were maximally active in different locations. Rarely do these effects interact with the individual differences variables of comprehension and lexical skill, indicating that the general pattern of responding was similar for all participants.

2. Interference and frequency effects. This includes the character/name effect in the writing task. All three picture tasks show main effects of interference. Homophones (and names) produced different activation than controls (pictures). In addition, the homophone effect in the Zek picture task interacts with lexical skill and comprehension skill. This is the only picture task with a significant learning/memory load, and thus the only one in which skill would be expected to have an effect. The picture task also has a main effect of frequency, and an interaction between interference and frequency. The extent to which brain activity varied due to homophone interference was dependent upon how familiar participants were with the stimulus. In the Zekkish and English reading tasks, homophone interference and word frequency only affected individuals in certain reading groups. For Zekkish, the interaction depended on lexical skill. For English, it depended on comprehension skill for the interference by frequency interaction, and both lexical skill and comprehension skill for the frequency effect.
3. Test time effects. Performance on two of the five tasks was based on the extent to which participants had learned the Zekkish vocabulary words. Test points were timed for maximal difference in the amount of consolidation of learning, with the first point being right after participants had learned the words to a minimal criterion, and the second point being after a great deal of practice. The three tests based on a minimum of new knowledge – already learned English, or only three items: Zek colors or Zek names, showed no test time effects. When the learning load was higher (48 word/picture/Zek associations), there were test time differences. Both Zekkish words and Zekkish pictures produced main effects of test time, as well as interactions with both comprehension and lexical skill. Further, test time affected the effects of interference and frequency for Zekkish words and pictures, but only for some reading groups.

6.6. Discussion

The ERP data, in that lexical skill differentiates Zekkish ERP reading effects and both lexical and comprehension skill differentiates English ERP reading effects, is cleaner than the associated behavioral data, where comprehension played a role in Zekkish performance and lexical skill played no role in English performance. Our explanation for these ERP effects is that when reading Zekkish, participants use their lexical skill because the decoding strategies and the words themselves are so new. When reading English, participants use both their lexical (here, decoding) skill and their comprehension (here, word experience) skill. And lexical skill is indeed important only when the English words are of low frequency, and thus newer to the participants. While the training data indicated that lexical skill affects the extent and rate of language learning, including both decoding and meaning activation, the ERP data indicate that it is also lexical skill (rather than comprehension skill) that affects the ability to use the language in new tasks once it is learned. Thus ERP data help to localize the source of the comprehension effects seen in the behavioral testing data: comprehension affects performance more as the testing tasks differed more from the training tasks. Comprehension skill affects the ability to use information in new ways, but both learning and performance in a language are primarily affected by lexical skill.

7. HOMOPHONE EXPERIMENT 3 (GERNSBACHER DESIGN)

In the introduction we mentioned two prior experiments in our lab. Both used homophones and controls of low and high frequency to manipulate lexical quality in good and poor comprehenders. Here we review the experiments in more detail and describe the advantages of doing a similar study in Zekkish.

The basic task design was taken from Gernsbacher & Faust (1991). Consider the words "fight" and "night." Both are fairly high frequency words. However, the phonology of "fight" leads to activation of a single lexical representation (an altercation), while the phonology of "night" leads to two (time after dusk, and king's army). Despite similar word frequencies, the lexical quality of "night" is expected to be lower than the lexical quality of "fight," because of the need to choose between activated lexical representations. Gernsbacher & Faust presented participants with a homophone or control (non-homophone) followed by a second word, either related or unrelated to the first word. Participants were given 450 or 1350 ms to read the first word before the second appeared on the screen. Participants judged whether or not the words were related. The critical trials were unrelated word pairs. All participants were slower for homophones than controls at 450 ms SOA. The conclusion was that participants had activated their lexical entries of the first word and were having trouble disambiguating between the homophone lexical entries. By 1350 ms SOA, only less-skilled comprehenders were slower for homophones than for controls. The conclusion was that more-skilled comprehenders had suppressed the irrelevant homophone meaning while less-skilled comprehenders, had less efficient suppression mechanisms and had not yet suppressed the irrelevant meaning.

Our Experiment 1 extended these findings with an earlier and a later SOA and with high frequency and low frequency words. Overall, slowdowns for homophones compared to controls were limited to 450 ms. This indicated that in general it took participants longer than 150 ms, but less than 2000 ms to activate word representations and disambiguate competing representations. In addition, slowdowns were generally limited to low frequency words, with high frequency words being somewhat protected from interference. The low frequency homophones were not of high enough quality to threaten the activation and selection of the representations of their higher frequency homophone mates.

Like Gernsbacher and Faust, we divided participants based on their reading comprehension in Experiment one. Participants with good reading comprehension (top third of the distribution of the Nelson-Denny reading comprehension subtest) were faster to activate word representations; they already showed a slower response time to homophones at 150 ms SOA. Participants with poor reading comprehension (bottom third of the distribution of the Nelson-Denny reading comprehension subtest) did not have a homophone interference effect until 450 ms. A subset who were also the slowest on the Nelson-Denny comprehension test, never did disambiguate meanings. This subgroup still showed a homophone interference effect at the 2000 ms SOA. In addition, the poor readers' interference effects were for the higher frequency words. Overall, words of high frequency for good comprehenders were of lower frequency for poor comprehenders, most likely due to less reading experience and fewer encounters on average with all words. Words that were of low frequency for good comprehenders were of such low frequency for poor readers that either their word representations were too unstable to be adequately activated, or their representations did not exist at all (participants simply did not have the words in their vocabularies).

While Experiment 1 was designed to show an effect of lexical quality on reading comprehension, it applies to manipulation of reading experience as well. Recall the assertion that lower word frequency is analogous to less experience with a word, and that less experience leads to lower quality word representations. This serves as a basis for understanding some individual differences: people with less reading experience will have lower quality word representations. In Experiment 1, participants with poorer reading comprehension are assumed to have less reading experience.

Experiment 1 provides some evidence that lexical quality and reading experience are related to reading comprehension in college-age people. However, the experiment design has some limitations. First, lexical quality and reading experience are confounded in this experiment. The extent to which each of these variables produces the response time effects is not clear.

Second, reading experience on average is manipulated in this experiment, but individual experience is not controlled. In other words, it is likely that each participant had a different amount of experience with each word in the stimulus set. While one participant might know the homophone pair "hair" and "hare" very well, another participant might not. Similarly, while a single participant might know some of the low frequency words well, he might not know the other half at all.

Third, this experiment did not separate lexical skill and comprehension skill. The object of the experiment was to show the extent to which lexical quality affects reading comprehension, not the extent to which lexical skill and reading comprehension differentially affect reading skill in college students.

Finally, there are aspects of reading experience other than the number of encounters with a word that can affect current readings skill. There is the extent to which learning to read focused on decoding, current reading strategy, motivation, and a host of other similar variables. None of these were controlled by the word frequency/experience manipulation

The second experiment in our lab (Balass & Hart, in preparation) addressed the first two limitations of Experiment one: reading experience was controlled at the level of individual participants and individual items. This manipulation removed reading experience, at least as measured by differential word encounters, as a source of variance and made the effects of word frequency clearer. Participants were given a homophone orally, and asked to spell and define it two different ways. Then they rated their familiarity with each spelling/meaning on a scale of 0 (never heard of it) to 3 (use it all the time). Twelve homophone pairs for which one word was rated as a 1 or, rarely, a 0 and the other was rated as a 3 or, rarely, a 2 were chosen for each participant. One half of the homophones rated as less familiar were chosen as training words. Participants practiced the meanings of these words in two 45 minute sessions in a game-like format designed to increase motivation[9]. Testing, in an experiment of the same format as in Experiment one, was conducted before and after training. Results were that all participants, regardless of comprehension skill, showed the same basic pattern of results: early activation, followed by eventual disambiguation, for homophones versus controls. In addition, while the lower frequency homophone showed a slowdown relative to controls prior to training, the higher frequency homophone showed a slowdown after training. The relative frequencies of the words were reversed with increased experience with the trained words. Lexical quality due to word frequency was the same as lexical quality due to word experience. The effects of lexical quality on comprehension skill found in Experiment one could essentially be retitled as the differences in lexical quality based on reading experience

Experiment two did not control all confounds. Individual differences were essentially removed by the individualized word familiarity ratings. While this demonstrates the effects of word experience on comprehension skill, it leaves open the question as to how lexical skill relates to reading experience and to comprehension skill. Experiment two also does not limit the effects of other experience variables such as motivation, method of reading instruction, or reading strategies.

The current experiment extends these findings by controlling experience by bypassing current language knowledge and training participants in an artificial orthography. Motivation to learn was controlled by experimental context. In addition, effects of lexical skill and comprehension

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[9] The game-like format designed to increase motivation seemed to have worked, as evidenced by the number of players cheering wildly for themselves as they increased to a new game level or won more lives, and by the number of players who were greatly concerned with their overall standing relative to the other players (something not mentioned as a study asset).

skill are separated. The English portion of this experiment also used a new stimulus set, which more carefully controlled for frequency and semantic relatedness (See Appendix J). We expect to find that lexical skill affects results of this test, but the effects of comprehension skill vary with reading experience, both in English and in Zekkish.

7.1. Methods

Participants were presented with a word on the computer screen, followed by another word. The first word was always a homophone or control, and high or low frequency, with word types in equal proportions. In English, the second word was either related to the first word, or unrelated but related to an equal extent to the word's partner. For example, "Chilly" is related to "snow" to the same extent that "chili" is related to "food." Unrelated pairs were "chilly – food" and "chili – snow." (More relatedness and frequency constraints are presented in Appendix J.) In Zekkish, the second word was always the name of a Zekkish character who was either related to the word presented, or related instead to its partner. Participants were asked to judge whether the words were related, by making a "yes" or "no" judgment. Each word pair was preceded by a cue, ~*****~. The task did not continue until the participants pressed the space bar, so they were maximally likely to be attending to the stimuli. The cue was followed by a 500ms orientation cross presented in the center of the screen where the words would be shown. Word one appeared, followed by a blank screen presented for an interstimulus interval (ISI), and word two appeared for two seconds or until participants made a response. No feedback was given. In English, the presentation time for word one was 100ms with 50ms ISI (for a total 150ms SOA), or 350ms with a 100ms ISI (450ms SOA), 1000ms ISI (1350ms SOA), or 1650ms ISI (2000ms SOA). For Zekkish, word one was always presented for 350ms. The ISIs were 100ms (450ms SOA), 650ms (1000ms SOA), 1150ms (1500ms SOA), and 1650ms (2000ms SOA). Assignment of SOAs to stimuli was pseudorandom, but stimulus order to participants was random. There were 192 stimuli in all, six in each condition (homophony by frequency by relatedness by SOA).

7.2. Homophone (Gernsbacher) Task Results - English

As in other chapters including behavioral data, information on data trimming is included in Appendix L and statistics of significant results are included in Appendix M. These data are very complex, so two separate ANOVAs were conducted. The first included the 150 ms and 450 ms SOAs. The second included the 1350 and 2000 ms SOAs. Figure 7.2.1 shows data that have been collapsed across skill variables because there were few effects of skill in the English data. The complete data are presented in Appendix K

Participants were faster and more accurate at 450 ms than at 150 ms and for unrelated than for related trials. Homophone interference increased from 150 ms to 450 ms for low frequency words while a homophone advantage increased from 150 ms to 450 ms for high frequency words – in some cases changing from a disadvantage at 150 ms to an advantage at 450 ms. The homophone effects on accuracy were exaggerated for participants with good lexical skill. Good comprehenders were more accurate than poor comprehenders (0.86 vs. 0.82). Participants in the extreme groups (good comprehension skill and good lexical skill, poor comprehension skill and poor lexical skill) gained less speed (43ms and 42 ms, respectively) than participants in the marginal groups (82ms for good lex/poor comp and 86ms for poor lex/good comp).

Participants were more accurate at 1350 ms than at 2000 ms, faster for related trials than for unrelated trials, and faster for unrelated controls than for unrelated homophones. Homophone interference was still present in most cases for low frequency words and homophone advantage continued to increase for high frequency words in most cases. There was more of a drop in accuracy over time for participants with poor lexical skill than for good lexical skill. Participants with better comprehension had higher accuracy overall (.89 vs. .86). Participants with good lexical skill were faster than participants with poor lexical skill (774ms vs. 870ms).

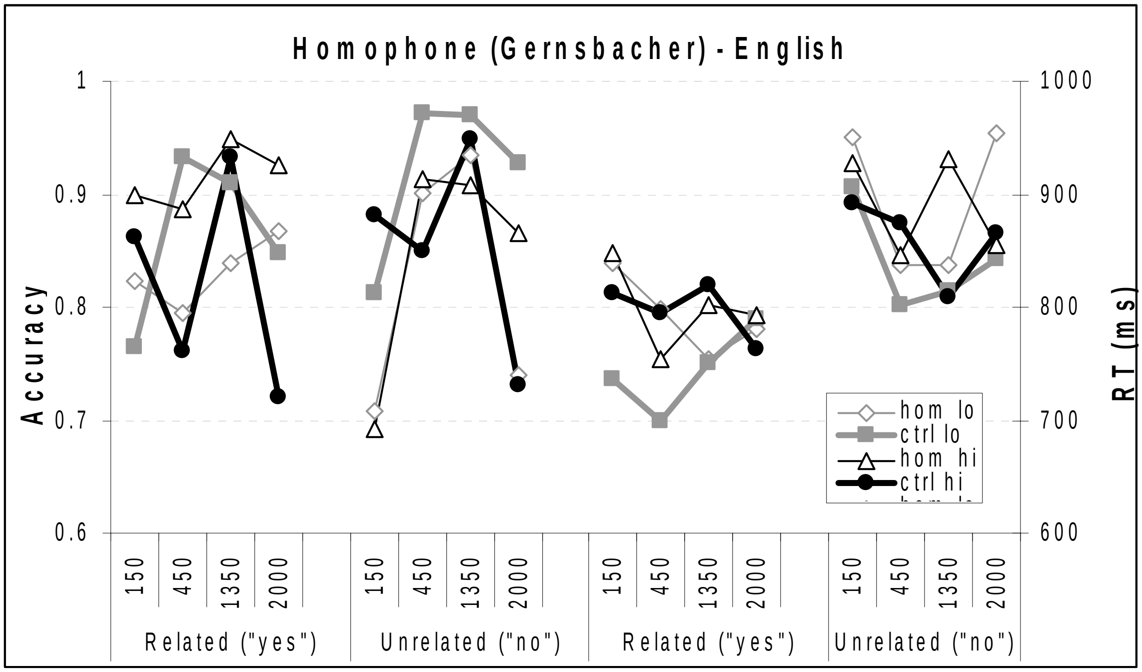


Figure 7.2.1 Accuracy and response time for the homophone (Gernsbacher) task in English.

7.3. Homophone (Gernsbacher) Task Results - Zekkish

In the complete design, there would be five within-participants variables, and two between participants variables. As the data from this task were messier than those of some other tasks due to its difficulty, the data were collapsed over relatedness and frequency to look at the main pattern of interest: lexical activation/deactivation patterns of homophones over time from the test point after partial training and the test point after complete training, in each of the four reading groups. The complete data are presented in Appendix K. ANOVAs were run on pairs of SOAs, and the data from the test sessions after partial training and complete training were analyzed separately to be as comparable as possible with the English data.

After partial training, participants were more accurate at 1000 ms than at 450 ms and faster at 2000 ms than at 1500 ms. They were more accurate for controls than for homophones at all SOAs. Participants with good lexical skill were more accurate than participants with poor lexical skill at all SOAs. Although Figure shows some evidence of a build in the homophone interference effect (for accuracy) from 450 ms to 1000 ms for participants with good lexical skill, the three-way interaction was not significant. By the later SOAs of 1500 and 2000 ms, however, there was a clear interference effect (in RT) for participants with good lexical skill but not for participants with poor lexical skill.

After complete training participants were more accurate at 1000ms than at 450ms. They were more accurate for controls than for homophones at all SOAs. Participants with good lexical skill were more accurate than participants with poor lexical skill at all SOAs, and participants with good comprehension skill were more accurate than participants with participants with poor comprehension skill at all SOAs, but especially at 1000ms. The homophone interference effect increased from 450ms to 1000ms. The interaction that shows participants with both good comprehension and good lexical skills to be the only ones to show homophone interference by 450 ms, and the interaction that shows a decrease in homophone interference by 2000 ms were not significant

Response time effects actually involve some homophone advantage. Participants with good lexical skill were actually slower than participants with poor lexical skill at the two earlier SOAs. While participants with good lexical skill show some building of homophone interference from 450 to 1000ms, participants with poor lexical skill actually show some building of homophone advantage. By the later SOAs, all the participants show a homophone interference effect.

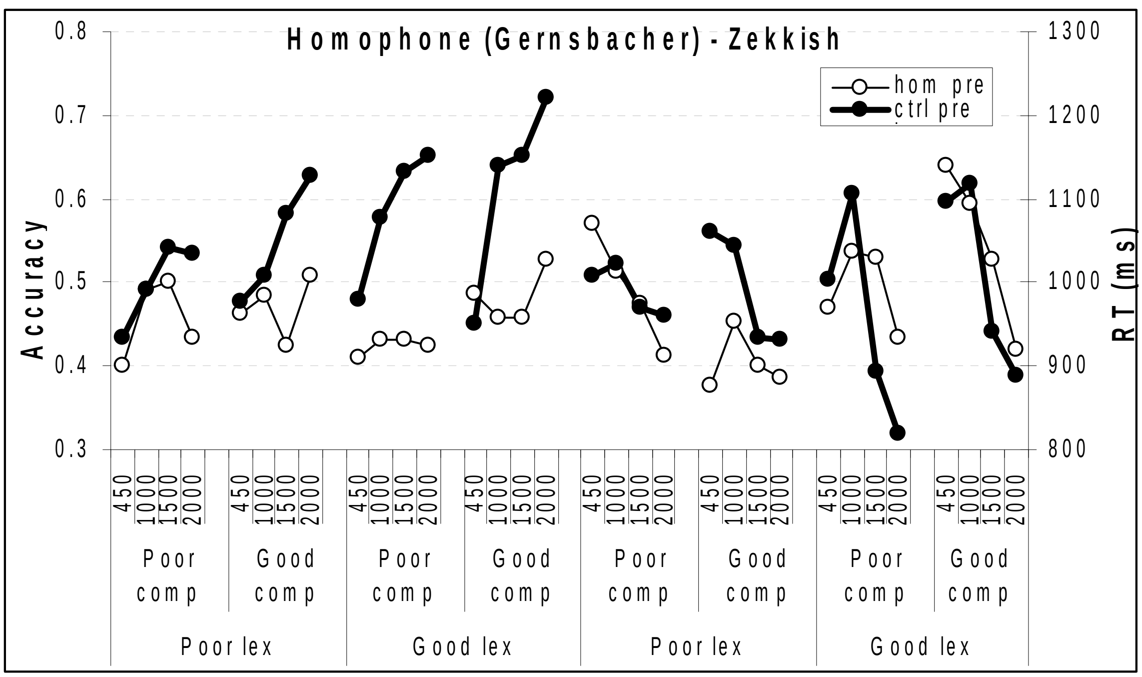


Figure 7.3.1 Data after partial training for homophone (Gernsbacher) task in Zekkish.

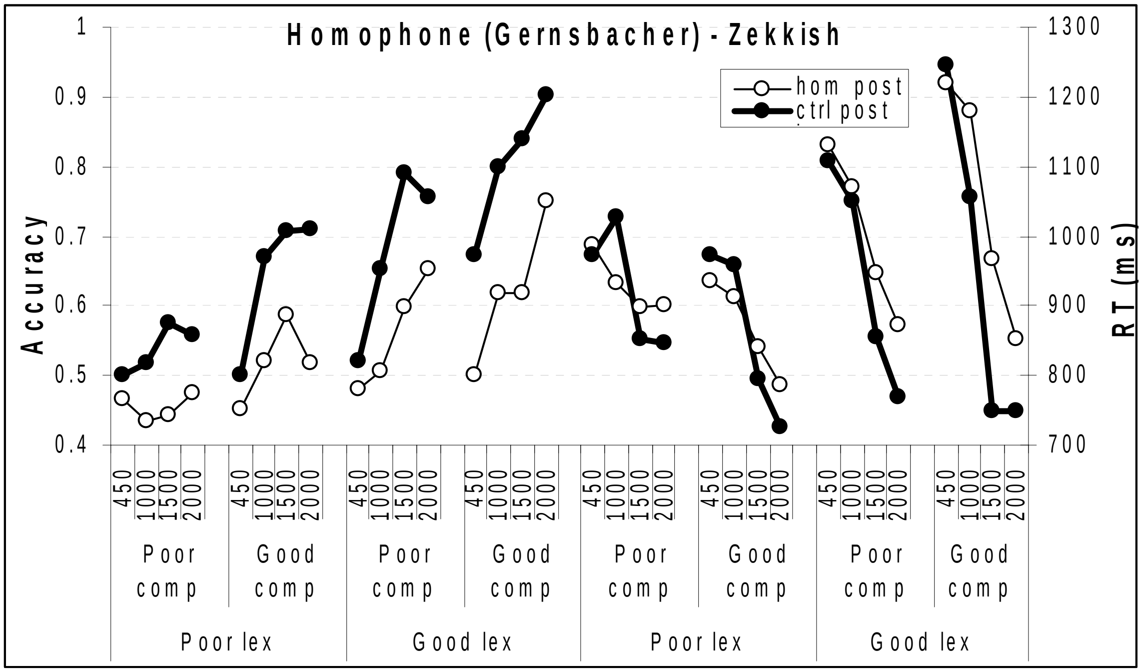


Figure 7.3.2 Data after complete training for the homophone (Gernsbacher) task in Zekkish.

The accuracy and response time data indicate that participants showed accuracy levels and patterns of lexical activation and deactivation commensurate with their reading skill and Zekkish experience, although response time data lagged slightly behind accuracy data.

1. Lexical skill affected data patterns after partial training and after complete training. Participants with good lexical skill showed a homophone interference effect by 1000 ms for accuracy and by 1500 ms for response time, while participants with poor lexical skill only did so after complete training, and even then only at the later SOAs for response time. Further, participants with poor lexical skill showed some homophone advantage in response time at the early SOAs after complete training.
2. Comprehension skill only affected data patterns after complete training, and only for accuracy. Participants with good comprehension skill showed more homophone interference at the early SOAs than participants with poor comprehension skill.
3. Experience shifted the pattern of lexical activation and deactivation to earlier SOAs for both accuracy and response time. In accuracy data, participants activated the dual meanings of the homophones earlier after complete training than after partial training, and actually began to show some release from interference by the latest SOA after complete training. There was no evidence for this release after partial training.

4. Higher order interactions, especially after partial training, were not significant, even when data patterns indicated differences. This is likely due to two factors. Skill variables were between participants, and the number of participants in each group was small and slightly unequal. The small and unequal n may have decreased chances of finding significant differences. Second, there were fewer significant effects overall after partial training. Participants' performance was much more variable after partial training than after complete training, even collapsing over frequency and relatedness. The performance variability could have led to fewer significant results. Nonetheless, there are some patterns of note. There was an indication that lexical skill and comprehension skill were interacting, to produce earlier homophone interference for the good/good group in both accuracy and RT (and even some recovery from interference at 2000 ms after complete training) and more early homophone advantage for the poor/poor group in RT. .

7.4. Discussion

Of the experiments in Zekkish and English, it is the Zekkish version that provided the most interesting results, even though it was much harder and there was more variability. The English experiment produced almost no differences due to individual differences in reading ability – comprehension skill or lexical skill. However, the effects of homophony and accuracy are exaggerated from those found in previous experiments. While previous experiments found solid evidence for homophone interferences effects in unrelated trials, this experiment finds robust, early homophone interference effects that are often sustained at the later SOAs. Further, the effect of frequency is exaggerated in the current experiment. Homophone interference occurred only for low frequency words while there was a homophone advantage for high frequency words. Finally, effects were present for both related and unrelated items. The few effects of reading skill included a tendency for participants with good comprehension skill to be more accurate overall than participants with poor comprehension skill, and for participants with good lexical skill to be faster and more prone to homophone effects than participants with poor lexical skill. Lexical skill appears to affect lexical activation resulting in an immediate effect on lexical quality with the outcome of larger homophone effects, while comprehension skill appears to be related to more word knowledge increasing overall accuracy, perhaps secondary to reading experience. There are three likely explanations for the differences between this experiment in English and the previous experiments. First, the stimuli used in this experiment were very tightly controlled for frequency and semantic relatedness (See Appendix J). Better stimuli could have improved the ability to find frequency and homophony effects, the early homophone interference, and the presence of homophone and frequency effects for both related and unrelated trials. Second, the participants in this experiment were highly motivated, making it more likely that all participants would show experimental effects. Third, in the experimental context, English was actually a novelty. It is possible that the need to switch from Zekkish to English was actually more difficult for better readers (presumably more entrenched in Zekkish), and that this equated the groups' performance. The explanation for the continuation of homophone and frequency effects to the later SOAs is not as clear.

Results from the Zekkish experiment included many more effects of individual differences variables, as well as homophone effects. Recall that data are collapsed over frequency and relatedness. This was to stabilize the data patterns. Relatedness was a good candidate for collapsing since the English experiment showed similar effects for related and unrelated items. Frequency was a good candidate for collapsing because of the time course of the experiment; in one sense, all words were low frequency, and some were just much lower than others. If training had continued for a longer period, frequency might have affected the data enough to analyze it as a variable.

Lexical skill affected performance after partial training and after complete training, while comprehension skill affects performance only after complete training. Data at the test point after partial training are similar to data from young children learning to read English, when decoding skill is being developed. Data after complete training are analogous to college students taking part in campus experiments, except that language experience is known. If this were a test of English, a likely explanation would be that good comprehenders read more, and had greater experience with words and thus more chances of developing high quality lexical representations. However, poor comprehenders in this Zekkish experiment had at least the same amount of experience as good comprehenders, if not more. The reading experience explanation is not valid. Instead, main effects of comprehension that grow over time may be due to a core comprehension ability causing differences in how efficiently lexical entries are updated. Perhaps they are updated in smaller increments for poor comprehenders, or perhaps the information isn't as available for update, as in cases where phonological working memory degrades the information before it can be stored. Interactions of lexical skill and comprehension skill may be due to less consistent, lower quality information being used to update lexical entries for participants with poor lexical skill. This again would lead to lower quality lexical representations.

At the time of partial training, most homophone effects were seen in accuracy. Participants with good lexical skill showed homophone interference by the second time point while participants with poor lexical skill did not show homophone interference until the third time point. However, homophone interference is somewhat of a misnomer, since homophone accuracy did not change much from one SOA to the next for any group. Homophone accuracy remained approximately at chance. It was control accuracy that increased, and earlier for participants with good lexical skill, indicating perhaps more efficient lexical activation when the system was not challenged by the dual activations from homophone phonology.

After complete training, accuracy patterns shifted to earlier homophone interference, this time with a concomitant increase in homophone accuracy for all but the poor/poor group. All groups showed a homophone interference effect by the second SOA, and the good/good group actually showed a homophone interference effect by the first SOA. Response time effects occurred on average one SOA later than the accuracy effects. Participants with poor lexical skill actually show some homophone advantage in speed along with their accuracy loss. This could be due to a strategy difference (e.g. answer "yes" for homophones because the words are probably related), or to a true skill difference. Since participants with poor lexical skill had larger homophone effects to high frequency words during training, it is possible that this homophone advantage is driven by high frequency words. High frequency homophones would be activated quickly given the fact that their phonology was experienced more often than even that of controls, and by the need for participants to pay careful attention to homophone discrimination during practice. With the extra time available at longer SOAs, lower frequency homophones could reach enough activation for their own identification to be threatened by their homophone mates on low frequency trials and for their activation to interfere with their homophone mates on high frequency trials. This would cause the late homophone interference effects.

The onset of homophone interference for participants with good lexical skill depended on comprehension skill, although the interaction is not significant. Participants with good lexical skill and poor comprehension skill showed homophone interference by the second SOA while participants with good lexical skill and good comprehension skill showed homophone interference by the first SOA. This effect only appears after complete training, so it appears that the effects of a basic comprehension ability build with experience.

In sum, the appearance of homophone advantage and homophone interference appears to be due to lexical quality. Lexical quality is affected by homophony, word frequency, lexical skill, and, after some experience, comprehension skill as well. Subsets of these effects are evident in the English and the Zekkish data.

8. GENERAL DISCUSSION

Data Summary

The experiment in this dissertation was designed to examine the origin of text comprehension skill in adults. We addressed three likely sources of comprehension skill: the existence of a basic skill, the adult manifestation of lexical skill, and the outcome of reading experience.

Lexical and sublexical skills, the ability to analyze, decode, and recognize single words, are responsible for a large amount of the variability in reading skill in the early elementary years. Eventually, these skills become overlearned and automatized and adults tend to have a ceiling effect on most tests. Using more sensitive and multiple tests, we found sufficient variability in phonological and orthographic skills in college students to examine the effects of both lexical skill and comprehension skill on reading tasks.

Measured a number of ways, for example vocabulary, number of words recognized on a lexical decision task, and number of authors recognized, reading experience correlates with reading comprehension. Reading experience can also influence reading comprehension in a number of ways that lend themselves less to measurement and more to being considered confounding variables. For example, the amount of time spent reading during childhood can only be measured by a proxy variable such as number of authors recognized, motivation to read is often measured by self-report or by proxy variables such as comprehension monitoring, and effective reading strategies are a broad and amorphous category hard to account for in an experiment. Further, these variables can interact – for example, motivation to read influences the amount of time people spend reading, which affects the development of good reading strategies, which affects reading skill, which affects motivation to read, and so on. Because the total variance due to the amount of reading experience is difficult to capture after the fact, we chose to negate English reading experience as much as possible by training college students in an artificial orthography.

Though comprehension is clearly influenced by a number of factors such as comprehension monitoring, working memory, and inference making ability (Cain, Oakhill & Bryant, 2004), it is possible that, like lexical skill, there is a core comprehension skill – affected by experience and training and other environmental variables, surely – but serving as a baseline from which to begin. This core skill sets a theoretical lower limit for comprehension performance, and interacts with environmental variables to set a theoretical upper limit for comprehension performance. Such a baseline comprehension ability could be measured, with error of measurement from other variables like lexical skill and reading experience, by standard tests of comprehension skill. Baseline comprehension ability would affect participants' performance when other variables were accounted for. We controlled reading experience and separated lexical and comprehension skill in the current experiment to look for influences of baseline comprehension ability on performance.

The experiment was designed to require decoding in a predictable orthography that was sufficiently different from English to derail strategies participants used to decode English words. For the same reason, syntax was altered from English. Non-English letters were arranged in a stacked fashion requiring students to read in a clockwise fashion, and sentences were arranged as verb/direct object combination (requiring decoding) followed by a participant (requiring only recognition). Verb/direct object concepts were kept simple to maximize the likelihood that all participants would not only be familiar with them but have them firmly established and well integrated into their knowledge bases.

Participants were introduced to the artificial orthography sequentially: letter sounds, followed by word decoding, vocabulary, and syntax. At this point of minimum competence participants were tested on a variety of Zekkish (the name of the artificial orthography given in the cover story) and English tasks. Some tasks were written, others oral in a one on one situation with the examiner, and others presented by computer. ERPs were collected along with some of the computer tasks. Participants then practiced decoding and understanding Zekkish sentences until their accuracy was very high and speed had increased, indicating some degree of automaticity with the orthography. They were then tested a second time.

The purpose of the multi-stage design was to artificially manipulate reading experience to mimic that of English reading experience on a smaller scale. The large number of tests was given to examine participants' ability to use the orthography in new testing situations, to account for other variables of interest such as working memory and inference making ability, and to control for performance in comparable tasks in English. A task capitalizing on the manipulations of homophony and frequency in Zekkish allowed us to follow up on a series of English experiments in our lab. Finally, accuracy, response time, and ERPs were collected because each provides different information. When accuracy does not differentiate performance, for example with experienced readers, sometimes response time continues to reveal differences in performance. When behavioral responses do not differentiate performance, as when tests are not sensitive enough or when the outcome of neural processing is the same, sometimes the course of that neural processing, as measured by ERPs, can reveal differences in performance.

During the training period, participants' lexical skill affected both their speed of learning and their degree of success, but comprehension skill did not. The few effects of comprehension skill appeared when participants needed to learn new tasks (such as when they were first introduced to the experiment), and not when they were simply acquiring knowledge or skill. Lexical skill revealed itself as a basic ability which directed the course of learning. Comprehension skill revealed itself as a basic ability which directed participants' flexibility in handling new learning situations. Comprehension skill and lexical skill did not interact.

During the testing periods, participants' comprehension skill affected performance on Zekkish tasks more than lexical skill. Comprehension skill affected performance more as participants were required to adapt to more novel testing situations, and lexical skill affected performance more as participants were directly using their Zekkish skill, for example in pseudoword decoding. These effects replicate the training effects.

The changes from the testing session after partial training to the testing session after complete training showed participants increased competence and automaticity with the Zekkish language. They also show some degree of test familiarity, as comprehension affected performance more after partial training than after complete training. Comprehension effects did not build over time, as would be expected if comprehension skill was an outcome of lexical skill. The effects of comprehension skill on performance were not accounted for by other variables suggested to underlie comprehension skill, such as working memory capacity and inference making ability.

Participants' performance on the English tests did not improve from one testing session to the next, nor was it expected to change. Participants were not trained in English, and English ability and strategies were resistant to any transfer from Zekkish training. Both lexical skill and comprehension skill affected performance on the English tasks, and occasionally interacted. The results of these tests show the continued influence of lexical skill on reading performance even for adults. Further, they replicate comprehension effects often reported in the literature. These data serve as a good comparison for Zekkish data because Zekkish data show a different pattern of results. The differences between the English and Zekkish data patterns underscore the importance of controlling for reading experience when studying reading comprehension.

In the ERP tasks, lexical skill reappeared as an important variable. Performance on the behavioral tasks – even behavioral performance on the ERP tasks - showed strong effects of comprehension, but amplitude data support the training effects. It appears that a basic lexical ability affects the speed and accuracy of learning and the resultant brain activation. Comprehension modulates the behavioral outcome of the brain activation by influencing the ability to assess the needs of new tasks and adapt performance accordingly.

Our previous experiments showed that comprehension was related to lexical activation by manipulating the presence of homophones and word frequency. Participants with better comprehension skill were better able to quickly activate lexical items and choose between competing entries. The source of this comprehension effect appeared to be reading experience for two reasons: 1) when word frequency was controlled by making the words equally familiar to good and poor comprehenders, differences between groups disappeared. 2) Increasing experience with words through training influenced their course of activation. When homophones were manipulated in Zekkish, lexical skill affected the extent and time course of activation as well as the direction of the effect. That is, sometimes homophones were more quickly activated than non-homophones. Comprehension effects interacted with lexical effects in that participants with both poor comprehension and poor lexical skill remained very inaccurate on this task, while participants with poor lexical skill but good comprehension skill were more accurate but showed no recovery from interference.

Across all the parts of this experiment two main points can be derived: First, there is a strong effect of a basic lexical skill in college age readers who have become proficient readers in English. Lexical skill affects lexical activation and the learning of a new orthography. Second, comprehension skill comes from a variety of sources. It is a basic skill, in that it affected the degree to which participants adapted to the requirements of new tasks. It is a derivative of lexical skill, in that comprehension skill enhanced the effects of lexical skill on some tasks. It is an outcome of reading experience, in that its strongest effects were found in the tasks performed in English.

Models of Lexical Activation

Zekkish, despite its single violation of 1:1 grapheme-phoneme correspondence, is completely regular. In all cases the pronunciation of the word is determined directly from its letters. The Zekkish homophone effect is large and reliable, and in opposite directions depending on the task. Reading homophones produces faster reaction times (compared to controls) for low frequency homophones but slower or similar reaction times (compared to controls) for high frequency words. Determining the meanings of homophones produces slower reaction times (compared to controls) for low frequency words and similar reaction times (compared to controls) for high frequency words. In other words, identification produces a homophone advantage for low frequency words and meaning judgment produces homophone interference for low frequency words.

While both of these effects have been reported in the literature before (e.g. Berent & Van Orden, 2003; Jared & Seidenberg, 1991), this Zekkish study produces both homophone advantage and interference in the same experiment; in fact in the same stimulus presentation. The dual effect provides some information on the connectivity of the lexical constituents. Assume that differential reading experience produces a more reliable representation of the high frequency homophone. During word identification orthography activates phonology. A simple reduction in efficiency of constituent activation in the low frequency homophone would predict slower low frequency word identification than control word identification. In fact, the homophone phonology (constituent, not the links to phonology has had more learning trials than the control phonology - four learning trials for every one trial for low frequency controls and three trials for high frequency controls. An alternative construction is that not only is there shared phonology of the homophone pair in a feed-forward direction, but also an activation from phonology to orthography as well. Kim, Taft, and Davis (2004) call this rebound activation. They support rebound activation with their data showing that pseudohomophones are identified more quickly than real word homophones, since pseudohomophones don't activate a competing orthography[10].

Consider for the purpose of illustration that activation strength is equal to the number of learning trials, and that each activation bounce, or turn in direction of activation reduces the influence by half. Rebound activation alone does not predict both low frequency advantage and high frequency disadvantage. However, when homophone interference from the competing orthography is taken into account, the model works. The calculations are worked out in Table 8.1[11].

Table 8.1. Patterns of activation strength including for lexical activation.

	Positive Activation			Interference Activation			Total Act.
	Feed-forward	Rebound		Rebound	Feed-Forw		
Ctrl	Orth → Phon	Phon	Tot	Phon → Orth	Phon	Tot	
	LFC1+ LFC1	+ LFC1/2	2.5				
	HFC3+ HFC3	+ HFC3/2	7.5				

[10] Note that this argument assumes that rebound activation occurs only with established lexical entries, since the pseudohomophone's orthography does not seem to interfere with decision making. A good test of this assumption would be to include a third word type – pseudohomophones of homophone pairs. The prediction would be that this word type would be as slow as the homophones, and slower than the pseudohomophones of non-homophones, since there would be two competing orthographies in both the slower cases. For example, reaction time to flour (flower) would be equal to selar (cellar, seller), and both would be slower than grene (green). In fact, slowest of all would be triple homophones like pear (pair, pare).

[11] Curiously, a direct link between orthographic representations produces the same effects, without rebound activation and in a more parsimonious design. It is difficult, however, to make a case for links directly between non-shared orthographic constituents rather than between lexical entries as a whole.

Hom	LFH1+ SHP4	+ LFH1/2	5.5	(SHP4 + HFH3)/4	SHP4/8	2.25	3.25
	HFH3+ SHP4	+ HFH3/2	8.5	(SHP4 +LFH1)/4	SHP4/8	1.75	6.75

Key: LFC = Low Frequency Control, HFC = High Frequency Control, LFH = Low Frequency Homophone, HFH = High Frequency Homophone, SP = Shared Homophone Phonology

A striking implication of this model is that word identification can occur without influence from the semantic lexical constituent, even taking into account homophone interference. Lange (2002) posited such a model based on the finding that experiment participants were more error-prone in letter detection from masked pseudohomophones, (when the letter was not in the pseudohomophone but was in its homophone mate) than from masked controls. In fact, she concluded that not only is semantic activation unnecessary, but lexical activation in general is unnecessary. All that is needed is multiple nonlexical phonological activation. Homophone advantage effects when the task doesn't involve meaning are well replicated, in designs using word identification (naming; McCann & Besner, 1987), backward masking (Berent & Van Orden, 2003), homophone judgment (Kim, Taft, & Davis, 2004), and letter detection (Kim, 2002). See Figure for a representation of necessary connections for word identification. Ferrand & Grainger (2003) found the opposite effect – that is, homophone interference – in a lexical decision task. Presumably in lexical decision, although meaning is not necessarily invoked, a lexical entry must be located in order to make a correct decision. The lexical activation introduces homophone interference that outweighs any homophone advantage that might be present.

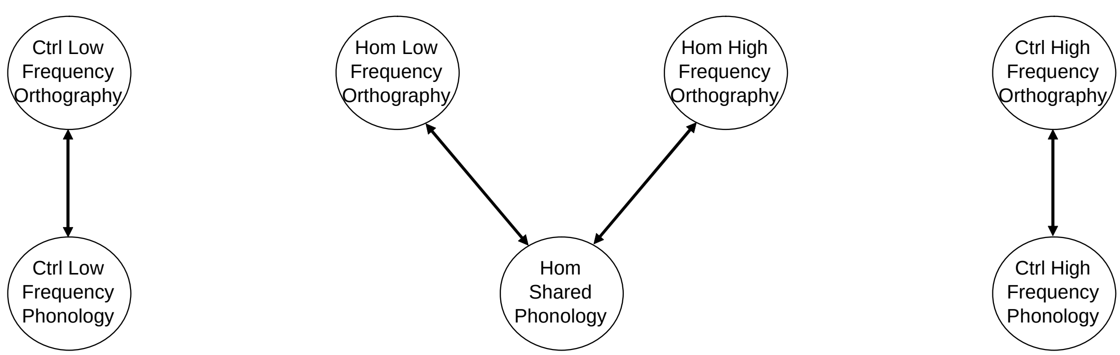


Figure 8.1. Connections between orthography and phonology for homophones of low and high frequency.

Models of comprehension influence

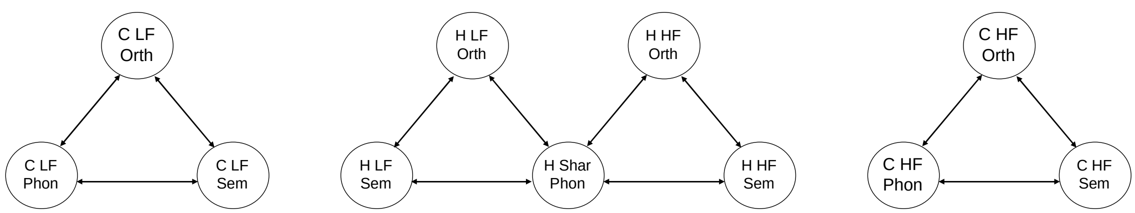
With only these data, one might infer that Zekkish might not have even produced a typical mental lexicon. However, Zekkish words were also assigned meanings. And the Zekkish tasks involving meaning produced homophone interference effects for low frequency words but not for high frequency words for readers with good lexical skills. Again assume that differential reading experience produces a more reliable representation of the high frequency homophone. During meaning judgments orthography activates phonology and semantics, in some order. Rebound activation from both phonology and semantics substantially reduces the activation of the low frequency homophone, making it take much longer to reach an activation threshold – longer, even, than the low frequency control. See Table 8.2 for calculations.

Table 8.2. Patterns of activation strength for comprehension influence.

	Positive Activation			Interference Activation			Total Act.
	Feed-forward Orth → Phon & Sem	Rebound Phon & Sem	Tot	Rebound Phon & Sem → Orth	Feed-Forw Phon & Sem	Tot	
Ctrl	LFC1+ LFC1 + LFS1	+ LFC1/2 + LFC1/2	4				4
	HFC3+ HFC3 + HFS3	+ HFC3/2 + HFC3/2	12				12
Hom	LFH1+ SHP4 + LFS1	+ LFH1/2 +LFH1/2	7	(SHP4 + HFS3 + HFH3)/4	HFS3/8 + SHP4/8	3.4	3.6
	HFH3+ SHP4 + HFS3	+ HFH3/2 + HFH3/2	13	(SHP4 + LFS1 +LFH1)/4	LFS1/8 + SHP4/8	2.1	10.9

Key: LFC = Low Frequency Control, HFC = High Frequency Control, LFH = Low Frequency Homophone, HFH = High Frequency Homophone, SP = Shared Homophone Phonology, LFS = Low Frequency Semantics, HFS = High Frequency Semantics.

These calculations produce homophone interference for both versions of the homophone. Our data suggest that readers with good lexical skill show homophone interference for low frequency homophones and readers with poor lexical skill show homophone interference for high frequency homophones. Our explanation for this interaction in the first two studies was that the relative word frequency for these groups of readers varies based on individual differences confounded by reading experience. That is not the case in the Zekkish study as both lexical groups had an equal number of learning trials. Instead, the readers with good lexical skills might more efficiently or accurately update their lexical representations during learning. Inaccurate learning trials incorrectly update lexical entries, possibly even creating links where there shouldn't be any, as in latter → climbing tool to reach high places. Invalid updating could both reduce the quality of the high frequency homophone's entry and completely destabilize the low frequency homophone's entry. Altered lexical quality and additional constituent connections could in combination explain the presence of homophone interference for high frequency homophones and its absence for low frequency homophones. Other additive effects are reported in the literature, as in the Ferrand & Grainger (2003) study in which high frequency homophone mates and other high frequency orthographic neighbors both lengthened the reaction times to low frequency homophones. See Figure for a representation of lexical activation pathways during semantic tasks.



Implications for the Lexical Quality Hypothesis

There are several implications for the Lexical Quality Hypothesis. The Lexical Quality Hypothesis states that, in order to support efficient comprehension, the activation of a word representation in the lexicon must be fast and of high quality. This occurs when the constituents of the word representation (orthography, phonology, and semantics) are of high quality, and redundantly activate the word representation, leading to a rapid rise in activation of a single word representation. Only words efficiently and effortlessly activated are able to free processing resources for building a text representation and comprehending the resulting structure.

The Lexical Quality Hypothesis was first proposed to explain data from the first experiment, in which readers were grouped only by text comprehension skill and not by lexical skill. The Zekkish data show homophone interference interactions with lexical skill, not comprehension skill. Lexical skill and comprehension skill are correlated, so the unmeasured lexical skill might actually be driving the results of experiment 1.

Further, it was posited that relative frequency rather than word frequency could be responsible for differences in homophone interferences. That is, poorer readers probably have less reading experience, making words that are high frequency for skilled readers somewhat lower in frequency for less skilled readers. In the Zekkish study all readers had the same number of learning trials, yet lexical effects remained. Experience alone does not make high quality lexical representations; instead, learning history is also important.

A third implication for the Lexical Quality Theory is that lexical activation is more complicated than a simple orthography-to-phonology-to-semantics activation. Activation rebounds from one constituent to another, layering and incrementing both the activation and the interference. Kim, et al. (2004) posit rebound activation, and other models include further influences among the constituents, in a reverberating system settling into a single lexical activation (Ziegler?), or in a settling into a local minimum of expended energy, tension, or interference (McClelland?). These continuing influences among constituents, as well as changing constituent weights based on number of learning trials, may account for the building of homophone interference for low frequency items, the reduction in homophone interference for high frequency items, and the tendency for reduction in group differences with more experience.

Finally, the influence of the constituents is changed based on context. When meaning is not necessary for a task to take place, homophone advantages can occur via non-lexical orthographic and phonological activation. When additional semantic information is available from text context, semantics can reduce or eliminate interference effects (Folk, 1999).

<u>Interaction of lexical and comprehension skills</u>

Lexical skill appears to strongly affect learning efficiency and to a lesser degree to affect the use of Zekkish. Lexical influence is primarily seen in tasks involving orthographic and phonological activation, but not necessarily lexical activation or semantic involvement.

While comprehension skill has less effect on learning, it has a large effect on the use of Zekkish. There are several possible sources of the comprehension effects. Comprehension skill may direct the updating and reliability of the semantic lexical constituent. However, incremental changes in lexical quality, even constrained to the semantic constituent, would imply effects throughout training, and training effects of comprehension skill were not present. Comprehension skill may also cause top-down semantic influences on lexical activation. For example, external influences such as text context or stimulus sets that invoke a processing bias due to an overload of a particular property (e.g. homophones, high frequency words, particular spelling patterns, semantic categories) could direct lexical activation. The Zekkish experiment was designed to avoid these processing biases by using all combinations of letters, and by using equal numbers of high and low frequency homophones and controls. Further, there was not a pattern to text context that would influence top-down processing; Zek characters were not predictably assigned to words at the phonological or orthographic level except to match different Zeks to each member of a homophone pair, and not predictably assigned to words at the semantic level except to advance the cover story, and these associations would not be top-down given that the word to be decoded came before the rest of the "text" (the Zek name). Therefore comprehension-related top-down influences on lexical processing are not likely to be the driving force behind the comprehension effects found in the Zekkish experiment.

Comprehension skill may also affect the use of lexical information after it has been activated. For example, comprehension processes external to lexical processes are responsible for understanding task requirements, shifting attention to appropriate environmental stimuli, and integrating existing knowledge with incoming information and the needs of the task. Integration at the text level has been shown to be problematic for less-skilled readers although these readers can integrate at a finer propositional level within sentences (Long, Oppy, & Seely, 1997). Analogously, less-skilled readers may be able to integrate within the confines of lexical activation, but not across various types of information such as instructions, environmental stimuli, and lexical activation. Integration of sublexical information with semantic information (somewhat extra-lexically) was verbalized by one participant, with good lexical and comprehension skill. After reading a pseudoword that was constructed by concatenating two legal Zekkish words (rescuing kitten, leaping hurdles) he remarked that the meaning of the pseudoword must be leaping hurdles to rescue a kitten.

Support for extra-lexical sources of comprehension skill come from Gough's (Gough, et al., 1996; Hoover & Gough, 1991) theory and supporting data that reading comprehension is the product of listening comprehension and decoding skill. Listening comprehension is the extra-lexical source of top down information, and decoding provides the lexical activation. Decoding skill, then, affects the quality of the lexical activation. This multiplicative model would explain both the lexical effects without comprehension effects during Zekkish training and the interaction of lexical effects and the strong comprehension effects during Zekkish testing. The interaction of lexical and comprehension skill was clear in another participant's comments. This participant had good lexical skill and good comprehension skill. In a plea for the reduction of practice sessions, she remarked "I can't read the words without automatically knowing what they mean anymore."

Such a model also implies that lexical skill and comprehension skill separately (although interactively) affect task performance in the Zekkish task and reading comprehension more generally.

While some studies, such as the correlational study by Jackson (2005) do not find correlations of lexical and sublexical skills with comprehension at the college level, many studies, such as the ones from our own lab including each of the three experiments in this series, have found lexical skill and comprehension skill to be correlated. If lexical skill and comprehension skill are in fact separate, then correlations and the resulting interactions between them are the outcome of bidirectional influences. However, correlation and interaction could also result from lexical and comprehension skill both measuring the same underlying processes. The implication then is that the skill groups in this Zekkish study did not completely separate lexical and comprehension skill. A single underlying reading skill variable was responsible for both lexical and comprehension performance and the groups high in one skill and low in another skill simply represent failure to completely segregate into skilled and less-skilled groups because of a regression to the mean on some tests. The somewhat unequal lexical and comprehension scores between the groups supports this explanation. The lack of lexical and comprehension interactions in many parts of the Zekkish experiment could be explained by a lack of power due to small sample size and high variability in performance for some tasks. Highly significant main effects, however, make a lack of power explanation less likely to be correct.

A third explanation for the interaction effects of lexical and comprehension skill is that subjects' English knowledge could have intruded into their processing of the Zekkish experiment. Although the design of the Zekkish experiment was designed to avoid these influences, differences in reading strategy, integration of Zekkish into the existing English lexicon, or a difference in understanding the concepts on which the Zekkish words were based could have affected Zekkish lexical activation and comprehension.

The implication of multiple sources of comprehension skill, either separate from or on a continuum with lexical skill, is the need to effect several changes early in a reader's career. Improving lexical skill with an intervention will have downstream effects on reading comprehension. Increasing opportunities to read and motivation to read will enhance reading experience. And providing variety in reading materials and exercises could improve the basic comprehension skill by making people more flexible and adaptable to change. The effects of intervention on English reading skill, although not addressed in this experiment, are nevertheless made clear by one participant's comments. This participant had low lexical skill and low comprehension skill. "The experiment itself was fun! I used some of the learning tactics here and applied them to my school work."

Future studies

Future studies utilizing Zekkish should capitalize on the valuable resource that readers of Zekkish become with experience. Additional subjects would eliminate lack of power as an explanation for absence of significant interactions between lexical skill and comprehension skill. Extending training time for better automatization with periodic testing would provide more information on the outcome of lexical and comprehension skill on Zekkish use. Altering the learning strategies of subjects, e.g. presenting all 48 words together from the beginning, with or without prior decoding experience, could separately affect attention to semantic and phonological information. Additional letters, control words, or Zek characters would make homophony and text associations of concepts and characters more opaque. Additional letters would also open avenues for replicating experiments using masking, lexical decision, homophone judgment, and naming (pseudoword and word) procedures because pseudowords and pseudohomophones could be created.

Other outcome variables could provide additional types of information about Zekkish learning. Eye movements could provide information on use of particular types of information such as text context and phonology as in the Folk (1999) study. fMRI data could provide information on the functional and structural organization of the neural system as Zekkish is being learned. Modeling could help test assumptions about use of information from lexical constituents as well as constituent connectivity, structure of the lexicon, and top-down influences of comprehension on lexical activation and use of lexical information.

Summary

In sum, there is a strong effect of a basic lexical skill in college age readers who have become proficient readers in English. Lexical skill affects lexical activation and the learning of a new orthography. Comprehension skill appears to come from three sources: as a basic skill, in that it affected the degree to which participants adapted to the requirements of new tasks, as a derivative of lexical skill, in that comprehension skill enhanced the effects of lexical skill on some tasks, and as an outcome of reading experience, in that its strongest effects were found in the tasks performed in English.

APPENDIX A: Recruitment Letters

Initial contact:
Hello,

I am a student in the cognitive psychology department and I would like to invite you to participate in my dissertation study. When you took Introductory Psychology, you participated in an experiment in which you took some reading tests. Based on your performance, you are eligible for this larger study. If you decide to participate, you would take part in a pretend exchange of diplomats between planets Earth and Zek. Your job as ambassador would be to meet the Zek ambassadors and learn 48 Zekkish vocabulary words – enough to communicate with them. Twice while you are learning and practicing the vocabulary words, you would take some reading tests. Some are computerized. Two one-hour tests use a cap with sponges on it to measure your brain's electrical activity as you read. Because learning is required, the experiment is long – about eight one-hour sessions, not including testing. I know this is a lot of time. To compensate you for your time and effort, you would be paid $300.00

I hope I have given you enough information to interest you. If you would like more information, please email me (lhart@pitt.edu) or call me (412-624-7073). We can communicate via email, or you can send me your current phone number. (I have an old phone number, but I am no longer sure it is accurate). If you would not like to be called or emailed again, please email me or call me to let me know.

I look forward to working with you.

Lesley Hart

Followup letter:
Hi (Name),

Here's the information about the Zekkish study. (I also answered any other specific questions participants had in this paragraph.)

Since people work on computers individually in this experiment, there are no exact times and dates. We can work around your schedule. Everything will be held on Pitt's campus, in the LRDC building (room 409).

Here's the basic setup:
Day 1: You learn about the pretend language, diplomats (the Zeks), and their culture. You also learn eight letters of their alphabet and how to sound out short words.
Day 2: You start learning the meanings of 24 words.
Day 3: You learn the meanings of 24 more words.
Day 4: You practice all the words together. You have this day and three more sessions just like it to get to 85% accuracy. Some people require one session; some require all four. As soon as you hit 85% accuracy, we go on.

Day 5: Like day 4, but we concentrate on associating the little Zek characters with the vocabulary words. If necessary, we can repeat this day to improve accuracy.
Day 6, Testing: Some reading, writing, and spelling in English and Zekkish. Also one hour in which you read while a machine records your brain's electrical activity.
Days 7 through 10: Practicing the vocabulary.
Day 11: testing repeated.

The learning and practicing sessions are about an hour to an hour and a half each. The testing sessions are closer to three hours (with breaks, of course).

In addition, there is a one hour test that can be taken at any time during the whole experiment.

The only scheduling requirement is that you can come on days that are back-to-back or close to it, except for weekends. For example, Monday to Friday of two weeks (plus a day). You don't have to come at the same time each day.

Payment works like this:
$50.00 for completing vocabulary learning
$60.00 for completing the first testing session.
$80.00 for completing the vocabulary practice sessions.
$90.00 for completing the second testing session.
$20.00 for taking the extra one hour test.
That adds up to $300.00 for finishing everything.

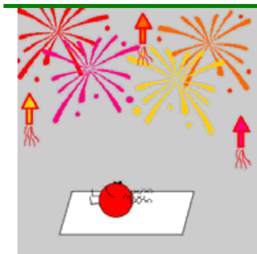
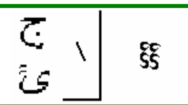
As you might guess, I have spent a lot of time with the Zeks and their Zekkish language at this point. Even though you will be learning word meanings, I don't think you'll get bored. The people who have already tried learning Zekkish have thought it was fun. I think it's fun, and not just because I will get a PhD when I finish this. (But it helps. :))

You are not obligated to participate, so if you decide that you do not want to (even after the experiment has begun), just tell me or Matt (the coordinator). If you have any more questions, please email me or call me. I hope you are still interested - I think you will have a good time with the Zeks.

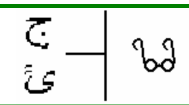
-Lesley

APPENDIX B: Zekkish Vocabulary

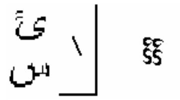
Set 1

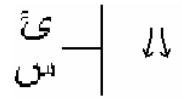
vuz, Teb.
Viewing fireworks, Teb.
Homophone
Low Frequency

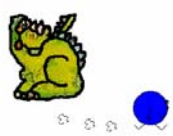
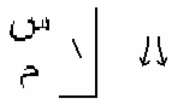
vuz, Dek.
Rescuing kitten, Dek.
Homophone
High Frequency

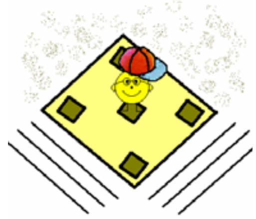
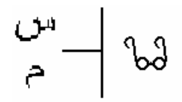
zuj, Teb.
Feeding chickens, Teb.
Homophone
High Frequency

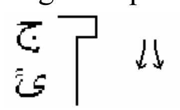
zuj, Gep.
Scoring basket, Gep.
Homophone
Low Frequency

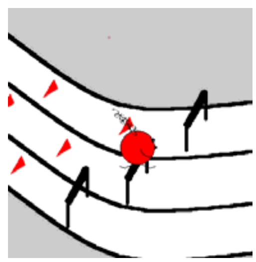
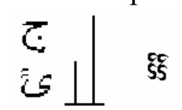
jum, Gep.
Fleeing dragon, Gep.
Homophone
High Frequency

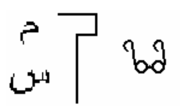
jum, Dek.
Pitching baseball, Dek.
Homophone
Low Frequency



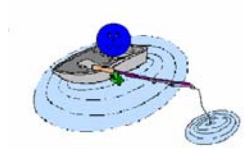
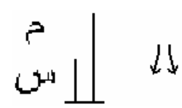
voz, Gep.
Asking question, Gep.
Control
High Frequency

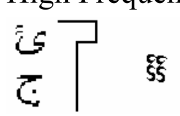
vOz, Teb.
Leaping hurdles, Teb.
Control
Low Frequency

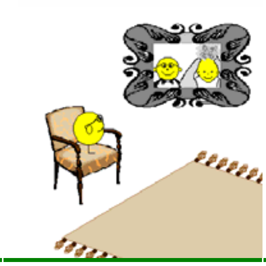
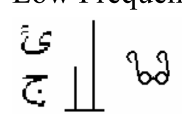
moj, Dek.
Receiving diploma, Dek.
Control
High Frequency

mOj, Gep.
Going fishing, Gep.
Control
Low Frequency

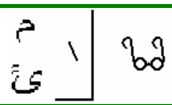



zov, Teb.
Spinning merrygornd, Teb.
Control
High Frequency

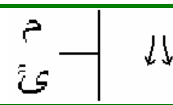



zOv, Dek
Hanging picture, Dek
Control
Low Frequency

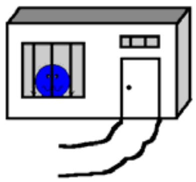
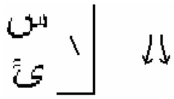
Set 2

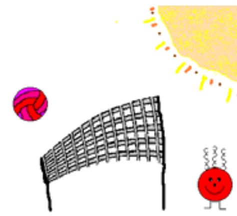
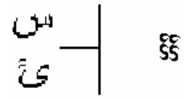
muz, Dek.
Attending school, Dek.
Homophone
High Frequency

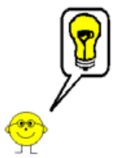
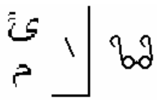
muz, Gep.
Buying groceries, Gep.
Homophone
Low Frequency

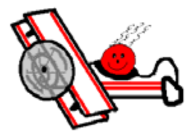
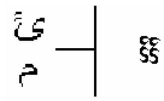
juz, Gep.
Behind bars, Gep.
Homophone
Low Frequency

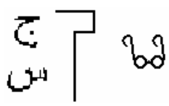
juz, Teb.
Spiking volleyball, Teb.
Homophone
High Frequency

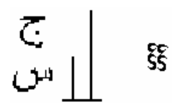
zum, Dek.
Having idea, Dek.
Homophone
Low Frequency

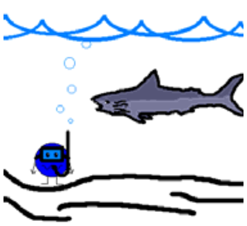
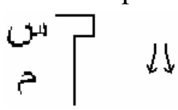
zum, Teb.
Riding plane, Teb.
Homophone
High Frequency

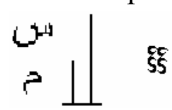
voj, Dek.
Hiking desert, Dek.
Control
Low Frequency

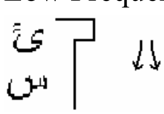
vOj, Teb.
Playing fetch, Teb.
Control
Low Frequency

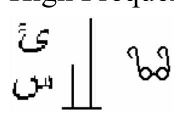
jom, Gep.
Snorkeling shark, Gep.
Control
Low Frequency

jOm, Teb.
Flying kite, Teb.
Control
High Frequency

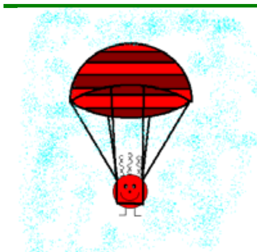
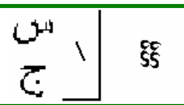



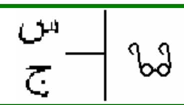
zoj, Gep.
Telling time, Gep.
Control
High Frequency

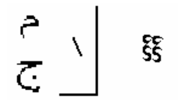



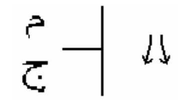
zOj, Dek.
Sliding slide, Dek.
Control
High Frequency

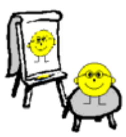
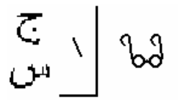
Set 3

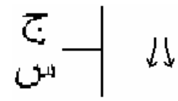


juv, Teb.
Falling parachute, Teb.
Homophone
Low Frequency

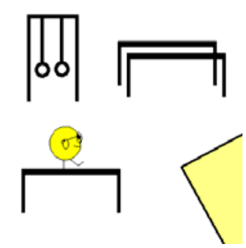
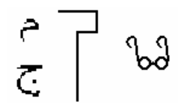


juv, Dek.
Bathing sun, Dek.
Homophone
High Frequency

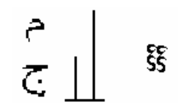


muv, Teb.
Building snowman, Teb.
Homophone
High Frequency

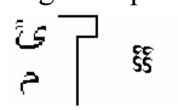


muv, Gep.
Holding umbrella, Gep.
Homophone
Low Frequency

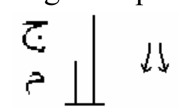


vuj, Dek.
Painting portrait, Dek.
Homophone
High Frequency

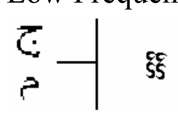


vuj, Gep.
Hiding box, Gep.
Homophone
Low Frequency

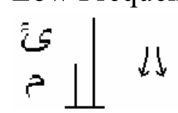


mov, Dek.
Balancing beam, Dek.
Control
High Frequency



mOv, Teb.
Climbing mountain, Teb.
Control
High Frequency

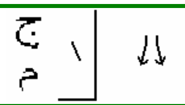


vom, Dek.
Admiring reflection, Dek.
Control
Low Frequency



vOm, Gep.
Planting flowers, Gep.
Control
Low Frequency

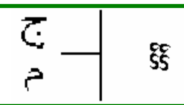


zom, Teb.
Tubing river, Teb.
Control
Low Frequency



zOm, Gep.
Roasting m-mallow, Gep.
Control
High Frequency

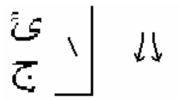
Set 4



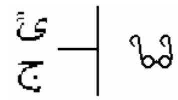
vum, Gep.
Taking temperature, Gep.
Homophone
Low Frequency



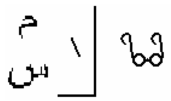
vum, Teb.
Driving car, Teb.
Homophone
High Frequency



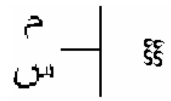
zuv, Gep.
Watching fish, Gep.
Homophone
High Frequency



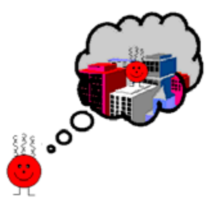
zuv, Dek.
Looking Microscope, Dek
Homophone
Low Frequency

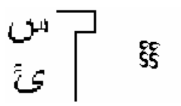


muj, Dek.
Milking cow, Dek.
Homophone
Low Frequency

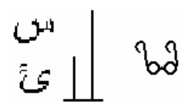


muj, Teb.
Pretending king, Teb.
Homophone
High Frequency

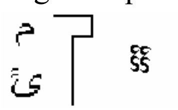




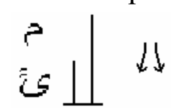
joz, Teb.
Imagining superhero, Teb.
Control
High Frequency



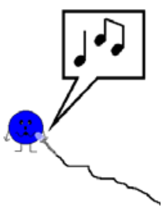
jOz, Dek.
Blowing bubbles, Dek.
Control
Low Frequency

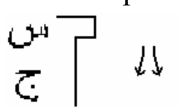


moz, Teb.
Skating skateboard, Teb.
Control
Low Frequency

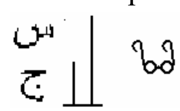


mOz, Gep.
Appearing television, Gep
Control
Low Frequency





jov, Gep.
Singing karaoke, Gep.
Control
High Frequency



jOv, Dek.
Getting married, Dek.
Control
High Frequency

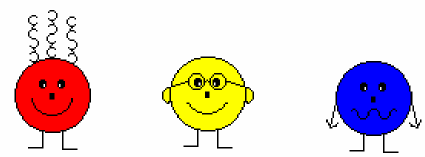
Recall that the pairing of word and picture was counterbalanced for some participants. These alternate pairings are given below.

Homophone	High Frequency	vuz(1) Gep	Snorkeling shark
Homophone	Low Frequency	vuz(2) Teb	Flying kite

Homophone	Low Frequency	zuj(1)	Dek	Admiring reflection
Homophone	High Frequency	zuj(2)	Gep	Planting flowers
Homophone	High Frequency	jum(1)	Gep	Asking question
Homophone	Low Frequency	jum(2)	Dek	Leaping hurdle
Homophone	High Frequency	juv(1)	Teb	Skating skateboard
Homophone	Low Frequency	juv(2)	Gep	Appearing television
Homophone	High Frequency	juz(1)	Dek	Balancing beam
Homophone	Low Frequency	juz(2)	Teb	Climbing mountain
Homophone	High Frequency	muj(1)	Teb	Spinning merry-go-round
Homophone	Low Frequency	muj(2)	Dek	Hanging picture
Homophone	Low Frequency	muv(1)	Teb	Imagining superhero
Homophone	High Frequency	muv(2)	Dek	Blowing bubbles
Homophone	Low Frequency	muz(1)	Gep	Singing karaoke
Homophone	High Frequency	muz(2)	Dek	Getting married
Homophone	Low Frequency	vuj(1)	Teb	Tubing river
Homophone	High Frequency	vuj(2)	Gep	Roasting marshmallow
Homophone	High Frequency	vum(1)	Gep	Telling time
Homophone	Low Frequency	vum(2)	Dek	Sliding slide
Homophone	High Frequency	zum(1)	Dek	Hiking desert
Homophone	Low Frequency	zum(2)	Teb	Playing fetch
Homophone	Low Frequency	zuv(1)	Dek	Receiving diploma
Homophone	High Frequency	zuv(2)	Gep	Going fishing
Control	High Frequency	jom	Teb	Viewing fireworks
Control	Low Frequency	jOm	Dek	Rescuing kitten
Control	Low Frequency	jov	Dek	Attending school
Control	Low Frequency	jOv	Gep	Buying groceries
Control	Low Frequency	joz	Teb	Building snowman
Control	High Frequency	jOz	Gep	Holding umbrella
Control	Low Frequency	moj	Gep	Watching fish
Control	High Frequency	mOj	Dek	Looking microscope
Control	Low Frequency	mov	Gep	Behind bars
Control	Low Frequency	mOv	Teb	Spiking volleyball
Control	High Frequency	moz	Teb	Falling parachute
Control	High Frequency	mOz	Dek	Bathing sun
Control	High Frequency	voj	Dek	Having idea
Control	High Frequency	vOj	Teb	Riding plane
Control	High Frequency	vom	Teb	Feeding chickens
Control	High Frequency	vOm	Gep	Scoring basket
Control	Low Frequency	voz	Gep	Fleeing dragon
Control	High Frequency	vOz	Dek	Pitching baseball
Control	Low Frequency	zoj	Gep	Taking temperature
Control	Low Frequency	zOj	Teb	Driving car
Control	High Frequency	zom	Dek	Painting portrait
Control	Low Frequency	zOm	Gep	Hiding box
Control	Low Frequency	zov	Dek	Milking cow
Control	High Frequency	zOv	Teb	Pretending king

APPENDIX C: Introduction to Zeks

These frames were presented one at a time to participants via E-Prime. Each one was the size of a full screen. Participants read the information at their own pace.

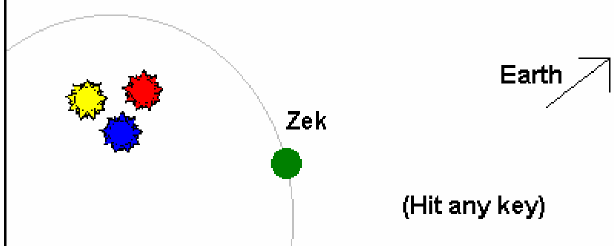


Hi! We're the Zeks! Our names are Teb, Dek, and Gep. We will introduce ourselves one by one in a minute. In the meantime, we are so glad you agreed to be one of Earth's ambassadors. We think that you will have a lot of fun visiting our planet.

(Hit any key for more information.)

The planet Zek is a Z-class planet far, far away. In many ways, it is similar to the Earth - third planet from the suns, favorable atmosphere, lots of H-two-Oh (we think that's what you call it), lots of Zek cities and countries with large populations.

Because it is so similar to Earth, you shouldn't have any trouble visiting it. Here's a map.

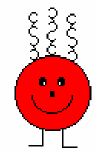


(Hit any key)

As an ambassador, you will be treated very well on our planet. There will be many festivals in your honor. There is, however, one thing you should know. Speaking any language other than Zekkish on our planet is considered very rude. Therefore, before you can embark on a journey to Zek, you must learn some of the Zekkish language.

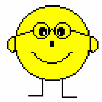
We shall now introduce ourselves and our language.

(Press any key for more information)



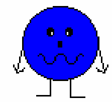
HI!!!! I'm Teb. I am a happy-go-lucky daredevil who likes outdoor sports, especially if they require competition, ability, and a little bit of danger. My big smile and red color reflect my personality. My hair is my most noticeable feature. For that reason, my name is written like this:

(Press the spacebar for more information)



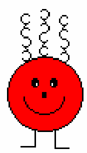
Hi! I'm Dek. I am very studious. My favorite thing to do is to go to school. I like to experiment, and take part in some competitive sports with firm rules. Family life is key for me - someday I hope to have a little Dek running around. My yellow color and shy smile reflect my personality. My glasses are my most noticeable feature, so my name is written like this:

(Press the spacebar for more information)



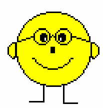
Hi. I'm Gep. I try to keep up with the others, but things don't usually go right for me. My friends call me Eeyore when they think I can't hear them. Not Teb and Dek, though, they are true friends. I hope you'll be my friend too. My blue color and confused expression reflect my personality. My most unique feature is the fact that I have arms (most Zeks don't), so my name is written like this:

(Press any key for more information)



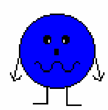
So now that you know a little bit about us, let us explain a little about our language. It only has eight letters, and only seven sounds (two letters have the same sound). There are four consonants and four vowels.

All words are three letters long - consonant, vowel, consonant.



Oh - and you will only need to learn 48 words to be a good speaker.

Our sentences are only two words long - one word being a verb and direct object, and the second word being the subject. I'm not making much sense - let me elaborate.



(Press any key)

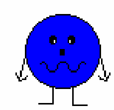
A sentence is two words long - verb/direct object, then subject. For example, if you saw a picture of your friend Sam riding a bike, you might say "Sam is riding a bike."

In Zekkish, you would say "Riding bike, Sam."

Get it?

Let's do another one. Your pet lion, Jud, is eating a cow. (Sorry if this isn't a good example - I'm not real familiar with Earth social life.) You would say "Jud is eating a cow."

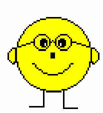
We would say, "Eating cow, Jud."



(Press any key for more information.)

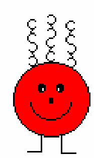
We'll review this information later, don't worry. Before you leave today you are going to learn the sounds of our letters, and begin to sound out words.

You won't have to worry about their meanings until next time.



(Press any key for more information.)

Are you ready? GREAT!!!



When you hit any key at the end of the page, the program will end. Let the experimenter know, so that the experimenter can start up the next program for you.

Good luck, I know you'll do great!!!

(Press any key)

APPENDIX D: Version Effects

This appendix lists the significant interactions of the variables with version. The variable "version" is the pairing of words with meanings. Pairings that were obviously easy were avoided, such as "vum" with driving a car, because "vum" could be considered the sound a car made. Some participants reported that some pairings were easier than others, although different participants reported different "rules" for learning the pairings. For example, one participant pointed out that "vuz" sounded like "fuzzy" when it was connected to "rescuing kitten" while another participant said a word sounded like its Japanese transliteration, and the meaning in Japanese shared some characteristics with the picture. Interestingly, both of these cases involved homophones (although many reported cases did not). A good future study would systematically vary the ease with which one homophone translation matched the picture, while the other did not. Background for this research could come from the second-language learning literature on cognates.

There are many order effects throughout these data. There are a few possible reasons. The most disturbing reason is that, even though the pairing were decided pseudorandomly, one version was easier than the other. Another reason is that fewer participants received Version 2. This was necessary because the decision to run fewer participants was made more than halfway through the study, when more participants had already received Version 1, and because a complete replication of the design required four participants. There may have been a difference in skill or motivation of the participants enrolled in the latter part of the experiment compared to those enrolled earlier (although screening data does not support this). Finally, the significant interactions may be spurious. This explanation is supported by the interactions of version and test time. It is unlikely that there is any systematic reason for participants to do better on one version at one point in training, and the other version at another point in training.

Table. Version effects for spoken response accuracy during vocabulary learning.

Interactions with version	F (dF)	p
Spoken response accuracy, vocabulary learning		
Lexical skill, comprehension skill	$F(1, 37) = 3.78$	$p = .060$
Frequency, lexical skill, comprehension skill	$F(1, 37) = 3.26$	$p = .079$
Spoken response time, vocabulary learning		
Round	$F(3, 111) = 2.16$	$p = .096$
Homophony, lexical skill	$F(1, 37) = 5.50$	$p < .05$
Frequency, lexical skill	$F(1, 37) = 3.62$	$p = .065$
Lexical skill, comprehension skill	$F(1, 37) = 4.99$	$p < .05$
Homophony, lexical skill, comprehension skill	$F(1, 37) = 4.32$	$p < .05$
Frequency, round, lexical skill	$F(3, 111) = 3.40$	$p < .05$
Homophony, round, lexical skill, comprehension skill	$F(3, 111) = 3.21$	$p < .05$
Meaning response accuracy, vocabulary learning		
Homophony	$F(1, 37) = 14.28$	$p < .001$
Homophony, frequency	$F(1, 37) = 8.05$	$p < .01$
Round, lexical skill	$F(3, 111) = 2.43$	$p = .069$
Homophony, frequency, comprehension	$F(3, 111) = 3.77$	$p = .060$
Homophony, frequency, lexical skill, comp skill	$F(1, 37) = 4.79$	$p < .05$

Meaning response time, vocabulary learning		
Homophony	F (1, 37) = 3.93	p = .068
Comprehension skill	F (1, 37) = 3.19	p = .082
Homophony, round	F (3, 111) = 2.31	p = .080
Frequency, round	F (3, 111) = 2.24	p = .088
Homophony, round, comprehension skill	F (3, 111) = 5.93	p < .001
Homophony, frequency, round, comprehension skill	F (3, 111) = 3.02	p < .05
Homophony, frequency, round, lex skill, comp skill	F (3, 111) = 2.39	p = .072
Spoken response accuracy, vocabulary competence		
Main effect	F (1, 37) = 3.66	p = .063
Time, lexical skill	F (3, 111) = 3.65	p < .05
Time, lexical skill, comprehension skill	F (3, 111) = 3.29	p < .05
Homophony, frequency, lexical skill, comp. skill	F (1, 37) = 5.71	p < .05
Spoken response times, vocabulary competence		
Frequency, lexical skill	F (1, 37) = 3.51	p = .069
Homophony, frequency, lexical skill	F (1, 37) = 7.32	p < .01
Homophony, lexical skill, comprehension skill	F (1, 37) = 3.68	p = .063
Homophony, frequency, lexical skill, comp. skill	F (1, 37) = 4.61	p < .05
Meaning response accuracy, vocabulary competence		
Homophony, frequency	F (1, 37) = 3.52	p = .069
Time, comprehension skill	F (3, 111) = 4.79	p < .05
Homophony, time, comprehension skill	F (3, 111) = 2.15	p = .098
Meaning response times, vocabulary competence		
Time	F (3, 111) = 2.14	p = .099
Frequency by lexical skill	F (1, 37) = 5.40	p < .05
Spoken response accuracy, grammar training		
Homophony, round	F (2, 74) = 4.12	p < .05
Homophony, frequency	F (1, 37) = 5.75	p < .05
Homophony, frequency, round	F (2, 74) = 4.64	p < .05
Homophony, frequency, comprehension skill	F (1, 37) = 3.98	p = .053
Frequency, lexical skill, comoprehension skill	F (1, 37) = 3.65	p = .064
Homophony, frequency, round, lexical skill	F (2, 74) = 2.51	p = .088
Spoken reponse time, grammar training		
Homophony, round	F (2, 74) = 3.81	p < .05
Homophony, lexical skill, comprehension skill	F (1, 37) = 3.36	p =.075
Frequency, round, comprehension skill	F (2, 74) = 4.81	p < .05
Meaning response accuracy, grammar training		
Homophony	F (1, 37) = 5.05	p < .05
Homophony, frequency	F (1, 37) = 7.22	p < .05
Meaning response time, grammar training		
Frequency, round	F (2, 74) = 2.62	p = .093
Round, comprehension skill	F (2, 74) = 2.45	p = .093
Frequency, round, comprehension skill	F (2, 74) = 7.27	p < .001
Frequency, round, lexical skill, comprehension skill	F (2, 74) = 3.83	p < .05
Spoken response accuracy, acquisition of experience		
Homophony	F (1, 37) = 3.32	p = .076

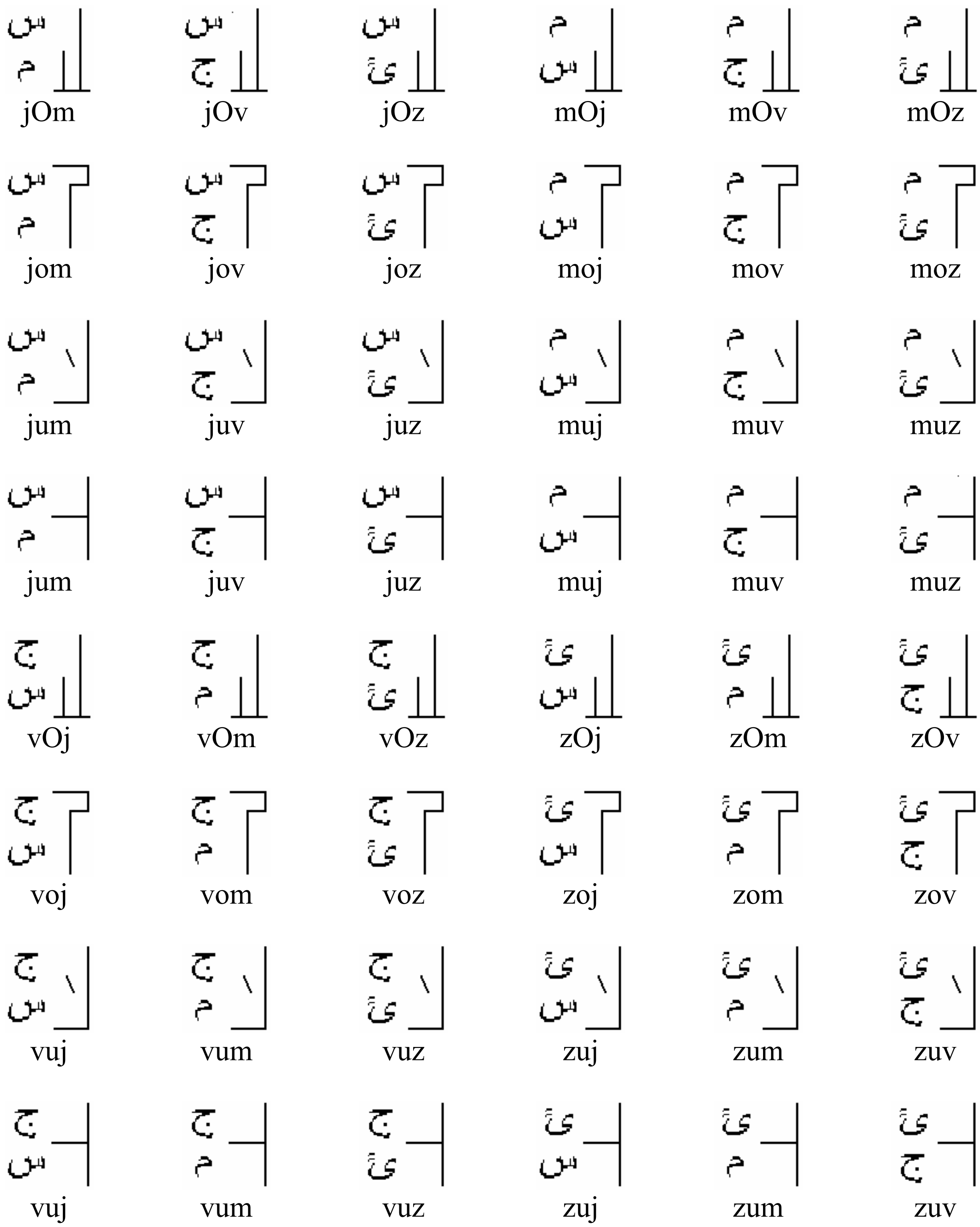
Frequency	F (1, 37) = 4.38	p < .05
Homophony, frequency	F (1, 37) = 5.74	p < .05
Homophony, frequency, lexical skill	F (1, 37) = 3.97	p = .054
Homophony, time	F (3, 111) = 2.25	p = .087
Frequency, time	F (3, 111) = 2.25	p = .087
Frequency, time, lexical skill	F (3, 111) = 3.15	p < .05
Frequency, time, comprehension skill	F (3, 111) = 2.44	p = .068
Frequency, time, lexical skill, comprehension skill	F (3, 111) = 3.60	p < .05
Spoken response time, acquisition of experience		
Homophony	F (1, 37) = 2.95	p = .094
Frequency, lexical skill	F (1, 37) = 5.60	p < .05
Time, lexical skill	F (3, 111) = 3.71	p < .05
Meaning response accuracy, acquisition of experience		
Homophony, frequency	F (1, 37) = 5.40	p < .05
Frequency, lexical skill	F (1, 37) = 3.52	p = .069
Homophony, frequency, time	F (3, 111) = 6.86	p < .0005
Meaning response accuracy, acquisition of experience		
Homophony, time, lexical skill	F (3, 111) = 2.40	p = .072
Frequency, time, lexical skill	F (3, 111) = 2.49	p = .064
Frequency, time, comprehension skill	F (3, 111) = 4.10	p < .01
Frequency, time, lexical skill, comprehension skill	F (3, 111) = 2.63	p = .053

APPENDIX E: Items for Behavioral Tests

Zekkish word identification.

Here and in all cases, testing shorthand transcriptions are given. Small ‘o’ has the short vowel sound, and large ‘O’ has the long vowel sound.

Instructions: You will see a Zekkish word appear on the screen. Please read it as quickly and accurately as possible into the microphone.



English word identification.
Instructions: You will see an English word appear on the screen. Please read it as quickly and accurately as possible into the microphone.

Form A

is	little	table	expert	urgent	prognosis	tuberculous
and	milk	stove	passage	wounded	causation	internecine
cat	swim	airplane	gasoline	petroleum	alkali	quadruped
come	down	because	human	spectacular	naive	dossier
help	with	slowly	certain	miser	carnivorous	oenology
play	said	early	furnace	pedestrian	quintessence	
blue	sleep	already	torpedo	mathematician	cygnet	
no	woman	hurry	departure	relativity	tableau	

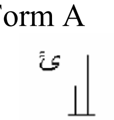
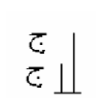
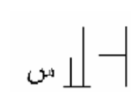
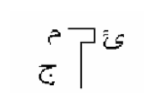
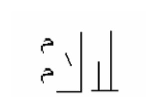
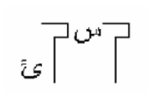
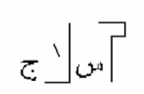
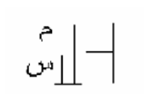
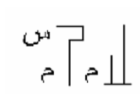
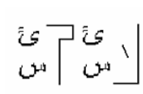
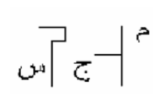
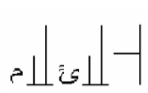
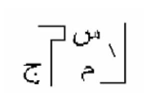
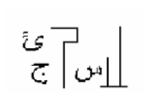
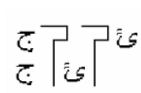
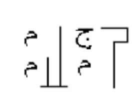
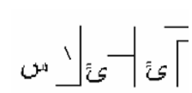
Form B

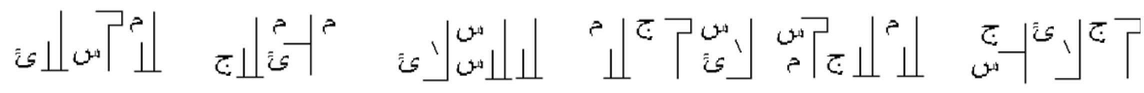
you	bed	work	evening	mechanic	judicious	surreptitious
up	car	ground	receive	zenith	vernacular	taupe
stop	fast	chair	calendar	stigma	philanthropist	epistrophe
jump	rug	beautiful	twilight	cologne	inordinate	picayune
book	find	watch	dwarf	hysterical	artesian	zeitgeist
sun	night	heavy	amazement	yacht	heterogeneous	
two	after	laugh	vehicle	almanac	expostulate	
boy	summer	largest	yardage	instigator	zymolysis	

Zekkish pseudoword identification.

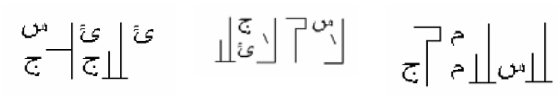
Instructions: You will see a pretend Zekkish word appear on the screen. Please read it as quickly and accurately as possible into the microphone. Sometimes the words will have less than three letters - in that case, one consonant will be missing. Sometimes they will have more than three letters - in that case, sets of three letters will be placed next to each other, and you read them left to right. (They start out easy, and get very hard.)

Form A

					
zO	ov	vOv	Oju	movz	mumO
					
ozjo	uvoj	mOju	jomOm	zojzuj	ojuvm
					
OmOzu	ovjum	zovOj	vovozz	mOmvom	ujuzoz

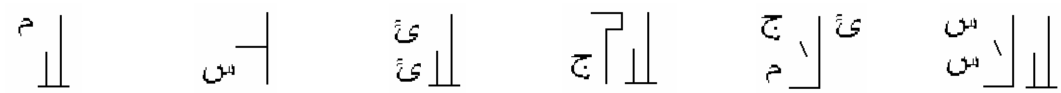


OzojmO Ovmuzm uzjOjO mOvojuz jomOvmO vujzuvo

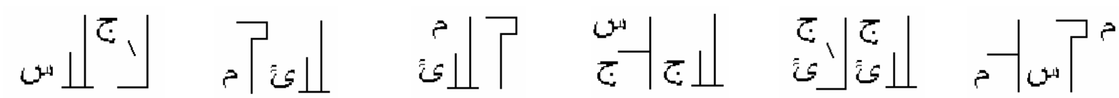


juvzOvz Ovuzoju ovmOmOj

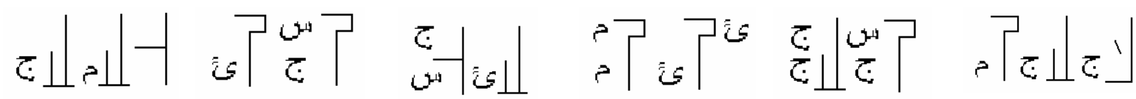
Form B



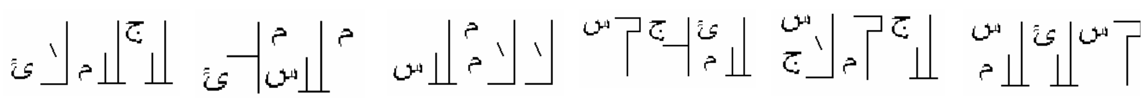
mO uj zOz ovO vumz jujO



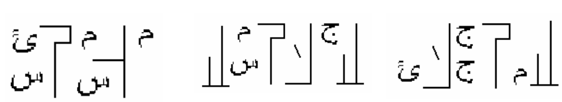
Ojvu omOz mOzo juvOv vuzvOz umojm



OvOmu ozjov vujOz momozz vOvjov omOvuv



uzOmvO uzmOjm Ojmumu jovuzOm juvomvO jOmzOjo



zojmujm Omojuvo uzvovOm

English pseudoword identification.

Instructions: You will see a pretend English word appear on the screen. Please read it as quickly and accurately as possible into the microphone. (They start out easy, and get very hard.)

Form A

tat	bim	oss	shab	straced	adjex	cigbet	vauge
dee	un	poe	vunhip	than't	yeng	wrey	quiles
ift	gat	plip	bufty	twem	gaked	translibsodge	pnomocher

Form B

op	nan	pog	whie	chad	gouch	mancingful	gnouthe
ap	fay	weat	nigh	tadding	zirdn't	bafmotbem	cyr
raff	roo	dud's	sy	laip	knoink	monglustamer	

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Zekkish phonological awareness

Instructions: I want you to use these cards to show me how many sounds I make, and in what order. For example, this says Zek. Take away the /z/, add /d/ to get Dek. Replace the /e/ with /A/ to get Dake. Replace the /k/ with /d/ to get Dade. Got it?

1.	Show me /O/.	Show me /u/.
2.	If that says /O/, show me /Ov/.	If that says /u/, show me /uz/.
3.	If that says /Ov/, show me /vO/.	If that says /uz/, show me /zu/.
4.	If that says /vO/, show me /vOv/.	If that says /zu/, show me /zuz/.
5.	If that says /vOv/, show me /Ov/.	If that says /zuz/, show me /uz/.
6.	If that says /Ov/, show me /ov/.	If that says /uz/, show me /Oz/.
7.	If that says /ov/, show me /jov/.	If that says /Oz/, show me /mOz/.
8.	If that says /jov/, show me /jovd/.	If that says /mOz/, show me /mOzd/.
9.	If that says /jovd/, show me /juvd/.	If that says /mOzd/, show me /mozd/.
10.	If that says /juvd/, show me /uvd/.	If that says /mozd/, show me /ozd/.
11.	If that says /uvd/, show me /udv/.	If that says /ozd/, show me /odz/.
12.	If that says /udv/, show me /dudv/.	If that says /odz/, show me /dodz/.

English phonological awareness

Instructions: Once again, I want you to use these cards to show me how many sounds I make, and in what order. This time, we will use sounds more common to English than to Zekkish. Do you remember how?

1.	Show me /a/.	Show me /oo/.
2.	If that says /a/, show me /ab/.	If that says /oo/, show me /ooth/.
3.	If that says /ab/, show me /ba/.	If that says /ooth/, show me /thoo/.
4.	If that says /ba/, show me /bab/.	If that says /thoo/, show me /thooth/.
5.	If that says /bab/, show me /ab/.	If that says /thooth/, show me /ooth/.
6.	If that says /ab/, show me /ib/.	If that says /ooth/, show me /eth/.
7.	If that says /ib/, show me /chib/.	If that says /eth/, show me /feth/.
8.	If that says /chib/, show me /chibs/.	If that says /feth/, show me /feths/.
9.	If that says /chibs/, show me /choobs/.	If that says /feths/, show me /fiths/.
10.	If that says /choobs/, show me /oobs/.	If that says /fiths/, show me /iths/.
11.	If that says /oobs/, show me /oosb/.	If that says /iths/, show me /isth/.
12.	If that says /oosb/, show me /soosb/.	If that says /isth/, show me /sisth/.

Zekkish working memory.

Instructions: (Forward) I'm going to read you a list of Zekkish words, and I want you to repeat them back to me, in the same order I read them to you. Okay? (Backward) Now I'm going to read you a list of Zekkish words, and I want you to repeat them to me backward. For example, if I say Moz-Vuj, you would say Vuj-Moz. Okay?

Form A

Forward	Backward
muv jov	vuj jom
vOj jom	juz muj
muj moz jOm	zoj jov jum
jov zuv vom	jOm moj voj
zoj zov zOm zuj	muz zOm vum zOv
mOv zum muz zOv	mOj moz mOz muv
jum juv jOz vuz moj	vom muv zum jOz vuz
vOz mOz mOj zOj voz	vOm juz vOj mov jum
mov juz zom vOm vuj voj	jom mOz zOv jOv juv zuj
joz vum juv voz zom vom	mOj moj jOm zOm muz zov
jOz zov mOv zuv zum vOm vuz	joz jov zOj voz vum moz vuj
vOj zOj vOz zuj jOv joz mov	muj zuv mOv zom vOz zoj voj

Form B

Forward	Backward
mOj voj	zoj muv
moj jOz	jOz muj
zOj jum zOm	jOv voz mOj
mOv joz muj	vom muz zom
jov moz vOm jom	juv vOj juz vOm
vom zuv jOv mOz	vuj jov zOv jOm
vOz zum muz mov jOm	joz jum jOv jov zOj
juz zOv zuj zov zom	voz juz mOj zom vOz
juv vum vOj zoj vuj vuz	mOv juv zuj jOm mOz moj
muv voz moz zuv vum vuz	jOz zOv zOm vOm vom jom
mov zOm zOj moj zuj jum joz	vuz mov muj vum zuv voj zum
zov jom vOz voj mOv zum mOz	moz zoj muz vOj muv zov vuj

English working memory – words

Instructions: (Forward) I'm going to read you a list of English words, and I want you to repeat them back to me, in the same order I read them to you. Okay? (Backward) Now I'm going to read you a list of English words, and I want you to repeat them to me backward. For example, if I say Dog-Cat, you would say Cat-Dog. Okay?

Form A

Forward	Backward
Cot Pill	Pat Lip
Lick Pal	Cop Cot
Tack Lot Pit	Tip Lip Cap
Tip Kill Top	Tick Pill Pal
Pock Cat Lap Cop	Cot Lock Pock Lot
Call Pick Tall Cap	Call Kill Lot Pick
Tick Lock Lit Lack Pot	Till Kit Cat Lack Top
Pat Tap Kit Pall Till	Lop Call Lick Pack Tack
Lop Kip Pack Lip Lack Tack	Tap Tall Pal Pock Lock Kill
Cop Pick Pack Lick Pall Tick	Call Pal Pick Lock Lick Tap
Tall Cat Tap Cap Pot Kit Till	Pat Tick Top Pot Till Lit Cop
Lap Kip Lit Lop Top Pit Tip	Lip Kit Tall Pall Cap Pit Lop

Form B

Forward	Backward
Cot Tip	Till Pick
Pack Cat	Cat Kip
Lack Kip Kill	Pot Top Cop
Pill Lap Pock	Cap Lock Lot
Lot Tack Lick Lock	Pock Tap Tall Pat
Pat Tick Tall Lit	Pack Lick Tick Lip
Pill Pot Pack Cap Pick	Lap Cot Pill Pit Lock
Call Cot Pall Lap Kit	Pick Lap Pock Lit Tall
Lack Pock Lop Tip Cat Till	Pack Pall Pat Kip Cat Pal
Lip Tack Pal Tap Pit Top	Cap Pot Kill Cot Pit Tap
Kill Kip Lot Cop Pal Pall Lit	Lop Lip Call Lot Tick Pill Top
Call Kill Kit Lack Tip Tack Lop	Kit Tip Lack Cop Tack Till Lick

English working memory – digits

Instructions: (Forward) I'm going to read you a list of numbers, and I want you to repeat them back to me, in the same order I read them to you. Okay? (Backward) Now I'm going to read you a list of numbers, and I want you to repeat them to me backward. For example, if I say 2-3, you would say 3-2. Okay?

Form A		Form B	
Forward	Backward	Forward	Backward
5-8	6-9	4-7	5-1
6-3	4-2	1-5	4-9
7-3-1	7-1-8	9-6-8	8-9-3
8-2-4	3-5-9	7-3-9	6-5-7
5-9-6-4	9-3-8-6	6-4-8-2	4-1-2-6
8-2-3-1	1-2-4-7	1-3-2-9	3-5-4-8
7-5-6-9-2	5-2-9-1-4	4-8-7-5-6	1-6-7-9-2

1-4-7-6-8	8-3-7-6-1	2-1-4-9-8	4-1-6-8-3
3-9-6-4-5-7	7-1-2-5-6-9	6-3-5-9-7-2	6-5-7-1-8-9
1-3-8-2-6-9	5-7-9-2-1-8	1-8-3-7-5-4	3-4-2-5-1-8
4-5-1-7-3-2-8	3-4-9-1-8-7-2	1-2-7-5-6-4-8	6-2-9-4-7-5-3
5-4-6-1-7-9-2	9-3-1-6-7-5-2	7-3-6-2-5-8-1	9-5-4-2-1-3-7
6-3-5-7-8-4-1-9	3-5-6-4-8-7-2-9	2-5-7-1-3-9-8-4	2-7-9-5-6-8-3-1
9-5-3-1-8-6-7-2	9-2-6-7-3-5-1-4	4-1-3-7-5-8-2-6	5-8-4-7-2-9-6.3
8-6-9-5-2-3-7-4-1	1-6-4-7-9-8-2-5-3	5-7-2-4-8-6-1-3-9	1-7-4-2-6-9-5-3-8
1-4-6-9-5-8-7-2-3	3-6-1-7-4-9-8-2-5	1-4-5-6-9-3-7-2-8	7-5-3-6-8-2-9-1-4

Zekkish word spelling

Instructions: I want you to spell some Zekkish words. I didn't want you to have to write the letters, though, so here are some cards with the letters printed on them. Just arrange the cards to spell the words I say. Ready?

Form A
voj, zOj, zuj, zum, moz, vOz, zuv, muj, zom, jum

Form B
jom, juz, vOm, mov, juv, vuj, mOz, vum, muz, voz

English word spelling

Instructions: I want you to spell some English words. They start out easy, and they get very hard.

Form A

see	letter	huge	urge	rudimentary	longevity	puerile
milk	between	sour	conspiracy	rescinded	regime	lucubration
then	stalk	clarify	quarantine	mitosis	internecine	inefficacious

Form B

red	city	plot	rancid	mosaic	predilection	factitious
was	cliff	humidity	deny	audacious	beatify	epithalamion
jar	grunt	residence	deteriorate	protuberance	regicidal	synecdoche

Zekkish pseudoword spelling

Instructions: I want you to spell some pretend Zekkish words for me, using the letter cards. (And if necessary: some of them can be correctly spelled in more than one way.)

Form A
ju, ove, mOm, jOmuv, ozuv, jumuv, vuvzoj, jOzmov, vOvujom, ozjuzvO

Form B
zO, uj, zuz, movOm, ojum, vOjov, zOmvoj, muzvOj, zozjuv, umjomzO

English pseudoword spelling

Instructions: I want you to spell some pretend English words. Just spell them like they sound. (And if necessary: there are many ways to spell each one; just spell them the way they look best to you.)

Form A

thrept	depnonlel	hap	grawl	yerch	cythe	phigh	cropitance
grinthen	lindify	mell	zoop	quog	loast	mafreatsun	hudned
coge	vizlet	saist	splaunch	paraphonity	feap	lish	

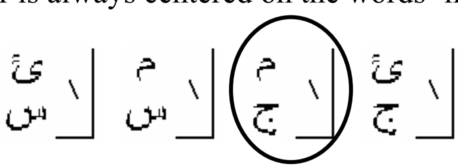
Form B

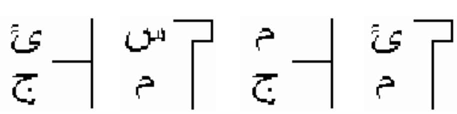
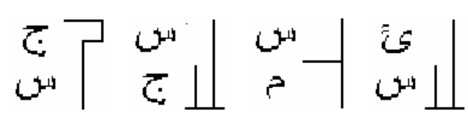
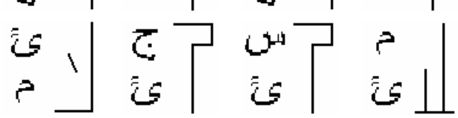
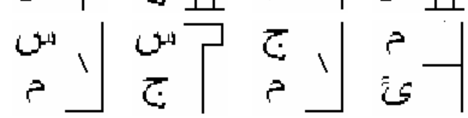
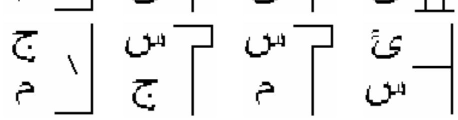
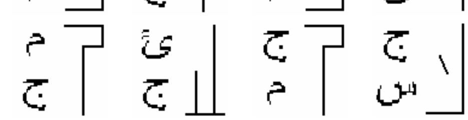
wheeg	quantric	sluke	cruzzle	mibgus	yosh	dright	apertuate
prunchiple	propinity	gusp	snirk	slonking	leck	wroutch	untriffity
whumb	trimnolide	chur	wuss	deprotenation	shomble	tayed	

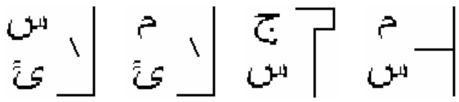
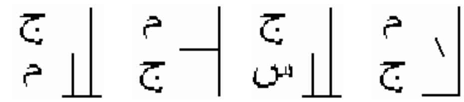
Zekkish inferencing - words

(Note: the words and pictures given to the participants were larger than the ones here, and were photocopied for participants and thus in greyscale. These have been reduced for the purposes of space conservation. Answers and explanations for word and picture sections are given following all the items.)

Form A
Instructions: In this test, you will see four Zekkish words. The MEANINGS of three words will have something in common. Circle the one that is different, and tell why it is different. For example, Number 1 has three words that involve animals, and one that does not.
Hint: The answer is never about who does the actions or what letters the words have. The answer is always centered on the words' meanings.

Ex. A:  __All have animals___

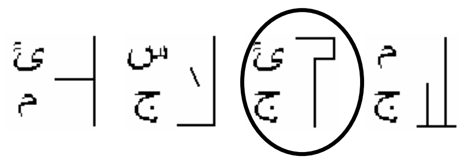
1. 
2. 
3. 
4. 
5. 
6. 

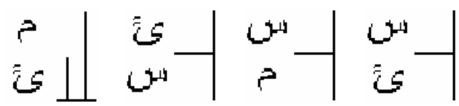
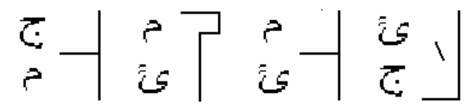
7.  8. 

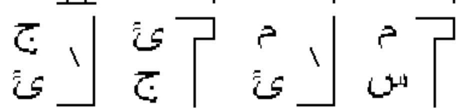
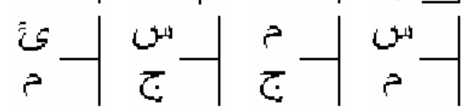
Form B

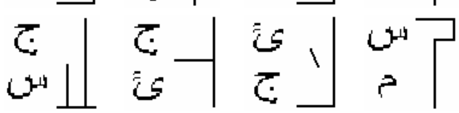
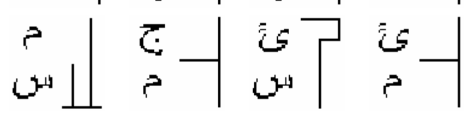
Instructions: In this test, you will see four Zekkish words. The MEANINGS of three words will have something in common. Circle the one that is different, and tell why it is different. For example, Number 1 has three words that involve being up in the air, and one that does not.

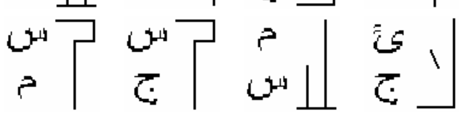
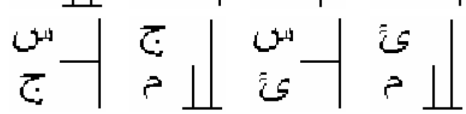
Hint: The answer is never about who does the actions or what letters the words have. The answer is always centered on the words' meanings.

Ex. B:  _All are up in the air__

1.  2. 

3.  4. 

5.  6. 

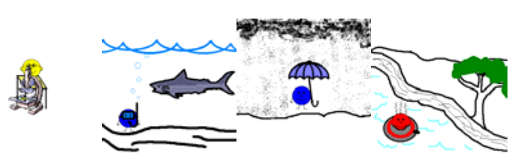
7.  8. 

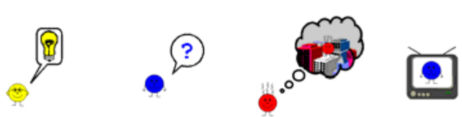
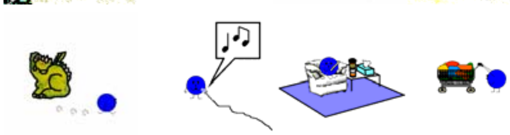
Zekkish inferencing - pictures

Form A

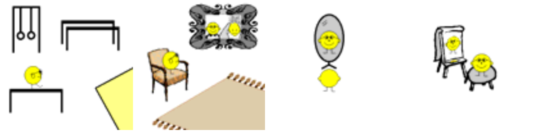
Instructions: Now you will do the same test, except that it is easier because the concepts are represented by pictures, not words.

Ex. A.  __All have animals_

1.  2. 

3.  4. 

5. 

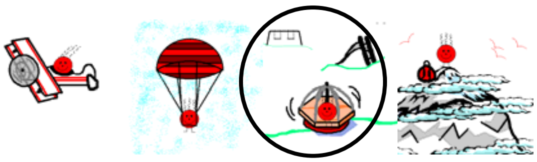
6. 

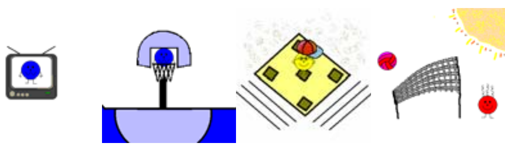
7. 

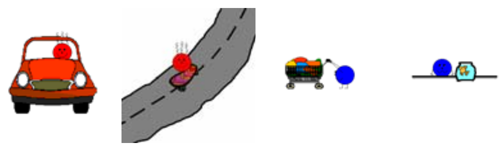
8. 

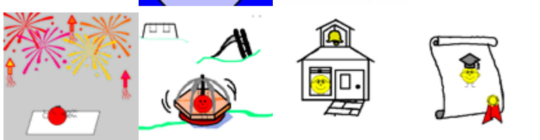
Form B

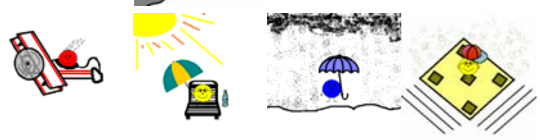
Instructions: Now you will do the same test, except that it is easier because the concepts are represented by pictures, not words.

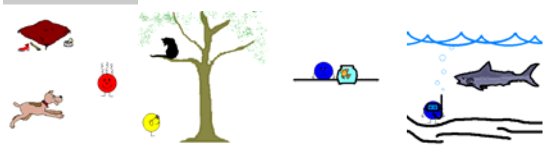
Ex. B.  _All are up in the air__

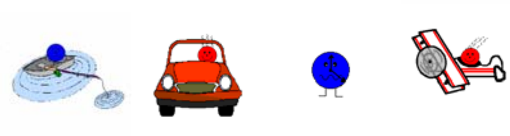
1. 

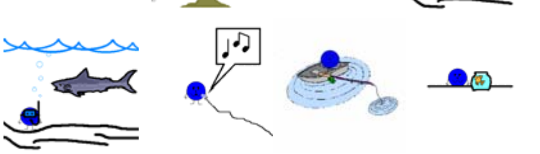
2. 

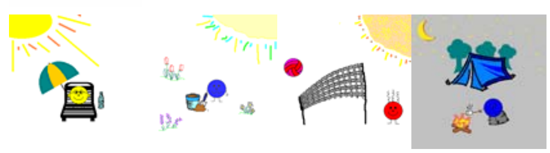
3. 

4. 

5. 

6. 

7. 

8. 

Answers, Form A

1. A. Water.
2. B. Sand.
3. D. Thought
4. C. Activity.
5. D. Something at/in mouth
6. A. Images of Dek.
7. C. Buildings/inside
8. C. Weather

Answers, Form B

1. A. Sports
2. D. Wheels
3. A. School-related
4. A. On/over head
5. D. Pets
6. C. Vehicles
7. B. Water animals
8. D. Daytime/sun

English inferencing – words

(Note: the pictures given to the participants were larger than the ones here, and were photocopied for participants and thus in greyscale. These have been reduced for the purposes of space conservation. Answers and explanations for word and picture sections are given following all the items.)

Form A.
Instructions: In this test, you will see four English phrases. The MEANINGS of three phrases will have something in common. Circle the one that is different, and tell why it is different. For example, Number 1 has three words that involve food (specifically fruit), and one that does not. Hint: The answer is never about who does the actions or what letters the words have. The answer is always centered on the words' meanings.

Ex. A. Baking apple pie __All involve fruit____________
Eating banana
Weeding garden
Slicing watermelon

1. Catching baseball, dining on fish and chips, baking apple pie, saluting flag
2. Smashing racquetball, cheering for football, returning tennis serve, watching badminton
3. Stopping at stop sign, squirting ketchup, eating banana, bleeding from knee
4. Talking on phone, typing email, reading book, writing letter
5. Blowing up balloons, blowing out candles, opening present, laying in bed
6. Knitting scarf, cooking dinner, starting fire, talking on phone
7. Waiting for subway, riding motorcycle, traveling by bus, commuting on train
8. Releasing dove, reading book, consulting with doctor, working as cashier

Form B.
Instructions: In this test, you will see four English phrases. The MEANINGS of three phrases will have something in common. Circle the one that is different, and tell why it is different. For example, Number 1 has three words that involve snow (specifically snow sports), and one that does not. Hint: The answer is never about who does the actions or what letters the words have. The answer is always centered on the words' meanings.

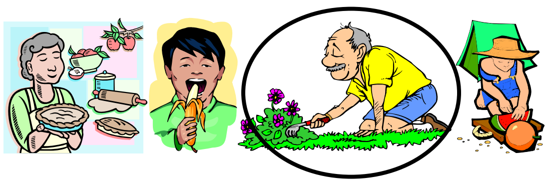
Ex. B. Falling from skis ___All involve snow sports_____
Snowboarding down hill
Painting sled
Blowing out candles

1. Winning lottery, losing soccer game, missing plane, laying in bed
2. Shopping at mall, getting exercise, playing video games, walking to school
3. Shopping at mall, starting kindergarten, ready for college, late for new job
4. Silencing alarm, tying shoe, dressing in pajamas, having breakfast
5. Releasing dove, feeding ducks, searching for birds, waving to penguins
6. Tying shoe, feeding ducks, waving to penguins, snacking on popcorn

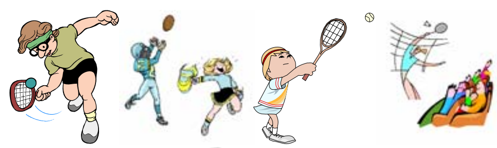
7. Riding motorcycle, racing on bike, balancing unicycle, piggyback riding moped
8. Falling off skis, relaxing in pool, raking leaves, typing email

English inferencing – pictures

Form A.
Now you will do the same test, except that it is easier because the concepts are represented by pictures, not words.

Ex. A  __All involve fruit____________

1. 

2. 

3. 

4. 

5. 

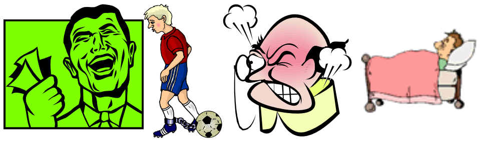
6. 

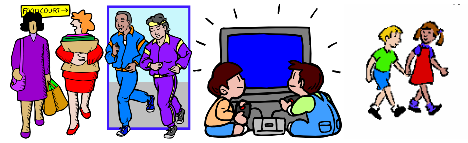
7. 

8. 

Form B.
Instructions: Now you will do the same test, except that it is easier because the concepts are represented by pictures, not words.

Ex. B.  __All involve snow sports_

1. 

2. 

3. 

4. 

5. 

6. 

7. 

8. 

Answers, Form A.

1. B. American
2. B. Raquet sports or D. Ball
3. C. Red
4. C. Communication or A. Written words
5. D. Birthday party
6. D. Creating new thing or D. Warmth
7. B. Mass transit or A. In transit
8. B. Helping another

Answers, Form B.

1. D. Strong emotions
2. C. Exercise/walking
3. A. Starting new life phase
4. C. Morning activities
5. C. See birds, or D. Birds that can fly
6. A. At park/zoo
7. C. Two wheels
8. D. Seasonal activities

APPENDIX F: Scoring of English Pseudoword Spelling

Scoring English pseudoword spelling was more difficult than scoring Zekkish pseudoword spelling. Although there was occasionally more than one way to spell a Zekkish pseudoword, the regularity of the Zekkish spellings made decisions easy: the word was spelled correctly, or it was not. For English, not only were there multiple correct spellings, but some more closely conformed to English spelling patterns than others; that is, some letter combinations were found in higher frequency in English words than others. In a book entitled Phoneme-Grapheme Correspondences as Cues to Spelling Improvement (1966), Hanna and colleagues tabulated the frequency of spellings for each English phoneme from a lexicon of all words in Merriam-Webster's New Collegiate Dictionary, sixth edition. The final word list included 17, 310 words after some particularly rare graphemic combinations (e.g. "of") and a number of foreign words were removed as exceptions to the alphabetic principle. Phonemes were scored largely according to Merriam-Webster's pronunciation code, as shown below.

Code	M-Web	Occurrences	Example	Code	M-Web	Occurrences	Example
A	ā	2248	Ale	B	b	2303	But
A2	a	220	Care	D	d	3691	Day
A3	a	4340	Add	F	f	2019	Fill
A5	a	580	Arm	G	g	1338	Go
E	ē	2538	Eve	H	h	778	Hat
E2	ē	198	Here	J	j	982	Joke
E3	e	3646	End	K	k	4712	Keep
E5	e	2170	Maker	L	l	5389	Late
I	ī	1482	Ice	M	m	3501	Man
I3	i	7815	Ill	N	n	7656	Nod
O	ō	2587	Old	P	p	3449	Pen
O2	o	767	Orb	R	r	9390	Rat
O3	o	1662	Odd	S	s	6326	Sit
O5	o	127	Soft	T	t	7793	To
O6	ōō	453	Food	V	v	1492	Van
O7	oo	368	Foot	W	w	626	Win

U	ū	1188	Unite	Y	y	120	Yet
U2	u	787	Urn	Z	z	995	Zone
U3	u	1410	Up	CH	ch	564	Chair
OI	oi	149	Oil	HW	hw	89	What
OU	ou	406	Out	KW	kw	196	Quilt
Schwa	italics	6013	about	L1	‘l	651	Able
				M1	‘m	97	Chasm
				N1	‘n	128	Pardon
				NG	ng	615	Sing
				SH	sh	1537	She
				T1	th	411	Thin
				T2	th	149	Then
				ZH	zh	102	azure

Note: In addition to the given consonants, KS (ks, n=271) and H9 (silent H, n=49) were used. These were unnecessary for scoring the pseudowords.

Frequencies and percentages of phoneme-grapheme (p-g) correspondences were tabulated by syllable position (initial, medial, and final position) and syllabic stress (primary, secondary, and unaccented). The necessity of tabulating by syllable position is particularly clear in the example of the L1 sound. The L1 sound never occurs in the initial position, occurs once in the medial position (spelled “l”), and occurs 650 times in the final position (spelled “l,” “el,” “il,” “al,” and “ol”). The necessity of tabulating by accent is particularly clear in the example the NG sound. For primary/secondary accents, the “n” and “ng” spellings are fairly equal (52% and 48%, respectively), but when unaccented, the “ng” spelling is much more common (97%, versus 3% for “n”).

An example of the variety of p-g correspondences and the variability in percentage by syllable position and stress is given below.

/SH/		Initial Position			Medial Position			Final Position		
N=1537		P	S	U	P	S	U	P	S	U
	TI	0.00	0.00	80.20	0.00	0.00	0.00	29.67	8.70	0.00
	SH	83.52	89.66	2.42	0.00	0.00	100.00	28.33	82.61	100.00
	CI	0.00	0.00	4.29	0.00	0.00	0.00	13.67	4.35	0.00

SSI	0.00	0.00	0.00	0.00	0.00	0.00	17.00	0.00	0.00
SI	0.00	0.00	4.18	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	0.00	2.42	0.00	0.00	0.00	5.33	0.00	0.00
CH	8.24	10.34	1.21	0.00	0.00	0.00	1.67	0.00	0.00
T	0.00	0.00	2.64	0.00	0.00	0.00	1.67	4.35	0.00
S	4.40	0.00	1.21	0.00	0.00	0.00	0.33	0.00	0.00
SS	2.75	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00
SC	0.55	0.00	0.33	0.00	0.00	0.00	0.67	0.00	0.00
SCI	0.00	0.00	0.44	0.00	0.00	0.00	0.33	0.00	0.00
X	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00
CE	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00
SCH	0.55	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00

Note: P = primary accent, S = secondary accent, U = unaccented syllable.

Coding for the pseudowords is given below.

Word	Syllables	Sounds									
thrept	1	t1	r	e3	p	t					
grinthen	2	g	r	i3	n	t1	e3	n			
coge	1	k	o	j							
depnonlel	3	d	e3	p	n	o	n	l	e3	l	
lindify	3	l	I3	n	d	Ə	f	I			
vislet	2	v	i3	z	l	e3	t				
hap	1	h	a3	p							
mell	1	m	e3	l							
saist	1	s	a	s	t						
grawl	1	g	r	o2	l						
zoop	1	z	o6	p							
splaunch	1	s	p	l	o2	n	ch				
yerch	1	y	u2	r	ch						
quog	1	kw	o2	g							
paraphonity	5	p	a	r	Ə	f	o3	n	Ə	t	y
cythe	1	s	I	t1							

loast	1	l	o	s	t							
feep	1	f	e	p								
phigh	1	f	I									
mafreatsun	3	m	Ə	f	r	e	t	s	n1			
lish	1	l	i3	sh								
cropitance	3	k	r	o3	p	i3	t	e3	n	s		
hudned	2	h	u3	d	n	e3	d					
wheeg	1	w	e	g								
prunchiple	3	p	r	u	n	ch	Ə	p	l1			
whumb	1	w	u3	m								
quantric	2	kw	a5	n	t	r	i3	k				
propinity	4	p	r	o	p	i3	n	i3	t	y		
trimnolide	3	t	r	i3	m	n	o	l	I	d		
sluke	1	s	l	o6	k							
gusp	1	g	u3	s	p							
chur	1	ch	u2	r								
cruzzle	2	k	r	u3	z	l1						
snerk	1	s	n	u2	r	k						
wus	1	w	u3	s								
mibgus	2	m	i3	b	g	u3	s					
slonking	2	s	l	o3	ng	k	i3	ng				
deprotination	5	d	e	p	r	o	t	Ə	n	a	sh	n1
yosh	1	e	a5	sh								
leck	1	l	e3	k								
shomble	2	sh	o3	m	b	l1						
dright	1	d	r	I	t							
wrouch	1	r	ou	ch								
tayed	1	t	a	d								
apertuate	4	Ə	p	Ə	r	ch	o6	a	t			
untriffity	4	u3	n	t	r	i3	f	i3	t	y		

Note: The schwa sound is indicated by the symbol Ə.

Once percentages were assigned to each pseudoword, they were scored three ways. The first method maximized the precision of the coding system. The percentages were added across the word to give a total score. Missing phonemes were scored as 0. Additional letters were scored with the nearest phoneme. For example, spelling depnonlel as depnonlelb would result in a score of 0 for the final phoneme, spelled "lb." The rationale for this scoring method was that the more often a spelling was found in the English spelling system, the more participants were capitalizing on their knowledge, conscious or not, of phoneme-grapheme correspondences. Note that even answers that are incorrect in total receive a positive score.

The second method scores each spelling as correct or incorrect. A correct designation is given to any word for which all phonemes are given an existing spelling, even if that spelling is rare. The rationale for this method was that the ultimate goal of spelling a pseudoword was to give a readable and reasonable spelling. It also gives an equal weight to each word on the list.

The third method scores each spelling as correct or incorrect. A correct designation is given to any word for which all phonemes are given a spelling that has a percentage of occurrence of at least 20%. The rationale for this method was that allowing for all spellings, but weighted toward a sensitivity toward normally occurring p-g patterns, might maximize the benefits of both of the previous scoring systems.

Methods 2 and 3 were reported in the text. Each showed the same pattern of results, although method 3, the one sensitive to p-g patterns, provided more significant data. There were no significant effects for method 1, although the pattern of results is the same. It is likely that simply adding the percentages across words resulted data that were too noisy to show effects. Scores of 0 or 1 per word give more stable data.

APPENDIX G: Answers given on the Inferencing tests

			Given Answer	#	Freq.
Zekkish Vers. A	1	Correct	water	76	84.44
			outdoors	5	5.56
			hobbies	2	2.22
			nice weather	1	1.11
		Incorrect	no answer	3	3.33
			gep	1	1.11
			sports	1	1.11
			summer	1	1.11
	2	Correct	outdoors	45	50
			recreation	12	13.33
			activity/movement/physical	7	7.78
			sand/dirt	6	6.67
			leisure/hobbies	5	5.56
			alone	3	3.33
			sports	2	2.22
		Incorrect	no answer	5	5.56
			dek	4	4.44
			things, not people	1	1.11
	3	Correct	thought/idea	56	62.22
			mind/brain/mental activity	12	13.33
			bubbles	6	6.67
			imagination	3	3.33
			abstract/intangible	2	2.22
		Incorrect	no answer	6	6.67
			communication	1	1.11
			dek	1	1.11
			not actual activity	1	1.11
			physically controlled	1	1.11
			things, not animals	1	1.11
	4	Correct	realistic	14	15.56
			surviving/health/taking care/vital necessities	7	7.78
			movement	7	7.78
			holding	6	6.67
			action/doing/standing	6	6.67
			not fun/unpleasant	4	4.44
			use device/object	2	2.22
			mouth	2	2.22
			pretending/fantasy	1	1.11
			obligations not easily cancelled	1	1.11
		Incorrect	no answer	31	34.44
			everyday life	2	2.22
			frightened	2	2.22
			fun	1	1.11

		gep	1	1.11
		geb's a mover and shaker	1	1.11
		animals	1	1.11
		no animals	1	1.11
5	Correct	hobbies/recreation/leisure	13	14.44
		actions/physical/doing	10	11.11
		mouth/voice/oral	7	7.78
		skill/talent	2	2.22
		"under" (water, weather, basket)	1	1.11
		clear glass or plastic	1	1.11
		holding	1	1.11
	Incorrect	no answer	19	21.11
		fun	16	17.78
		start with /s/ sound	6	6.67
		land	3	3.33
		gep	2	2.22
		alone	1	1.11
		balls	1	1.11
		I never do	1	1.11
		no animals	1	1.11
		not vocal	1	1.11
		outside	1	1.11
		require health	1	1.11
		safe	1	1.11
		social	1	1.11
6	Correct	image	16	17.78
		self-reflection	15	16.67
		look at	12	13.33
		look at self	8	8.89
		picture	8	8.89
		self	4	4.44
		>1 dek	2	2.22
		appearance	2	2.22
		frames	1	1.11
		standing on	1	1.11
		things superficial people do	1	1.11
		think about self	1	1.11
	Incorrect	no answer	8	8.89
		actions	2	2.22
		Dek	2	2.22
		not moving feet	2	2.22
		animals	1	1.11
		at home	1	1.11
		coordination	1	1.11
		playground	1	1.11
		small children activities	1	1.11

	7	Correct	buildings	24	26.67
			indoors	32	35.56
			inside building	11	12.22
			going then staying	1	1.11
			stuck somewhere	1	1.11
		Incorrect	no answer	9	10
			real	3	3.33
			good/happy	2	2.22
			volunteer	2	2.22
			children's things	1	1.11
			dirt/sand	1	1.11
			do	1	1.11
			learning	1	1.11
			physical	1	1.11
	8	Correct	weather	16	17.78
			seasons	11	12.22
			water/precipitation	4	4.44
		Incorrect	outside	24	26.67
			no answer	15	16.67
			playing	3	3.33
			yard	3	3.33
			activities	3	3.33
			hobbies/leisure	2	2.22
			warm weather	2	2.22
			cold weather	1	1.11
			fun	1	1.11
			holding	1	1.11
			not raining	1	1.11
			solitary	1	1.11
			summer	1	1.11
			nature	1	1.11
Zekkish Vers. B	1	Correct	sports	77	85.56
			balls/throwing	6	6.67
			activity/physical	2	2.22
		Incorrect	animals	2	2.22
			no answer	1	1.11
			holding	1	1.11
			realistic	1	1.11
	2	Correct	wheels	52	57.78
			motion/movement/travel	15	16.67
			vehicles	3	3.33
			operating/steering	2	2.22
			active verbs	2	2.22
		Incorrect	no answer	7	7.78
			outside	3	3.33
			fun	2	2.22

		no animals	2	2.22
		inside	1	1.11
		don't need other things to do	1	1.11
3	Correct	school	59	65.56
		fun/joyous	5	5.56
		celebrations in sequence (school, diploma, fireworks)	1	1.11
	Incorrect	no answer	17	18.89
		children's activities	2	2.22
		not earned	2	2.22
		physical places	1	1.11
		look forward	1	1.11
		looking at	1	1.11
		rewarding life experiences	1	1.11
4	Correct	good weather/sunny	32	35.56
		head cover/shelter from elements	11	12.22
		on ground	8	8.89
		sky/in air	4	4.44
	Incorrect	no answer	21	23.33
		outdoors	7	7.78
		not physical/not sport/recreation	3	3.33
		Dek	1	1.11
		interacting with	1	1.11
		realistic	1	1.11
		summer	1	1.11
5	Correct	pets/domesticated animals	32	35.56
		interaction with animals	8	8.89
		on dry land	5	5.56
		safe	4	4.44
		playful/active	2	2.22
		outdoors	2	2.22
		fear/danger	1	1.11
	Incorrect	animals	17	18.89
		no answer	11	12.22
		with animal	2	2.22
		Gep	2	2.22
		animals in something	1	1.11
		animals in title	1	1.11
		not with animal	1	1.11
		watching animal	1	1.11
6	Correct	transportation/vehicles/riding in	55	61.11
		outdoors	5	5.56
		engine/motor	3	3.33
	Incorrect	no answer	11	12.22
		moving/going somewhere	8	8.89
		actions/activities/doing	5	5.56
		enjoyable	1	1.11

			not in air	1	1.11
			recreation	1	1.11
	7	Correct	water	39	43.33
			fish/marine life	38	42.22
			animals	4	4.44
		Incorrect	no answer	6	6.67
			dek	1	1.11
			gep and water	1	1.11
			stationary activities	1	1.11
	8	Correct	daytime	46	51.11
			beach	6	6.67
			camping	1	1.11
		Incorrect	no answer	14	15.56
			outside	8	8.89
			sun/fair weather	5	5.56
			leisure/recreation/relaxing	4	4.44
			enjoy nature	3	3.33
			summer	2	2.22
			use hands	1	1.11
English Vers. A	1	Correct	American/independence day/patriotism	46	51.11
			uniforms	1	1.11
		Incorrect	no answer	23	25.56
			baseball	7	7.78
			hands (in, lift, use)	5	5.56
			activities	4	4.44
			not recreation/sports	3	3.33
			other countries	1	1.11
	2	Correct	Raquet	43	47.78
			Active participation	22	24.44
			Balls	11	12.22
		Incorrect	Sports	5	5.56
			Net	4	4.44
			no answer	2	2.22
			Arms moving	1	1.11
			Motion	1	1.11
			Yelling	1	1.11
	3	Correct	Things that are red	66	73.33
			Controllable	8	8.89
			Liquid/messy	3	3.33
		Incorrect	no answer	8	8.89
			Painless	2	2.22
			Body	1	1.11
			People	1	1.11
			Summer	1	1.11
	4	Correct	communicatiojn	65	72.22
			text/words/written language	15	16.67

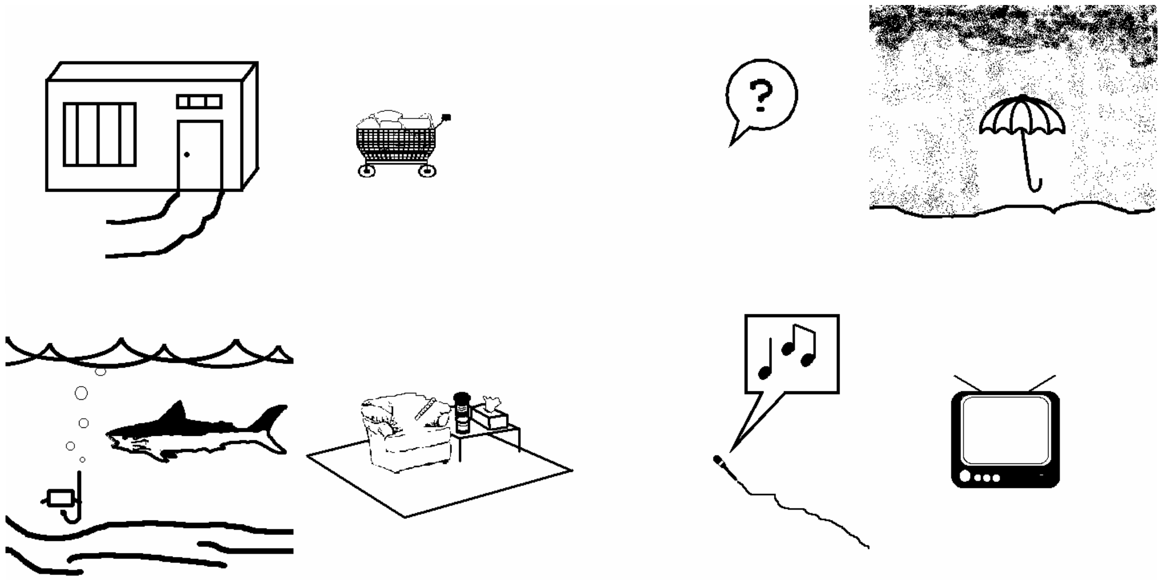
		quiet/silent comprehension/reading	6	6.67
		someone else	1	1.11
	Incorrect	1 person	1	1.11
		dialogue	1	1.11
		working hard	1	1.11
5	Correct	birthday/party	85	94.44
		action/physical activity	5	5.56
	Incorrect	None	0	0
6	Correct	creation	15	16.67
		warmth	11	12.22
		domestic	4	4.44
	Incorrect	no answer	17	18.89
		female/womanly/motherly/grandmotherly	12	13.33
		downtime/leisure	10	11.11
		acquired skills	6	6.67
		active/exert energy	3	3.33
		verbal/nonverbal	3	3.33
		hands	2	2.22
		nighttime routine	2	2.22
		both hands	1	1.11
		consequences if you do all at once	1	1.11
		finish task	1	1.11
		standing	1	1.11
		tools	1	1.11
7	Correct	mass transit	43	47.78
		in transit	37	41.11
	Incorrect	vehicle	4	4.44
		transportation	2	2.22
		travel	2	2.22
		no answer	1	1.11
		means of moving	1	1.11
8	Correct	indoors (trapped)	11	12.22
		can't do alone; with another; interaction	11	12.22
		work/occupation	5	5.56
		personal/not for monetary gain	3	3.33
		freeing (animal, mind, worries)	2	2.22
		papers/paperwork	2	2.22
		helping	2	2.22
		reading	1	1.11
		taking in	1	1.11
	Incorrect	no answer	30	33.33
		learn/gain knowledge	7	7.78
		use hands	4	4.44
		alone	2	2.22
		not flaky/have purpose	2	2.22
		women	2	2.22

			opening	2	2.22
			active	1	1.11
			tedious things	1	1.11
			to do list	1	1.11
English Vers. B	1	Correct	emotions	24	26.67
			chance/luck/fortune/misfortune	11	12.22
			win(Gain)/loss	10	11.11
			controllable/preventable	1	1.11
		Incorrect	sad/bad/negative	23	25.56
			no answer	15	16.67
			unexpected	2	2.22
			actions	1	1.11
			important events	1	1.11
			missing out on good thing	1	1.11
			physical	1	1.11
	2	Correct	legs/movement/walking	53	58.89
			exercise/physical/active	29	32.22
			leisure	2	2.22
		Incorrect	no answer	2	2.22
			enjoyed company	1	1.11
			fun activities	1	1.11
			leaving home	1	1.11
			voluntary activities	1	1.11
	3	Correct	new beginnings/life stages	45	50
			nervous/stressful/anticipated	8	8.89
			time	5	5.56
			grown-up	2	2.22
			impression important	1	1.11
		Incorrect	work/school/career	13	14.44
			no answer	8	8.89
			responsibilities	2	2.22
			happy	2	2.22
			important	2	2.22
			going to	1	1.11
			not in hurry	1	1.11
	4	Correct	morning/get ready/start day/wake up	83	92.22
			daily activities	1	1.11
			happen at certain times	1	1.11
		Incorrect	no answer	3	3.33
			sleep	2	2.22
	5	Correct	flying birds	14	15.56
			wild birds	8	8.89
			park/zoo	2	2.22
			specific bird type	2	2.22
		Incorrect	see/touch birds	41	45.56
			no answer	10	11.11

		birds	9	10
		helping birds	3	3.33
		>1 bird	1	1.11
6	Correct	zoo/animal park	20	22.22
		hands/fingers touching/holding	14	15.56
		park/lake	4	4.44
		tongues	3	3.33
	Incorrect	no answer	37	41.11
		fun/enjoyable	2	2.22
		outside	1	1.11
		children's activities	1	1.11
		food/birds	1	1.11
		healthy	1	1.11
		no weight gain	1	1.11
		not focus on foot	1	1.11
		one handed	1	1.11
		unfruitful activities	1	1.11
		unnecessary actions	1	1.11
		activities	1	1.11
7	Correct	2 wheels	45	50
		1 person	8	8.89
		hands	4	4.44
	Incorrect	no answer	5	5.56
		riding	5	5.56
		moving	5	5.56
		controlling the bike	4	4.44
		bike	4	4.44
		1 leg on each side	2	2.22
		cycle type	2	2.22
		no motor	2	2.22
		wheels	2	2.22
		bend over	1	1.11
		no pedal	1	1.11
8	Correct	outdoors	56	62.22
		seasons	12	13.33
	Incorrect	no answer	8	8.89
		work/effort/active	7	7.78
		hobby/relaxation/leisure	3	3.33
		annoyances	2	2.22
		not involving technology	1	1.11
		cold weather	1	1.11

APPENDIX H: ERP Stimuli

Picture stimuli, in black and white, with Zeks removed.



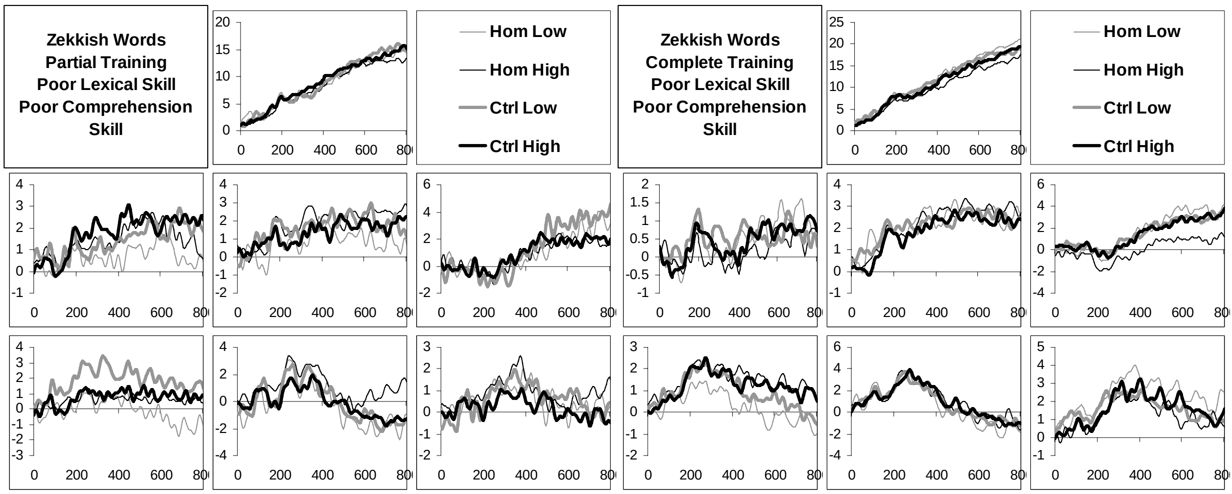
Stimuli included in English ERP task.

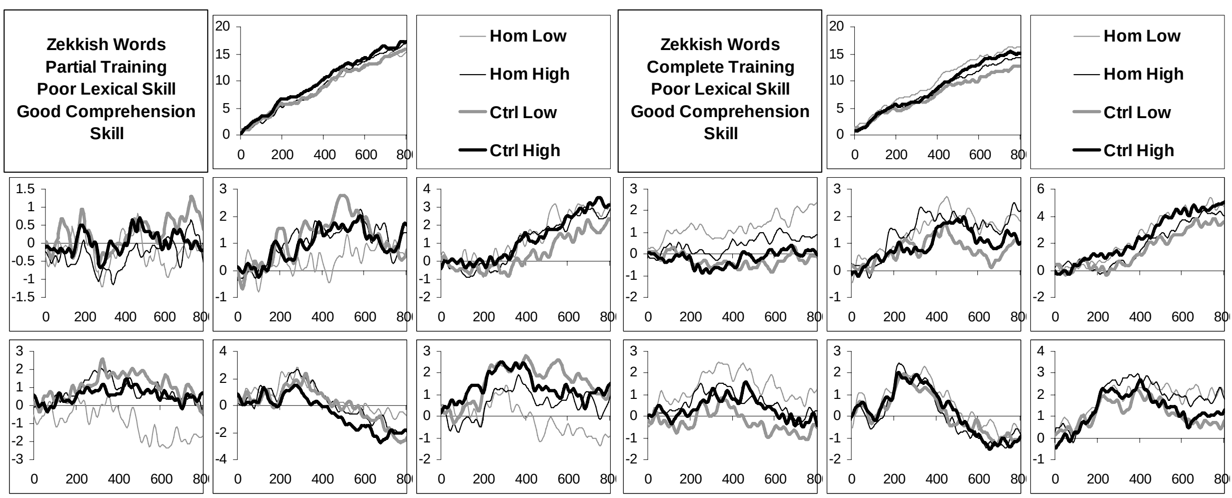
High freq Homophone	freq	High freq Control	freq	Low freq Homophone	freq	Low freq Control	freq
guerilla	1	felon	1	gorilla	0	giraffe	0
surf	1	smog	1	serf	0	eunuch	0
logger	1	florist	1	lager	0	toga	0
rumor	1	anthem	1	roomer	0	skater	0
fryer	2	crater	2	friar	1	cleric	1
llama	3	tortoise	3	lama	0	crier	0
magnet	3	morsel	3	magnate	1	broker	1
foul	4	fuss	4	fowl	1	snail	1
borough	5	bedside	5	burro	1	donkey	1
corral	5	chestnut	5	chorale	1	diva	1
wrapper	5	woodwork	5	rapper	2	robber	2
heroine	5	puritan	5	heroin	2	inferno	2
burger	6	banquet	6	burgher	1	burglar	1
queue	6	ledge	6	cue	1	crutch	1
cougher	7	youngster	7	coffer	0	chalice	0
peer	8	spy	8	pier	3	peach	3
ferry	11	furnace	11	fairy	4	foreman	4
dough	13	debt	13	doe	1	fawn	1
links	16	lungs	16	lynx	0	puma	0
pros	16	monks	16	prose	14	purse	14
collar	17	basket	17	caller	2	cellist	2
bell	18	brick	18	belle	1	bloke	1
border	20	bundle	20	boarder	1	addict	1
aunt	22	gang	22	ant	6	rat	6
locks	23	decks	23	lox	0	prawn	0
profit	28	passion	28	prophet	5	plaintiff	5

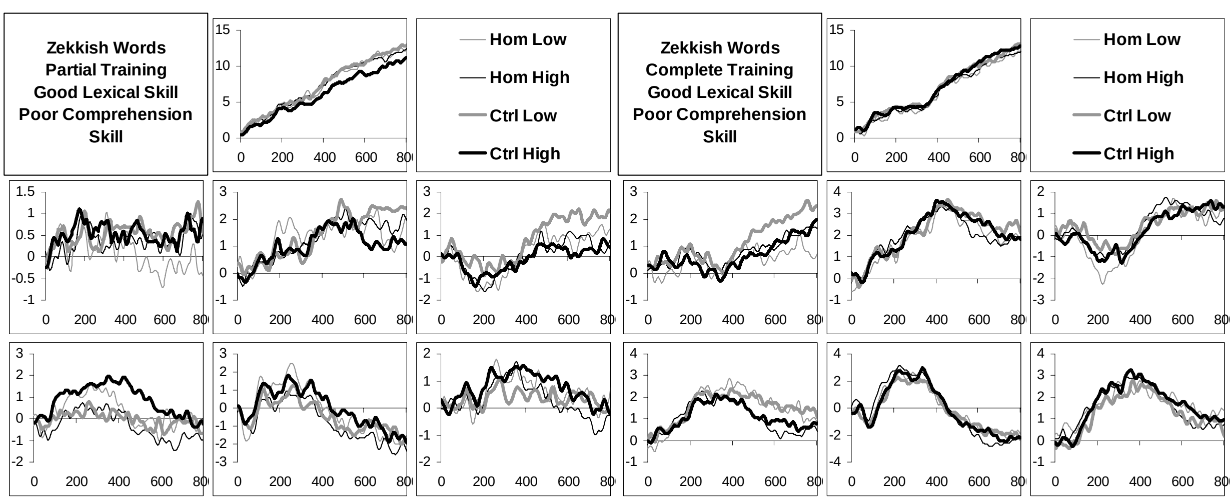
residence	29	proportion	29	residents	13	receivers	13
prince	33	bride	33	prints	18	pens	18
crews	36	guides	36	cruise	2	crate	2
colonel	37	consumer	37	kernel	3	kettle	3
seller	41	queen	41	cellar	26	contest	26
muscle	42	journal	42	mussel	0	crustacean	0
guys	51	cousins	51	guise	6	poise	6
mail	47	skin	47	male	37	fool	37
patients	86	captains	85	patience	22	protest	22
assistance	87	battle	87	assistants	36	bakers	36
click	91	dinner	91	clique	17	nurse	17
doc	100	poet	99	dock	8	deed	8
news	102	rise	102	gnus	0	reindeer	0
corps	109	professional	105	core	37	paint	37
hair	148	earth	150	hare	1	frog	1
air	257	question	257	heir	7	dame	7
night	411	end	410	knight	18	squad	18
him	2619	she	2859	hymn	9	hint	9
you	3286	her	3037	ewe	1	elk	1
principle	109	income	109	principal	92	everyone	94
son	166	committee	168	sun	112	shot	112
our	1252	man	1207	hour	144	club	145

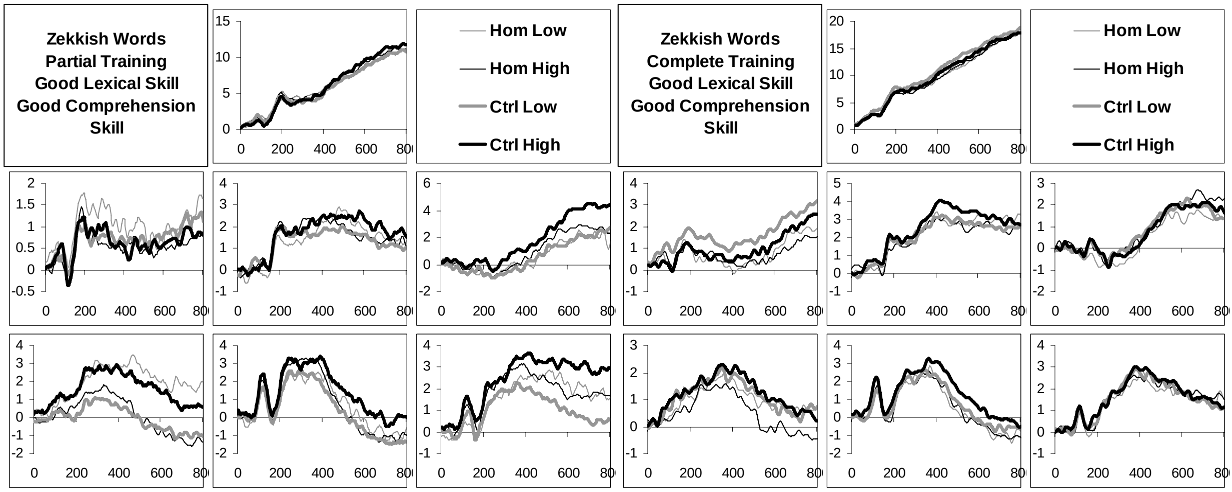
APPENDIX I: ERP Waveforms

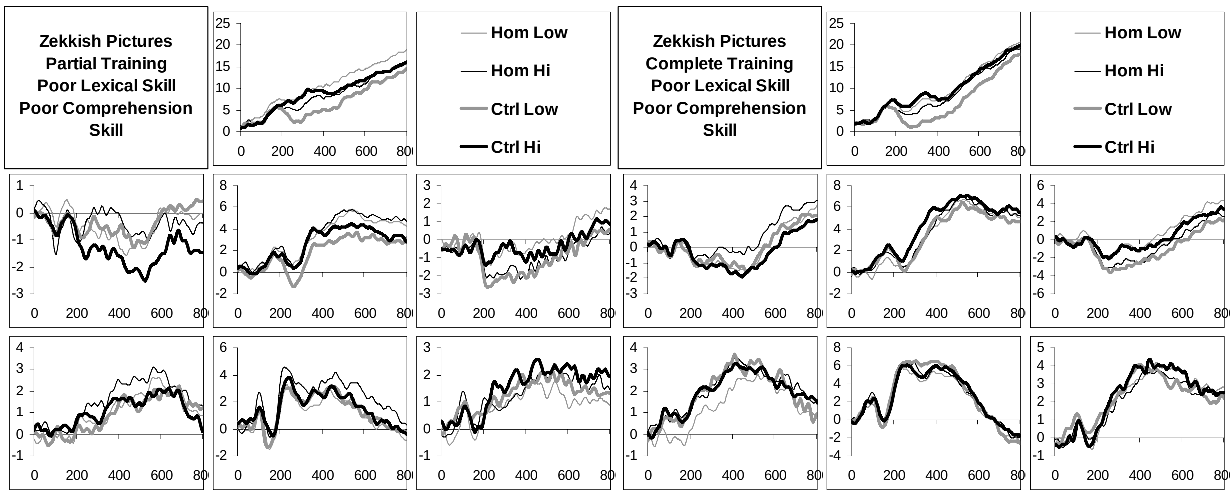
Electrode groups were averaged together. Only electrodes common to all ERP analyses and unique to a given spatial factor were included.

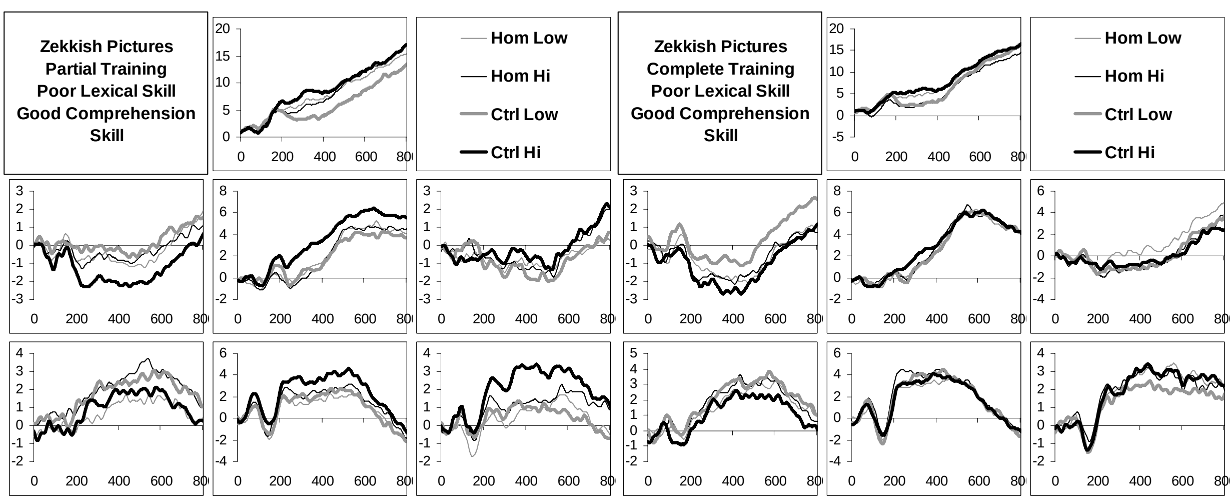


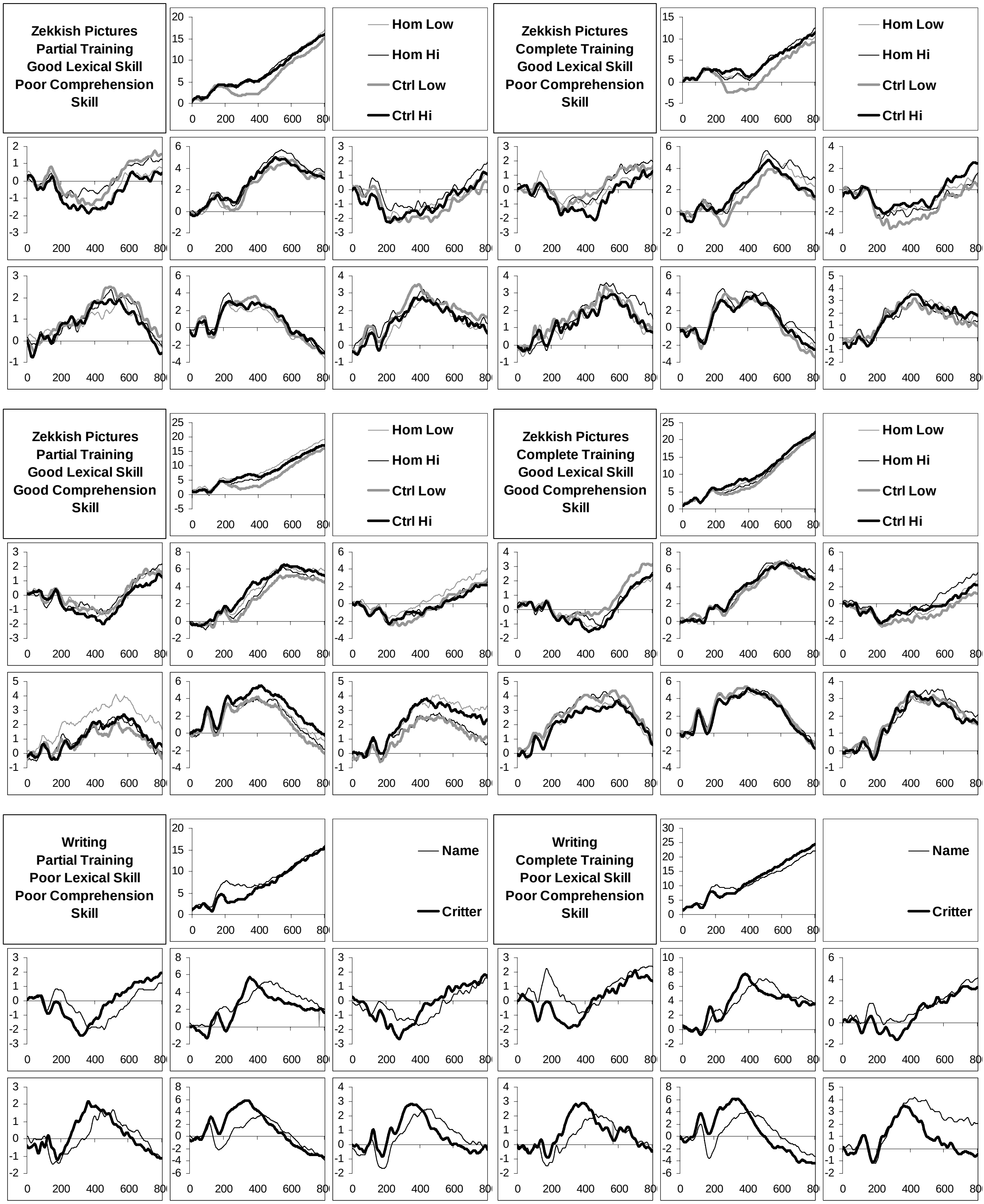


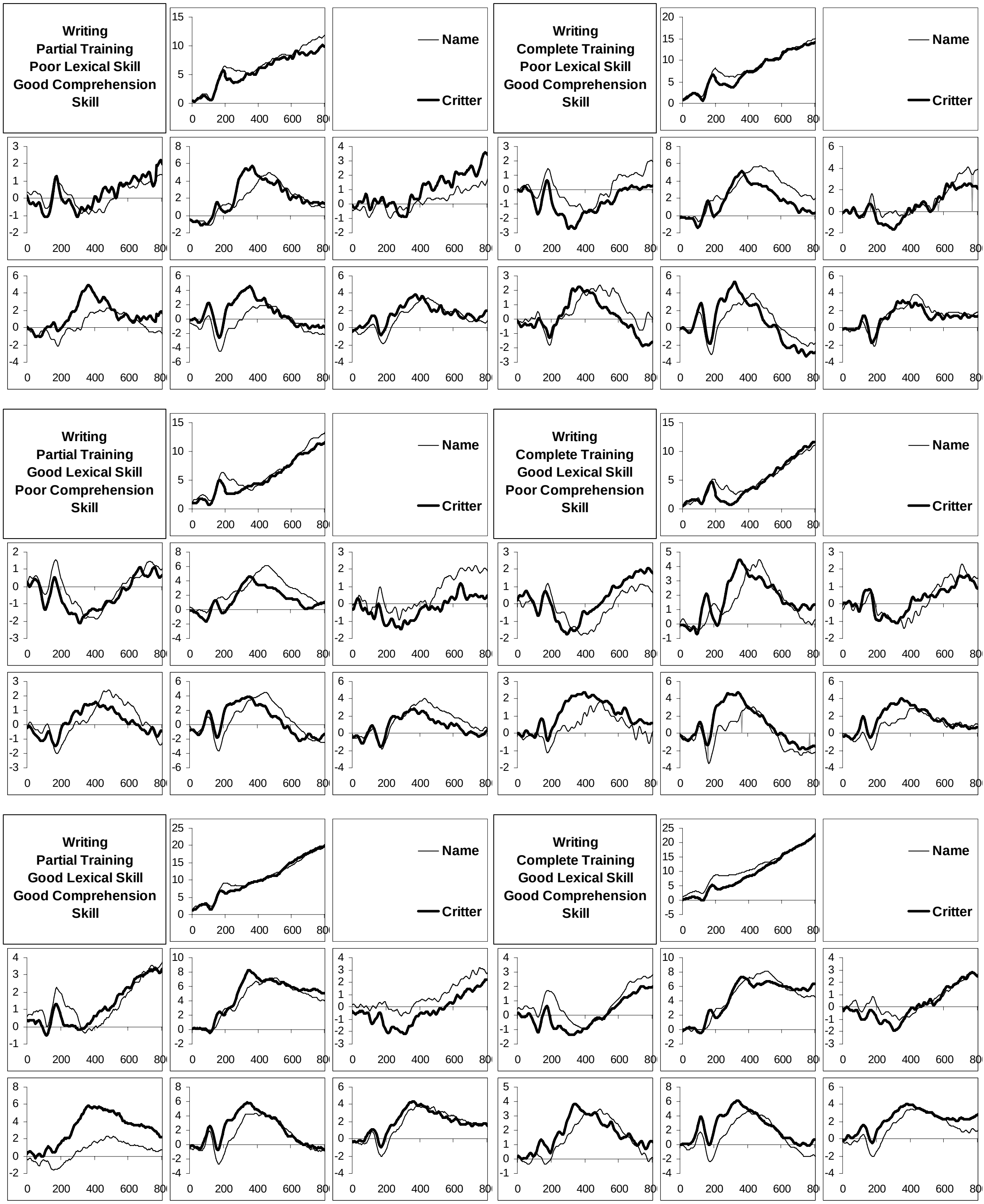



Zekkish Words
Partial Training
Good Lexical Skill
Good Comprehension Skill
Hom Low
Hom High
Ctrl Low
Ctrl High
Zekkish Words
Complete Training
Good Lexical Skill
Good Comprehension Skill
Hom Low
Hom High
Ctrl Low
Ctrl High


Zekkish Pictures
Partial Training
Poor Lexical Skill
Poor Comprehension Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi
Zekkish Pictures
Complete Training
Poor Lexical Skill
Poor Comprehension Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi


Zekkish Pictures
Partial Training
Poor Lexical Skill
Good Comprehension Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi
Zekkish Pictures
Complete Training
Poor Lexical Skill
Good Comprehension Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi


Zekkish Pictures
Partial Training
Good Lexical Skill
Poor Comprehension
Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi
Zekkish Pictures
Complete Training
Good Lexical Skill
Poor Comprehension
Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi
Zekkish Pictures
Partial Training
Good Lexical Skill
Good Comprehension
Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi
Zekkish Pictures
Complete Training
Good Lexical Skill
Good Comprehension
Skill
Hom Low
Hom Hi
Ctrl Low
Ctrl Hi
Writing
Partial Training
Poor Lexical Skill
Poor Comprehension
Skill
Name
Critter
Writing
Complete Training
Poor Lexical Skill
Poor Comprehension
Skill
Name
Critter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Skill
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Skill
Name
Critter
Writing
Partial Training
Good Lexical Skill
Poor Comprehension
Skill
Name
Critter
Writing
Complete Training
Good Lexical Skill
Poor Comprehension
Skill
Name
Critter
Writing
Partial Training
Good Lexical Skill
Good Comprehension
Skill
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Critter
Writing
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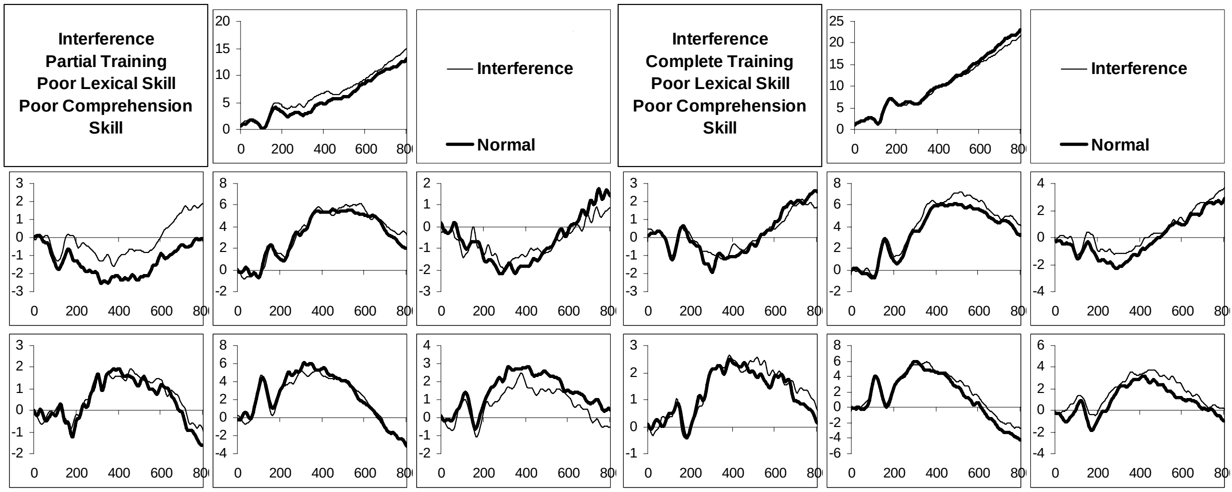
Good Lexical Skill
Good Comprehension
Skill
Name
Critter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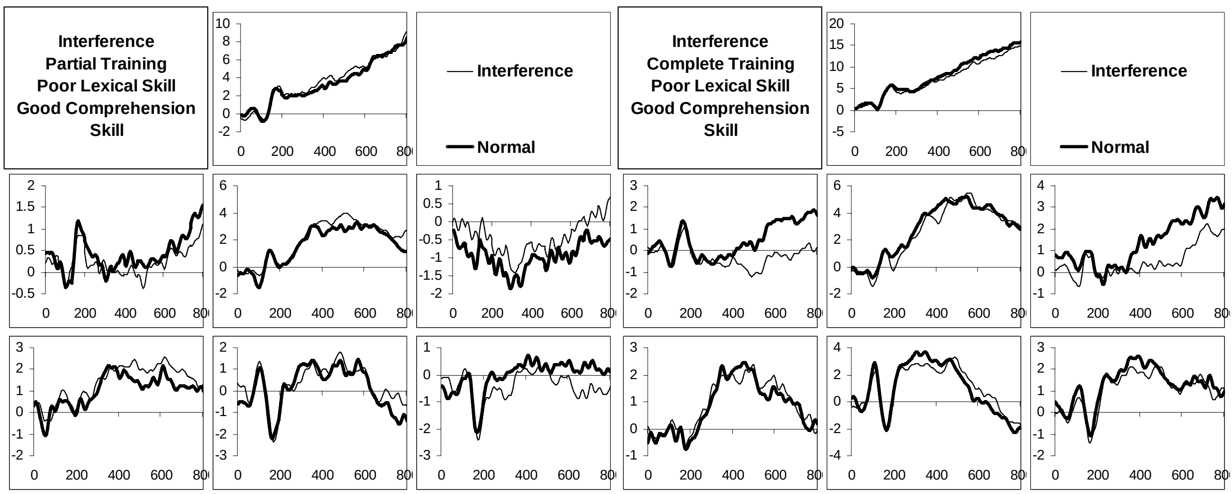
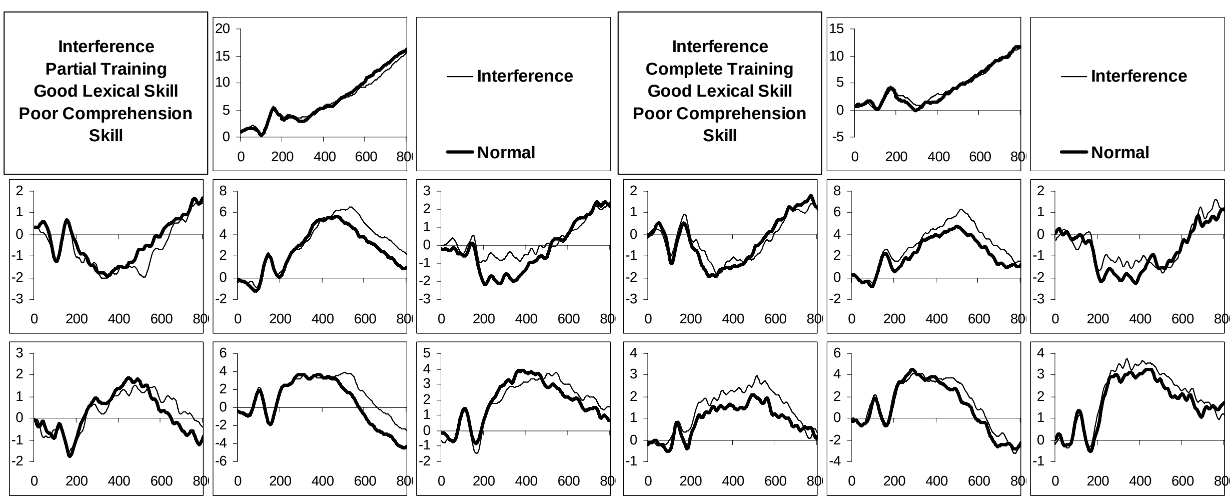
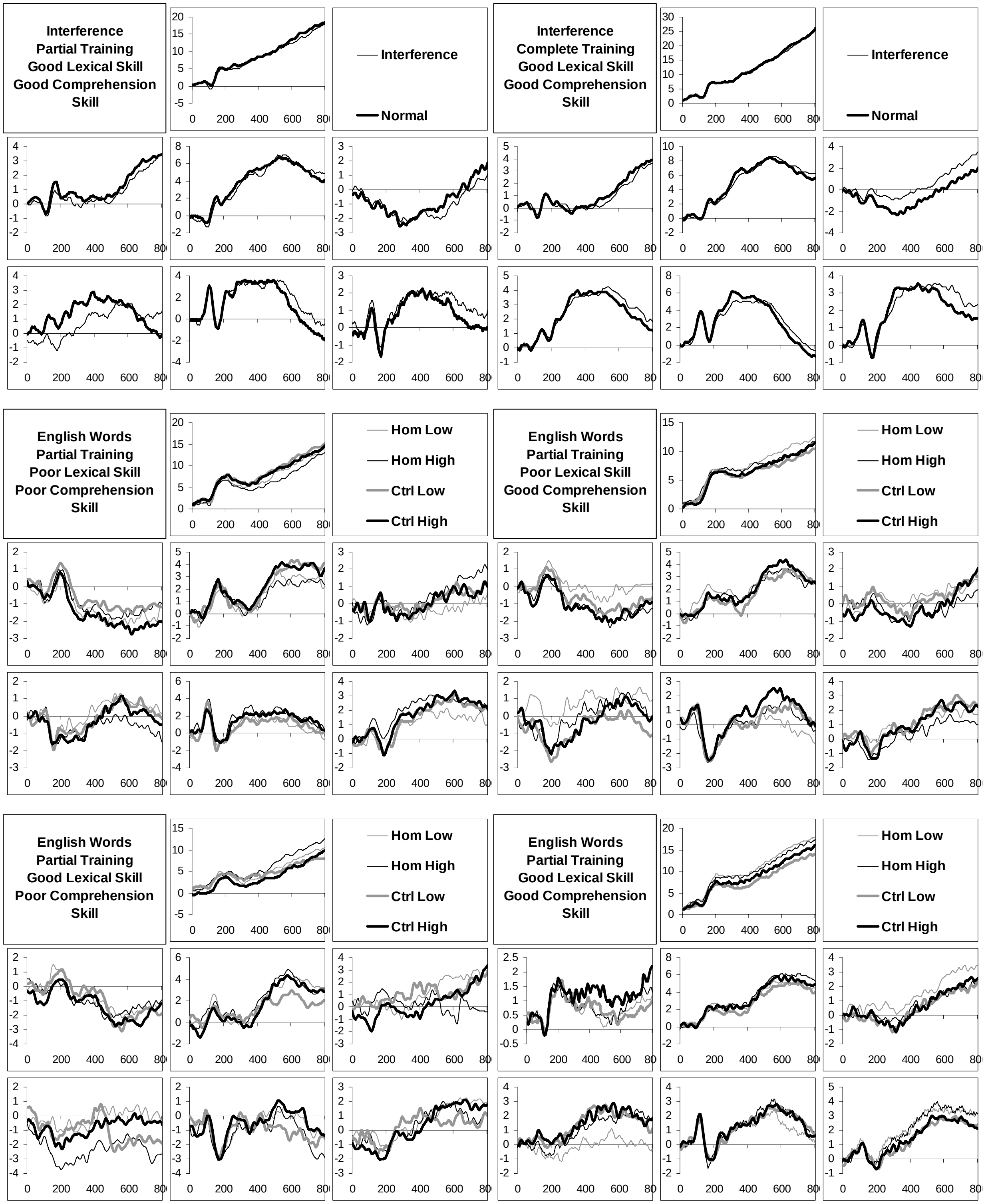
Partial Training
Poor Lexical Skill
Poor Comprehension
Skill
Interference
Normal
Interference
Complete Training
Poor Lexical Skill
Poor Comprehension
Skill
Interference
Normal


Interference
Partial Training
Poor Lexical Skill
Good Comprehension
Skill
Interference
Normal
Interference
Complete Training
Poor Lexical Skill
Good Comprehension
Skill
Interference
Normal


Interference
Partial Training
Good Lexical Skill
Poor Comprehension
Skill
Interference
Normal
Interference
Complete Training
Good Lexical Skill
Poor Comprehension
Skill
Interference
Normal


Interference
Partial Training
Good Lexical Skill
Good Comprehension Skill
Interference
Normal
Interference
Complete Training
Good Lexical Skill
Good Comprehension Skill
Interference
Normal
English Words
Partial Training
Poor Lexical Skill
Poor Comprehension Skill
Hom Low
Hom High
Ctrl Low
Ctrl High
English Words
Partial Training
Poor Lexical Skill
Good Comprehension Skill
Hom Low
Hom High
Ctrl Low
Ctrl High
English Words
Partial Training
Good Lexical Skill
Poor Comprehension Skill
Hom Low
Hom High
Ctrl Low
Ctrl High
English Words
Partial Training
Good Lexical Skill
Good Comprehension Skill
Hom Low
Hom High
Ctrl Low
Ctrl High

APPENDIX J: Homophone (Gernsbacher) Stimuli

309 groups of six words each were created. Each group of stimuli went through a rigorous set of selection criteria designed to equate word frequencies and semantic relatedness among pairings from the six words. First, a list of homophone pairs was generated from internet lists, thesauruses and dictionaries. Then lists of words that were synonyms of and related to each homophone were generated, again from a variety of sources including the near neighbors version of the Latent Semantic Analysis (LSA) database at the University of Colorado (Landauer, Foltz, & Laham, 1998; http://lsa.colorado.edu/), dictionaries, thesauruses, internet lists, and largely from the free association norms available on the internet and established by Nelson, McEvoy & Schreiber (1998; http://w3.usf.edu/FreeAssociation/)[12]. Written frequencies of the homophones and their related words were determined from the Kucera & Francis (1967) norms available on the psycholinguistic database (Coltheart, 1981; http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm). Semantic relatedness of the homophones to each other and to all their related words was determined using the matrix comparison version of LSA. From these data sets of six words were selected: the two homophones, two nonhomophone controls, and two words to serve as probes. The following constraints were imposed:

1. The two homophones had to be of different frequencies, such that one was called the low frequency homophone and the other was called the high frequency homophone.
2. The two nonhomophones had to be as equal as possible in frequency to the homophones, such that one was called the low frequency control and the other was called the high frequency control.
3. Two more nonhomophones, called probe words, had to be equal in frequency and have a frequency greater than ten per million to increase the likelihood that all participants would be familiar with the words.
4. None of the words could be abbreviations, single letters (e.g. B and bee), capitalized (e.g. Greece and grease), or so uncommon that many participants were unlikely to know the words at all. Words could be plural or past tense (e.g. acts and axe) but the frequency was tallied

[12] This author highly recommends the Introductory Essay on these free association norms available at the given internet address as a humorous work.

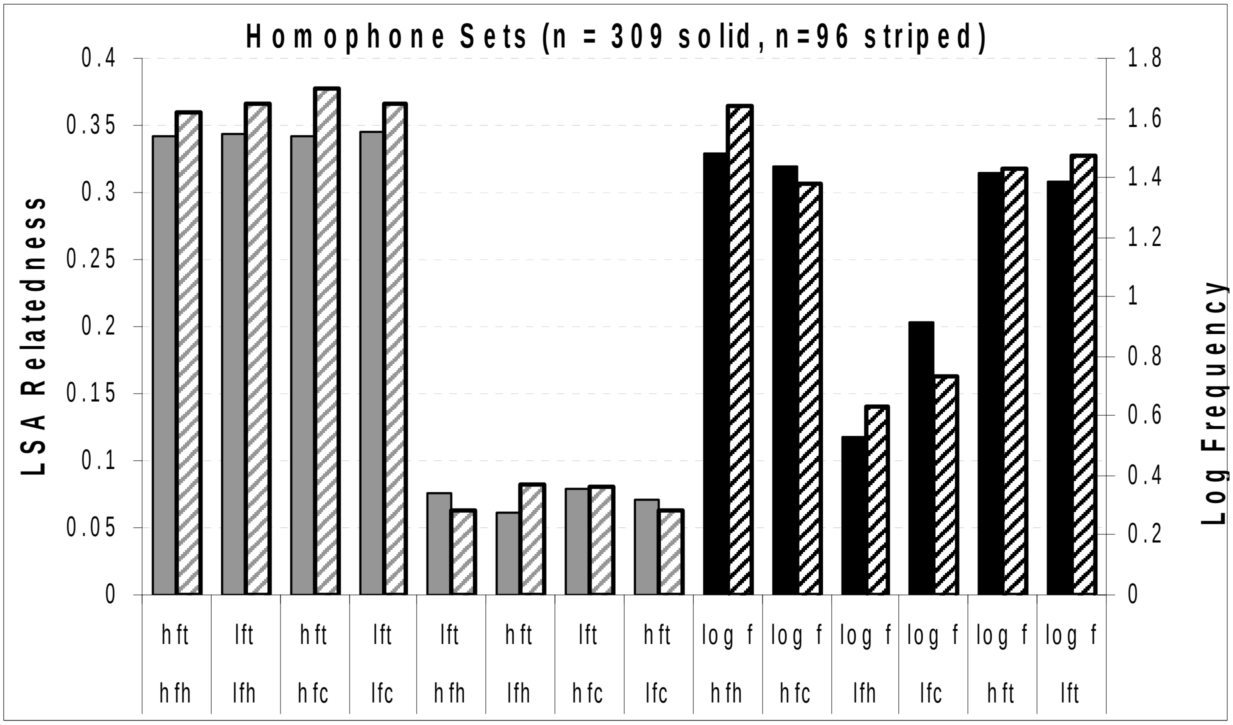
and the word was entered into LSA from the singular or present tense, since this was the more frequent and more semantically related word form.

5. One probe had to be equally related to the high frequency homophone and the high frequency control and equally unrelated to the low frequency homophone and the low frequency control.

6. The other probe had to be equally related to the low frequency homophone and the low frequency control and equally unrelated to the high frequency homophone and the high frequency control.

7. The probes had to be equally related and unrelated to the homophones and controls.

The complete set of words, their frequencies, and their semantic relatedness are listed in the second table below. Some of the homophones, generally those with word sets not as well controlled, were removed and used for the ERP task. It was our intention to counterbalance the words such that each participant got one homophone and one control from a set at the testing session after partial training and the other homophone and control after complete training, with the order counterbalanced across participants. This counterbalancing slipped through the cracks and the omission was not noticed until the data were being analyzed. Consequently, only one homophone and one control word from each word set was presented to each participant, and the same words were presented at each testing session. We only analyzed data from session one. The presented words are listed bold in the second table below, and the SOA at which they were presented is given. Statistics on frequency and relatedness in the presented set and the entire set of words are given in the first table below, along with a figure showing means of frequency and relatedness. On the x-axis and the first y-axis are semantic relatedness of word pairings, e.g. hfh-hft indicates the relatedness between the high frequency homophone (hft) and the target chosen to be related to the high frequency words (hft). On the x-axis and the second y-axis are the log values of frequencies. When the word frequency was zero the log value was artificially set to zero.



	N=309			N=96		
Pairs	t	dF	p	t	dF	p
hfh_hft - lfh_lft	-0.12	308	ns	-0.16	46	ns
hfc_hft - lfc_lft	-0.68	308	ns	0.27	46	ns
hfh_hft - hfc_hft	0.29	308	ns	-0.51	46	ns
lfh_lft - lfc_lft	-0.46	308	ns	-0.01	46	ns
hfh_lft - lfh_hft	4.16	308	<.00005	-1.10	46	ns
hfc_lft - lfc_hft	1.98	308	<.05	1.24	46	ns
hfh_lft - hfc_lft	-0.78	308	ns	-1.39	46	ns
lfh_hft - lfc_hft	-3.03	308	<.005	1.04	46	ns
hfh_l10 - hfc_l10	1.08	308	ns	1.84	94	ns
lfh_l10 - lfc_l10	-9.75	308	<.00001	-0.79	94	ns
hft_l10 - lft_l10	0.74	308	ns	1.24	190	ns

In general, the control of the word pairs was successful. Major deviations are for the difference between semantic UN-relatedness of words, in that high frequency homophones and controls remained slightly more related to the alternate controls than their low frequency counterparts. A second difference is in the frequencies of the low frequency homophones and controls. This is a result of the need to choose control words, while low frequency homophones came as part of the set. It was often the case that low frequency controls had a frequency of zero, while the low frequency controls had to have a frequency of at least one in order to be available to be chosen from a list. These deviations are only true for the whole set; the subset used in the current task shows no significant differences between critical conditions.

grp	type	word	w freq	probe 1	p1 freq	p1 rel	probe 2	p2 freq	p2 rel	soa
1	hf hom	act	2.45	try	1.15	0.24	cut	2.28	0.09	
1	hf ctrl	**show**	2.46	try	1.15	0.32	**cut**	2.28	0.1	150
1	lf hom	**axe**	0.78	**try**	1.15	0.1	cut	2.28	0.39	450
1	lf ctrl	hatchet	0.6	try	1.15	0.13	cut	2.28	0.42	
2	hf hom	addition	2.15	plus	1.86	0.44	magazine	1.59	0.13	
2	hf ctrl	total	2.32	plus	1.86	0.51	magazine	1.59	0.06	
2	lf hom	edition	1.57	plus	1.86	0.09	magazine	1.59	0.32	
2	lf ctrl	writer	1.86	plus	1.86	0.04	magazine	1.59	0.35	
3	hf hom	air	2.41	balloon	0	0.55	kingdom	1.41	0.03	
3	hf ctrl	blow	1.52	balloon	0	0.3	kingdom	1.41	0.08	
3	lf hom	heir	0.85	balloon	0	0.03	kingdom	1.41	0.49	
3	lf ctrl	duke	1.04	balloon	0	-0.01	kingdom	1.41	0.41	
4	hf hom	all	3.48	joy	0.6	0.52	drill	1.52	0.19	
4	hf ctrl	over	3.09	joy	0.6	0.43	drill	1.52	0.18	
4	lf hom	awl	0	joy	0.6	0.14	drill	1.52	0.39	
4	lf ctrl	hammer	0.95	joy	0.6	0.04	drill	1.52	0.33	
5	hf hom	allow	1.86	accept	1.86	0.37	speak	1.04	0.17	
5	hf ctrl	**permit**	1.89	accept	1.86	0.37	**speak**	1.04	0.14	2000
5	lf hom	**aloud**	1.11	**accept**	1.86	0.14	speak	1.04	0.26	1350
5	lf ctrl	shout	0.95	accept	1.86	0.11	speak	1.04	0.27	
6	hf hom	alter	1.18	adjust	1.2	0.28	bible	1.77	0.07	
6	hf ctrl	finish	1.59	adjust	1.2	0.31	bible	1.77	0.06	
6	lf hom	altar	0.7	adjust	1.2	-0.03	bible	1.77	0.44	
6	lf ctrl	steeple	0.95	adjust	1.2	0.06	bible	1.77	0.31	
7	hf hom	assent	0.6	agree	1.71	0.34	ascend	0	0.04	
7	hf ctrl	allow	1.86	agree	1.71	0.35	ascend	0	0.12	
7	lf hom	ascent	0	agree	1.71	0.02	ascend	0	0.2	
7	lf ctrl	lift	1.36	agree	1.71	0.02	ascend	0	0.2	
8	hf hom	**ate**	1.2	taste	1.77	0.28	**number**	2.67	0.05	450
8	hf ctrl	swallow	0	taste	1.77	0.28	number	2.67	0.02	
8	lf hom	eight	0	taste	1.77	0.07	number	2.67	0.24	
8	lf ctrl	**figure**	0.3	**taste**	1.77	0.01	number	2.67	0.23	150
9	hf hom	aunt	1.34	cousin	1.71	0.68	insect	1.15	0	
9	hf ctrl	uncle	1.76	cousin	1.71	0.57	insect	1.15	0	
9	lf hom	ant	0.78	cousin	1.71	0.03	insect	1.15	0.69	
9	lf ctrl	pest	0.6	cousin	1.71	0.03	insect	1.15	0.74	
10	hf hom	bail	0.85	boat	1.86	0.33	barn	1.46	0.04	
10	hf ctrl	**sink**	1.36	boat	1.86	0.25	**barn**	1.46	0.18	450
10	lf hom	**bale**	0.70	**boat**	1.86	0.06	barn	1.46	0.28	150
10	lf ctrl	loft	0.30	boat	1.86	0.09	barn	1.46	0.53	
11	hf hom	bald	0.7	hat	1.75	0.49	cry	1.68	0.16	
11	hf ctrl	wig	0	hat	1.75	0.33	cry	1.68	0.04	
11	lf hom	bawled	0	hat	1.75	0.16	cry	1.68	0.3	
11	lf ctrl	lament	0	hat	1.75	0.06	cry	1.68	0.22	
12	hf hom	ball	2.04	sphere	1.34	0.23	scream	1.11	0.04	

12	hf ctrl	**circle**	1.78	**sphere**	1.34	0.48	scream	1.11	0.13	450
12	lf hom	**bawl**	0.00	sphere	1.34	0.12	**scream**	1.11	0.36	150
12	lf ctrl	frown	0.00	sphere	1.34	0.06	scream	1.11	0.42	
13	hf hom	band	1.72	parade	1.4	0.38	limit	1.68	0.13	
13	hf ctrl	concert	1.59	parade	1.4	0.38	limit	1.68	0.05	
13	lf hom	banned	0	parade	1.4	0.04	limit	1.68	0.23	
13	lf ctrl	exclude	0.85	parade	1.4	-0.01	limit	1.68	0.23	
14	hf hom	barred	0.9	prison	1.62	0.27	sing	1.53	0.06	
14	hf ctrl	restrain	0	prison	1.62	0.22	sing	1.53	0.08	
14	lf hom	bard	0.48	prison	1.62	0.03	sing	1.53	0.35	
14	lf ctrl	minstrel	0.3	prison	1.62	0.07	sing	1.53	0.38	
15	hf hom	**barren**	0.85	fertile	0.7	0.45	**duke**	1.04	-0.01	150
15	hf ctrl	desert	1.32	fertile	0.7	0.47	duke	1.04	0	
15	lf hom	baron	0.3	fertile	0.7	0	duke	1.04	0.33	
15	lf ctrl	**royalty**	0.85	**fertile**	0.7	0.04	duke	1.04	0.38	450
16	hf hom	base	1.96	locate	1.2	0.25	oven	0.85	0.1	
16	hf ctrl	spot	1.76	locate	1.2	0.25	oven	0.85	0.11	
16	lf hom	baste	0	locate	1.2	0.08	oven	0.85	0.27	
16	lf ctrl	broth	0.48	locate	1.2	0.08	oven	0.85	0.4	
17	hf hom	be	3.8	alive	1.76	0.33	queen	1.61	0.16	
17	hf ctrl	this	3.71	alive	1.76	0.38	queen	1.61	0.19	
17	lf hom	bee	1.04	alive	1.76	0.03	queen	1.61	0.26	
17	lf ctrl	honey	1.4	alive	1.76	0.08	queen	1.61	0.29	
18	hf hom	**beach**	1.79	**sunset**	1.15	0.27	willow	0.95	0.07	2000
18	hf ctrl	boat	1.86	sunset	1.15	0.26	willow	0.95	0.07	
18	lf hom	beech	0.78	sunset	1.15	0.14	willow	0.95	0.22	
18	lf ctrl	**elm**	0.48	sunset	1.15	0.15	**willow**	0.95	0.3	1350
19	hf hom	bear	1.76	zoo	0.95	0.21	shower	1.18	0.02	
19	hf ctrl	**snake**	1.64	zoo	0.95	0.25	**shower**	1.18	0.08	150
19	lf hom	**bare**	1.46	**zoo**	0.95	0	shower	1.18	0.23	450
19	lf ctrl	naked	1.51	zoo	0.95	0.03	shower	1.18	0.25	
20	hf hom	beat	1.83	sound	0.3	0.26	food	2.17	0.09	
20	hf ctrl	**strike**	0.7	**sound**	0.3	0.2	food	2.17	0.03	150
20	lf hom	**beet**	0	sound	0.3	0.01	**food**	2.17	0.25	450
20	lf ctrl	spicy	0	sound	0.3	0.05	food	2.17	0.3	
21	hf hom	bell	1.26	tone	1.89	0.25	lady	0.9	0.13	
21	hf ctrl	alarm	1.2	tone	1.89	0.2	lady	0.9	0.16	
21	lf hom	belle	0	tone	1.89	0.13	lady	0.9	0.26	
21	lf ctrl	swoon	0	tone	1.89	0.07	lady	0.9	0.3	
22	hf hom	bill	2.16	dollar	1.66	0.22	create	1.73	0.09	
22	hf ctrl	month	1.11	dollar	1.66	0.22	create	1.73	0.09	
22	lf hom	build	1.93	dollar	1.66	0.07	create	1.73	0.26	
22	lf ctrl	structure	1.96	dollar	1.66	0.01	create	1.73	0.21	
23	hf hom	birth	1.82	beginning	2.21	0.29	bed	2.1	0.03	
23	hf ctrl	create	1.73	beginning	2.21	0.31	bed	2.1	0.03	
23	lf hom	berth	0.6	beginning	2.21	0.09	bed	2.1	0.24	
23	lf ctrl	cabin	1.36	beginning	2.21	0.11	bed	2.1	0.24	
24	hf hom	bite	0	snake	1.64	0.51	output	1.54	0.02	
24	hf ctrl	poison	0	snake	1.64	0.35	output	1.54	0	
24	lf hom	byte	0	snake	1.64	-0.03	output	1.54	0.4	
24	lf ctrl	software	0	snake	1.64	-0.02	output	1.54	0.33	

25	hf hom	bizarre	0.85	unique	1.76	0.24	bag	1.62	0.07	
25	hf ctrl	obscure	1.23	unique	1.76	0.29	bag	1.62	0.08	
25	lf hom	bazaar	0.85	unique	1.76	0.01	bag	1.62	0.23	
25	lf ctrl	shelf	1.08	unique	1.76	0	bag	1.62	0.3	
26	hf hom	bologna	0.3	cheese	0.95	0.2	crazy	1.53	0.17	
26	hf ctrl	salami	0.85	cheese	0.95	0.22	crazy	1.53	0.2	
26	lf hom	baloney	0	cheese	0.95	0.17	crazy	1.53	0.37	
26	lf ctrl	nonsense	1.11	cheese	0.95	0.13	crazy	1.53	0.3	
27	hf hom	**booze**	0.6	champagne	1.11	0.23	**ghost**	1.04	-0.02	150
27	hf ctrl	rum	0.48	champagne	1.11	0.34	ghost	1.04	0.16	
27	lf hom	boo	0	champagne	1.11	0.12	ghost	1.04	0.44	
27	lf ctrl	**goblin**	0	**champagne**	1.11	-0.02	ghost	1.04	0.23	450
28	hf hom	border	0.3	frontier	0.48	0.26	residence	1.46	0.13	
28	hf ctrl	conflict	1.72	frontier	0.48	0.25	residence	1.46	0.08	
28	lf hom	boarder	0	frontier	0.48	0.05	residence	1.46	0.23	
28	lf ctrl	homeless	0	frontier	0.48	0.04	residence	1.46	0.26	
29	hf hom	**bore**	1.38	useless	1.23	0.23	**hunt**	1.00	0.09	450
29	hf ctrl	dull	1.43	useless	1.23	0.22	hunt	1.00	0.14	
29	lf hom	boar	0.00	useless	1.23	0.03	hunt	1.00	0.51	
29	lf ctrl	**coyote**	0.00	**useless**	1.23	0.06	hunt	1.00	0.57	150
30	hf hom	borough	0.7	province	1.18	0.25	pack	1.4	0.02	
30	hf ctrl	realm	1.28	province	1.18	0.35	pack	1.4	0.03	
30	lf hom	burro	0	province	1.18	-0.05	pack	1.4	0.36	
30	lf ctrl	cart	0.7	province	1.18	0.06	pack	1.4	0.25	
31	hf hom	bowl	1.36	roll	1.54	0.27	brave	1.38	0.06	
31	hf ctrl	spare	1.36	roll	1.54	0.21	brave	1.38	0.25	
31	lf hom	bold	1.32	roll	1.54	0.12	brave	1.38	0.38	
31	lf ctrl	loud	0.3	roll	1.54	0.21	brave	1.38	0.28	
32	hf hom	brayed	0	loud	0.3	0.25	ribbon	1.08	0.05	
32	hf ctrl	harsh	1.08	loud	0.3	0.25	ribbon	1.08	0.09	
32	lf hom	braid	0	loud	0.3	0.13	ribbon	1.08	0.22	
32	lf ctrl	strip	0.48	loud	0.3	0.06	ribbon	1.08	0.23	
33	hf hom	break	1.94	apart	1.76	0.49	fluid	1.32	0.06	
33	hf ctrl	**separate**	1.9	apart	1.76	0.39	**fluid**	1.32	0.12	1350
33	lf hom	**brake**	0.3	**apart**	1.76	0.09	fluid	1.32	0.44	2000
33	lf ctrl	steering	0.95	apart	1.76	0.07	fluid	1.32	0.32	
34	hf hom	breeches	0	leather	1.38	0.5	obligati	1.2	0.07	
34	hf ctrl	trousers	0.85	leather	1.38	0.62	obligati	1.2	0.06	
34	lf hom	breaches	0	leather	1.38	0	obligati	1.2	0.56	
34	lf ctrl	violate	0.85	leather	1.38	0.04	obligati	1.2	0.42	
35	hf hom	brew	0.6	coffee	1.89	0.35	fight	1.99	0.19	
35	hf ctrl	**saucer**	0	coffee	1.89	0.27	**fight**	1.99	0.07	2000
35	lf hom	**bruise**	0.48	**coffee**	1.89	0.22	fight	1.99	0.17	1350
35	lf ctrl	torture	0.48	coffee	1.89	0.07	fight	1.99	0.26	
36	hf hom	**bridal**	0.3	**wedding**	1.51	0.54	ride	1.69	-0.03	450
36	hf ctrl	ceremony	1.26	wedding	1.51	0.57	ride	1.69	0.09	
36	lf hom	bridle	0	wedding	1.51	0.13	ride	1.69	0.66	
36	lf ctrl	**pony**	0	wedding	1.51	0.05	**ride**	1.69	0.69	150
37	hf hom	brood	0.95	hatch	0.7	0.31	beer	1.53	0.01	
37	hf ctrl	bird	1.49	hatch	0.7	0.29	beer	1.53	-0.01	

37	lf hom	brewed	0	hatch	0.7	0.03	beer	1.53	0.3	
37	lf ctrl	ale	0	hatch	0.7	-0.04	beer	1.53	0.32	
38	hf hom	buy	0.85	purchase	1.67	0.49	kiss	1.23	0.05	
38	hf ctrl	**store**	1.87	purchase	1.67	0.36	**kiss**	1.23	0.08	1350
38	lf hom	**bye**	0.3	**purchase**	1.67	0.01	kiss	1.23	0.43	2000
38	lf ctrl	hug	0.48	purchase	1.67	0.03	kiss	1.23	0.53	
39	hf hom	buyer	0.3	product	1.94	0.36	barn	1.46	0.05	
39	hf ctrl	purchase	1.67	product	1.94	0.34	barn	1.46	0.02	
39	lf hom	byre	0	product	1.94	0	barn	1.46	0.37	
39	lf ctrl	trap	0.3	product	1.94	0.07	barn	1.46	0.29	
40	hf hom	**caller**	2.27	emergency	1.59	0.44	**jacket**	1.52	0.26	150
40	hf ctrl	telephone	1.88	emergency	1.59	0.4	jacket	1.52	0.13	
40	lf hom	collar	1.23	emergency	1.59	0.04	jacket	1.52	0.35	
40	lf ctrl	**stiff**	1.32	**emergency**	1.59	0.05	jacket	1.52	0.73	450
41	hf hom	cannon	0.85	blast	1.18	0.29	priest	1.2	0.13	
41	hf ctrl	loud	0.3	blast	1.18	0.25	priest	1.2	0.12	
41	lf hom	canon	0.7	blast	1.18	0.07	priest	1.2	0.3	
41	lf ctrl	cathedral	0.9	blast	1.18	0.15	priest	1.2	0.39	
42	hf hom	carrot	0.00	stick	1.59	0.32	precious	1.46	0.07	
42	hf ctrl	**bunch**	1.23	**stick**	1.59	0.41	precious	1.46	0.07	450
42	lf hom	**karat**	0.00	stick	1.59	0.01	**precious**	1.46	0.64	150
42	lf ctrl	gold	1.72	stick	1.59	0.05	precious	1.46	0.53	
43	hf hom	cast	1.65	stone	1.76	0.29	tradition	1.97	0.17	
43	hf ctrl	plaster	1.36	stone	1.76	0.32	tradition	1.97	0.03	
43	lf hom	caste	0.48	stone	1.76	0	tradition	1.97	0.22	
43	lf ctrl	rank	1.38	stone	1.76	0.09	tradition	1.97	0.21	
44	hf hom	**cause**	2.11	**affect**	1.54	0.48	bird	1.49	0.04	150
44	hf ctrl	effect	2.33	affect	1.54	0.46	bird	1.49	0.04	
44	lf hom	caw	0.00	affect	1.54	0.08	bird	1.49	0.41	
44	lf ctrl	**raven**	0.00	affect	1.54	0.17	**bird**	1.49	0.35	450
45	hf hom	ceiling	1.49	cathedral	0.90	0.28	rubber	1.18	0.11	
45	hf ctrl	**roof**	1.77	cathedral	0.90	0.34	**rubber**	1.18	0.06	150
45	lf hom	**sealing**	0.00	**cathedral**	0.90	0.06	rubber	1.18	0.43	450
45	lf ctrl	tight	1.45	cathedral	0.90	0.08	rubber	1.18	0.46	
46	hf hom	cent	2.2	dollar	1.66	0.37	smell	1.53	0.06	
46	hf ctrl	**ten**	2.22	**dollar**	1.66	0.35	smell	1.53	0.09	450
46	lf hom	**scent**	0.78	dollar	1.66	0.04	**smell**	1.53	0.44	150
46	lf ctrl	fragrance	0.78	dollar	1.66	0.08	smell	1.53	0.37	
47	hf hom	**cereal**	1.23	food	2.17	0.32	**number**	2.67	0.06	450
47	hf ctrl	wheat	0.95	food	2.17	0.21	number	2.67	0.03	
47	lf hom	serial	0.85	food	2.17	0.01	number	2.67	0.34	
47	lf ctrl	**continuum**	0.85	**food**	2.17	0.02	number	2.67	0.2	150
48	hf hom	**chance**	2.12	luck	1.67	0.51	**melody**	1.32	0.1	1350
48	hf ctrl	try	1.15	luck	1.67	0.37	melody	1.32	0.13	
48	lf hom	chants	0	luck	1.67	0.08	melody	1.32	0.35	
48	lf ctrl	**drum**	1.04	**luck**	1.67	0.13	melody	1.32	0.43	2000
49	hf hom	chase	1.26	quick	1.83	0.39	holy	1.69	0.08	
49	hf ctrl	follow	1.99	quick	1.83	0.33	holy	1.69	0.16	
49	lf hom	chaste	0	quick	1.83	0.09	holy	1.69	0.38	

49	lf ctrl	virgin	1.54	quick	1.83	0.05	holy	1.69	0.28	
50	hf hom	cheap	1.38	price	0	0.22	cry	1.68	0.07	
50	hf ctrl	priceless	0.7	price	0	0.2	cry	1.68	0.02	
50	lf hom	cheep	0	price	0	0.03	cry	1.68	0.3	
50	lf ctrl	peep	0.3	price	0	0.01	cry	1.68	0.3	
51	hf hom	**chilly**	0.7	**snow**	1.77	0.39	food	2.17	0.04	450
51	hf ctrl	shiver	0.6	snow	1.77	0.27	food	2.17	0.03	
51	lf hom	chili	0	snow	1.77	0	food	2.17	0.31	
51	lf ctrl	**spicy**	0	snow	1.77	0.11	**food**	2.17	0.3	150
52	hf hom	choose	0.7	select	1.36	0.63	jaw	1.2	0.03	
52	hf ctrl	**decide**	0.6	select	1.36	0.52	**jaw**	1.2	0.03	150
52	lf hom	**chew (s)**	0.3	**select**	1.36	0.03	jaw	1.2	0.58	450
52	lf ctrl	grind	0.3	select	1.36	0.14	jaw	1.2	0.5	
53	hf hom	chord	0.85	string	1.28	0.31	spine	0.78	0.04	
53	hf ctrl	vocal	1.15	string	1.28	0.3	spine	0.78	0.13	
53	lf hom	cord	0.78	string	1.28	0.08	spine	0.78	0.32	
53	lf ctrl	socket	0.48	string	1.28	0.14	spine	0.78	0.27	
54	hf hom	clause	0.95	article	1.83	0.32	nail	0.78	0	
54	hf ctrl	document	1.11	article	1.83	0.24	nail	0.78	-0.01	
54	lf hom	claw	0	article	1.83	0.01	nail	0.78	0.25	
54	lf ctrl	hook	0.7	article	1.83	-0.01	nail	0.78	0.25	
55	hf hom	climate	1.41	location	1.8	0.27	fence	0.48	-0.02	
55	hf ctrl	region	1.88	location	1.8	0.22	fence	0.48	0.03	
55	lf hom	climb	1.08	location	1.8	0.05	fence	0.48	0.37	
55	lf ctrl	limb	0.7	location	1.8	0.03	fence	0.48	0.36	
56	hf hom	coke	0.6	pizza	0	0.28	trick	1.18	0.11	
56	hf ctrl	soda	0.48	pizza	0	0.27	trick	1.18	0.14	
56	lf hom	coax	0	pizza	0	0.02	trick	1.18	0.25	
56	lf ctrl	fool	1.57	pizza	0	0.14	trick	1.18	0.37	
57	hf hom	colonel	1.57	rank	1.38	0.35	corn	1.53	0.03	
57	hf ctrl	soldier	1.59	rank	1.38	0.37	corn	1.53	0.05	
57	lf hom	kernel	0.48	rank	1.38	0	corn	1.53	0.38	
57	lf ctrl	husk	0	rank	1.38	-0.01	corn	1.53	0.29	
58	hf hom	colonel	1.57	grass	1.72	0.28	crooked	0.48	0.07	
58	hf ctrl	wheat	0.95	grass	1.72	0.32	crooked	0.48	0	
58	lf hom	wry	0.7	grass	1.72	0.04	crooked	0.48	0.21	
58	lf ctrl	twist	1.26	grass	1.72	0.12	crooked	0.48	0.2	
59	hf hom	complement	1.32	complete	2.26	0.43	courtesy	0.85	0.01	
59	hf ctrl	part	2.7	complete	2.26	0.38	courtesy	0.85	0.11	
59	lf hom	compliment	0.48	complete	2.26	0.06	courtesy	0.85	0.33	
59	lf ctrl	offend	0.6	complete	2.26	0.13	courtesy	0.85	0.31	
60	hf hom	coop	0.48	flew	1.43	0.25	seat	1.73	0.1	
60	hf ctrl	cage	0.95	flew	1.43	0.3	seat	1.73	0.07	
60	lf hom	coupe	0.3	flew	1.43	0.05	seat	1.73	0.43	
60	lf ctrl	carriage	1.04	flew	1.43	0.17	seat	1.73	0.39	
61	hf hom	core	1.57	iron	1.63	0.36	soldier	1.59	0.02	
61	hf ctrl	mining	1.08	iron	1.63	0.47	soldier	1.59	0.03	
61	lf hom	corps	0	iron	1.63	0.06	soldier	1.59	0.35	
61	lf ctrl	officer	0	iron	1.63	0.02	soldier	1.59	0.45	
62	hf hom	cough	0.85	smoke	1.61	0.26	clay	2	0.01	
62	hf ctrl	sniff	0.3	smoke	1.61	0.26	clay	2	0.06	

62	lf hom	coffer	0	smoke	1.61	-0.03	clay	2	0.23	
62	lf ctrl	stick	1.59	smoke	1.61	0.14	clay	2	0.22	
63	hf hom	counsel	1.23	lawyer	1.63	0.71	mayor	1.58	0.04	
63	hf ctrl	attorney	1.81	lawyer	1.63	0.73	mayor	1.58	0.18	
63	lf hom	council	0	lawyer	1.63	0.08	mayor	1.58	0.67	
63	lf ctrl	city	2.59	lawyer	1.63	0.09	mayor	1.58	0.6	
64	hf hom	coup	0.6	triumph	1.34	0.31	cry	1.68	-0.01	
64	hf ctrl	success	1.97	triumph	1.34	0.31	cry	1.68	0.08	
64	lf hom	coo	0	triumph	1.34	0.01	cry	1.68	0.23	
64	lf ctrl	mom	0.48	triumph	1.34	0.03	cry	1.68	0.22	
65	hf hom	court	2.36	murder	1.88	0.25	volume	2.13	0	
65	hf ctrl	**evidence**	2.31	murder	1.88	0.36	**volume**	2.13	0.01	150
65	lf hom	**quart**	0.48	**murder**	1.88	0.05	volume	2.13	0.21	450
65	lf ctrl	gallon	0.78	murder	1.88	0.1	volume	2.13	0.22	
66	hf hom	creek	1.15	stream	1.71	0.43	noise	1.57	0.16	
66	hf ctrl	**brook**	0.48	**stream**	1.71	0.46	noise	1.57	0.16	2000
66	lf hom	**creak**	0	stream	1.71	0.15	**noise**	1.57	0.45	1350
66	lf ctrl	squeak	0	stream	1.71	0.02	noise	1.57	0.47	
67	hf hom	crew	1.56	men	2.88	0.31	island	2.22	0.2	
67	hf ctrl	crowd	1.72	men	2.88	0.27	island	2.22	0.02	
67	lf hom	cruise	0.3	men	2.88	0.16	island	2.22	0.24	
67	lf ctrl	port	1.32	men	2.88	0.14	island	2.22	0.28	
68	hf hom	crocodile	0	swamp	0.7	0.35	pot	1.45	0.02	
68	hf ctrl	alligator	0.6	swamp	0.7	0.32	pot	1.45	0.05	
68	lf hom	crock	0	swamp	0.7	0.1	pot	1.45	0.26	
68	lf ctrl	butter	1.43	swamp	0.7	0.07	pot	1.45	0.27	
69	hf hom	crumb	0.48	cookie	0	0.31	bum	0.85	0.06	
69	hf ctrl	napkin	0.48	cookie	0	0.33	bum	0.85	0.08	
69	lf hom	crummy	0.48	cookie	0	0.11	bum	0.85	0.26	
69	lf ctrl	punk	0.3	cookie	0	0.1	bum	0.85	0.29	
70	hf hom	cubical	0	shape	1.93	0.27	desk	1.81	0.05	
70	hf ctrl	plastic	1.49	shape	1.93	0.28	desk	1.81	0.16	
70	lf hom	cubicle	0	shape	1.93	0.02	desk	1.81	0.2	
70	lf ctrl	booth	0.85	shape	1.93	0.04	desk	1.81	0.22	
71	hf hom	current	0	stream	1.71	0.2	fruit	1.54	0.01	
71	hf ctrl	flow	1.83	stream	1.71	0.3	fruit	1.54	0.04	
71	lf hom	currant	0	stream	1.71	0.07	fruit	1.54	0.22	
71	lf ctrl	oatmeal	0	stream	1.71	0.08	fruit	1.54	0.23	
72	hf hom	damn	1.53	swear	0	0.48	flow	1.83	0.02	
72	hf ctrl	curse	1.04	swear	0	0.43	flow	1.83	0.06	
72	lf hom	dam	0.7	swear	0	-0.03	flow	1.83	0.29	
72	lf ctrl	flood	1.28	swear	0	0.06	flow	1.83	0.3	
73	hf hom	dear	1.73	sweetheart	0.95	0.44	antler	0.48	0	
73	hf ctrl	**darling**	1.23	sweetheart	0.95	0.4	**antler**	0.48	0.05	450
73	lf hom	**deer**	1.11	**sweetheart**	0.95	0.06	antler	0.48	0.43	150
73	lf ctrl	hunt	0	sweetheart	0.95	0.1	antler	0.48	0.45	
74	hf hom	dense	0.95	fog	1.4	0.26	scratch	0.95	0.08	
74	hf ctrl	**smoke**	1.61	**fog**	1.4	0.31	scratch	0.95	0.01	150
74	lf hom	**dents**	0	fog	1.4	0.11	**scratch**	0.95	0.27	450
74	lf ctrl	scrape	0.48	fog	1.4	0.12	scratch	0.95	0.29	
75	hf hom	descent	1.04	origin	1.64	0.31	disagree	0.85	0.13	

75	hf ctrl	ancestry	0.9	origin	1.64	0.36	disagree	0.85	0.17	
75	lf hom	dissent	0.7	origin	1.64	0.12	disagree	0.85	0.33	
75	lf ctrl	refuse	1.2	origin	1.64	0.13	disagree	0.85	0.26	
76	hf hom	dew	0.48	drop	1.77	0.32	fellow	1.8	0.04	
76	hf ctrl	grass	1.72	drop	1.77	0.25	fellow	1.8	0.12	
76	lf hom	dude	0	drop	1.77	0.15	fellow	1.8	0.32	
76	lf ctrl	cowboy	1.2	drop	1.77	0.05	fellow	1.8	0.22	
77	hf hom	die	1.86	grave	1.52	0.38	paint	1.57	0.01	
77	hf ctrl	**murder**	1.88	**grave**	1.52	0.32	paint	1.57	0.02	1350
77	lf hom	**dye**	0	grave	1.52	0.05	**paint**	1.57	0.29	2000
77	lf ctrl	tint	0	grave	1.52	0.02	paint	1.57	0.21	
78	hf hom	discrete	0.85	finite	1.04	0.39	modest	1.46	0.07	
78	hf ctrl	continuous	1.64	finite	1.04	0.21	modest	1.46	0.14	
78	lf hom	discreet	0.48	finite	1.04	-0.01	modest	1.46	0.2	
78	lf ctrl	subtle	1.4	finite	1.04	0.07	modest	1.46	0.27	
79	hf hom	dock	0.9	launch	0	0.23	vet	0	0.07	
79	hf ctrl	ship	1.92	launch	0	0.23	vet	0	0.01	
79	lf hom	doc	0	launch	0	0	vet	0	0.23	
79	lf ctrl	surgeon	1.04	launch	0	0.1	vet	0	0.21	
80	hf hom	done	1.51	finish	1.59	0.4	debt	1.11	0.17	
80	hf ctrl	ready	2.16	finish	1.59	0.39	debt	1.11	0.06	
80	lf hom	dun	0	finish	1.59	0.02	debt	1.11	0.32	
80	lf ctrl	rent	1.32	finish	1.59	0.06	debt	1.11	0.36	
81	hf hom	dough	1.11	pastry	0.6	0.52	hunt	0	0.04	
81	hf ctrl	cake	1.11	pastry	0.6	0.54	hunt	0	0.07	
81	lf hom	doe	0	pastry	0.6	-0.05	hunt	0	0.49	
81	lf ctrl	fawn	0	pastry	0.6	0	hunt	0	0.44	
82	hf hom	dough	1.11	bread	1.61	0.59	sleep	1.81	0.08	
82	hf ctrl	yeast	0.48	bread	1.61	0.48	sleep	1.81	0.03	
82	lf hom	doze	0	bread	1.61	0.16	sleep	1.81	0.45	
82	lf ctrl	nap	0.6	bread	1.61	0.18	sleep	1.81	0.42	
83	hf hom	duck	0.95	hide	1.34	0.35	canal	0.48	0.05	
83	hf ctrl	head	2.63	hide	1.34	0.45	canal	0.48	0.09	
83	lf hom	duct	0	hide	1.34	0	canal	0.48	0.37	
83	lf ctrl	passage	1.69	hide	1.34	0.08	canal	0.48	0.24	
84	hf hom	**due**	2.15	mortgage	1.23	0.32	**moist**	1.04	0.1	1350
84	hf ctrl	money	2.42	mortgage	1.23	0.34	moist	1.04	0.03	
84	lf hom	dew	0.48	mortgage	1.23	-0.01	moist	1.04	0.24	
84	lf ctrl	**condense**	0	**mortgage**	1.23	0	moist	1.04	0.22	2000
85	hf hom	earn	1.2	salary	1.63	0.41	cup	1.65	0.03	
85	hf ctrl	**merit**	1.46	**salary**	1.63	0.4	cup	1.65	0	150
85	lf hom	**urn**	0.3	salary	1.63	0	**cup**	1.65	0.48	450
85	lf ctrl	jar	1.2	salary	1.63	0.01	cup	1.65	0.43	
86	hf hom	effective	2.11	useless	1.23	0.22	upset	1.15	0.14	
86	hf ctrl	complete	2.26	useless	1.23	0.25	upset	1.15	0.12	
86	lf hom	affect	1.54	useless	1.23	0.07	upset	1.15	0.34	
86	lf ctrl	cry	1.68	useless	1.23	0.22	upset	1.15	0.36	
87	hf hom	epic	1.26	story	2.18	0.24	age	2.36	0.15	
87	hf ctrl	movie	1.46	story	2.18	0.3	age	2.36	0.08	
87	lf hom	epoch	0.78	story	2.18	0.04	age	2.36	0.27	
87	lf ctrl	era	0.48	story	2.18	0.07	age	2.36	0.33	

88	hf hom	eve	1.28	event	1.91	0.35	wall	1.2	0.08	
88	hf ctrl	holiday	1.23	event	1.91	0.33	wall	1.2	0.09	
88	lf hom	eave	0	event	1.91	0	wall	1.2	0.42	
88	lf ctrl	cliff	1.04	event	1.91	0.12	wall	1.2	0.3	
89	hf hom	eye	2.09	pupil	0.3	0.65	yes	2.16	0.16	
89	hf ctrl	vision	1.75	pupil	0.3	0.48	yes	2.16	0.11	
89	lf hom	aye	0	pupil	0.3	0.06	yes	2.16	0.49	
89	lf ctrl	okay	0.3	pupil	0.3	0.04	yes	2.16	0.42	
90	hf hom	fair	1.89	judge	1.89	0.35	fee	1.2	0.15	
90	hf ctrl	honest	1.67	judge	1.89	0.34	fee	1.2	0.17	
90	lf hom	fare	0.85	judge	1.89	0.14	fee	1.2	0.24	
90	lf ctrl	admission	1.52	judge	1.89	0.18	fee	1.2	0.27	
91	hf hom	feet	2.45	flat	1.83	0.28	task	0.78	0.07	
91	hf ctrl	head	2.63	flat	1.83	0.26	task	0.78	0.1	
91	lf hom	feat	0.78	flat	1.83	0.1	task	0.78	0.22	
91	lf ctrl	display	1.61	flat	1.83	0.06	task	0.78	0.22	
92	hf hom	ferry	1.04	boat	1.86	0.35	maiden	0.3	0.05	
92	hf ctrl	bay	1.76	boat	1.86	0.35	maiden	0.3	0.03	
92	lf hom	fairy	0.6	boat	1.86	0.06	maiden	0.3	0.37	
92	lf ctrl	goddess	0.48	boat	1.86	-0.03	maiden	0.3	0.48	
93	hf hom	find	2.6	yourself	1.83	0.33	legal	1.86	0.05	
93	hf ctrl	look	2.6	yourself	1.83	0.31	legal	1.86	0.04	
93	lf hom	fined	0	yourself	1.83	0.02	legal	1.86	0.44	
93	lf ctrl	penalty	1.15	yourself	1.83	0.08	legal	1.86	0.35	
94	hf hom	fish	1.54	pond	1.4	0.39	crack	1.32	-0.01	
94	hf ctrl	lake	1.73	pond	1.4	0.33	crack	1.32	0.11	
94	lf hom	fissure	0	pond	1.4	0.08	crack	1.32	0.44	
94	lf ctrl	fracture	0	pond	1.4	0.04	crack	1.32	0.23	
95	hf hom	flair	0.9	talent	0.6	0.2	burst	1.52	0.04	
95	hf ctrl	smart	1.32	talent	0.6	0.25	burst	1.52	0.17	
95	lf hom	flare	0.48	talent	0.6	0.02	burst	1.52	0.29	
95	lf ctrl	erupt	0.3	talent	0.6	0.03	burst	1.52	0.25	
96	hf hom	**flea**	0.30	**cat**	1.36	0.27	escape	1.81	0.02	1350
96	hf ctrl	collar	1.23	cat	1.36	0.18	escape	1.81	0.09	
96	lf hom	flee	0.00	cat	1.36	-0.01	escape	1.81	0.25	
96	lf ctrl	**vanish**	0.70	cat	1.36	0.02	**escape**	1.81	0.26	2000
97	hf hom	flew	1.43	wing	1.26	0.69	virus	1.11	-0.02	
97	hf ctrl	**bird**	1.49	**wing**	1.26	0.62	virus	1.11	0.02	2000
97	lf hom	**flu**	0.9	wing	1.26	-0.02	**virus**	1.11	0.66	1350
97	lf ctrl	disease	1.72	wing	1.26	0	virus	1.11	0.71	
98	hf hom	flower	1.36	leaf	1.08	0.33	biscuit	0.3	0.08	
98	hf ctrl	**tulip**	0.6	**leaf**	1.08	0.37	biscuit	0.3	0.11	2000
98	lf hom	**flour**	0.9	leaf	1.08	0.1	**biscuit**	0.3	0.36	1350
98	lf ctrl	sack	0.9	leaf	1.08	0.04	biscuit	0.3	0.39	
99	hf hom	foul	0.6	vulgar	0.85	0.22	hunt	0	0.06	
99	hf ctrl	silly	1.18	vulgar	0.85	0.28	hunt	0	0.16	
99	lf hom	fowl	0	vulgar	0.85	0.1	hunt	0	0.23	
99	lf ctrl	duck	0.95	vulgar	0.85	0.05	hunt	0	0.24	
100	hf hom	fourth	1.87	year	1.82	0.27	go	2.8	0.16	

100	hf ctrl	grade	1.54	year	1.82	0.24	go	2.8	0.17	
100	lf hom	forth	1.85	year	1.82	0.2	go	2.8	0.32	
100	lf ctrl	forward	2.06	year	1.82	0.17	go	2.8	0.26	
101	hf hom	fry	0.3	roast	0	0.34	monk	1.2	0.06	
101	hf ctrl	boil	1.08	roast	0	0.35	monk	1.2	0.07	
101	lf hom	friar	0	roast	0	0.08	monk	1.2	0.29	
101	lf ctrl	priest	1.2	roast	0	0.06	monk	1.2	0.37	
102	hf hom	fur	1.11	seal	1.23	0.32	cone	1.11	0.16	
102	hf ctrl	**otter**	0.70	seal	1.23	0.39	**cone**	1.11	0.07	1350
102	lf hom	**fir**	0.30	**seal**	1.23	0.25	cone	1.11	0.08	2000
102	lf ctrl	pine	1.15	seal	1.23	0.36	cone	1.11	0.17	
103	hf hom	gate	1.57	keeper	0.48	0.29	stagger	0.3	0.15	
103	hf ctrl	fence	0.48	keeper	0.48	0.24	stagger	0.3	0.18	
103	lf hom	gait	0.9	keeper	0.48	0.12	stagger	0.3	0.23	
103	lf ctrl	pace	1.63	keeper	0.48	0.14	stagger	0.3	0.24	
104	hf hom	**gene (s)**	0.95	parent	1.18	0.48	**pocket**	1.66	0.02	2000
104	hf ctrl	reproduction	0.78	parent	1.18	0.43	pocket	1.66	0.04	
104	lf hom	jeans	0	parent	1.18	0.06	pocket	1.66	0.36	
104	lf ctrl	**faded**	0	**parent**	1.18	0.05	pocket	1.66	0.43	1350
105	hf hom	graph	1.23	increase	2.29	0.28	money	2.42	0.07	
105	hf ctrl	statistics	1.34	increase	2.29	0.36	money	2.42	0.04	
105	lf hom	graft	0	increase	2.29	0	money	2.42	0.2	
105	lf ctrl	stolen	1.26	increase	2.29	0.04	money	2.42	0.29	
106	hf hom	great	2.82	pleasing	0	0.21	ash	1.04	0.14	
106	hf ctrl	**good**	0.9	**pleasing**	0	0.36	ash	1.04	0.05	2000
106	lf hom	**grate**	0.48	pleasing	0	0.03	**ash**	1.04	0.23	1350
106	lf ctrl	hearth	0.6	pleasing	0	0.11	ash	1.04	0.2	
107	hf hom	guilt	1.52	trial	2.13	0.45	beautiful	2.1	0.02	
107	hf ctrl	accuse	0	trial	2.13	0.39	beautiful	2.1	0.08	
107	lf hom	gilt	0.48	trial	2.13	0	beautiful	2.1	0.27	
107	lf ctrl	adore	0.3	trial	2.13	0.02	beautiful	2.1	0.21	
108	hf hom	hair	2.17	trim	0.3	0.21	rabbit	1.04	0.08	
108	hf ctrl	cut	2.28	trim	0.3	0.45	rabbit	1.04	0.06	
108	lf hom	hare	0	trim	0.3	0.05	rabbit	1.04	0.41	
108	lf ctrl	bunny	0	trim	0.3	0.05	rabbit	1.04	0.36	
109	hf hom	**hall**	2.18	dance	0.95	0.24	**carry**	1.94	0.08	150
109	hf ctrl	stage	2.24	dance	0.95	0.23	carry	1.94	0.08	
109	lf hom	haul	0.7	dance	0.95	0.03	carry	1.94	0.3	
109	lf ctrl	**basket**	1.23	**dance**	0.95	0.08	carry	1.94	0.24	450
110	hf hom	hay	1.28	wheat	0.95	0.48	yell	0.95	0.15	
110	hf ctrl	sheep	1.36	wheat	0.95	0.54	yell	0.95	0.12	
110	lf hom	hey	1.18	wheat	0.95	0.02	yell	0.95	0.54	
110	lf ctrl	hello	0	wheat	0.95	0.05	yell	0.95	0.41	
111	hf hom	**heard**	2.39	**whisper**	1.08	0.65	cattle	1.99	0.05	450
111	hf ctrl	sound	0.3	whisper	1.08	0.61	cattle	1.99	0.03	
111	lf hom	herd	1.34	whisper	1.08	0.09	cattle	1.99	0.79	
111	lf ctrl	**sheep**	1.36	whisper	1.08	0.05	**cattle**	1.99	0.8	150
112	hf hom	**heel**	0.95	boots	0.3	0.35	**cure**	1.45	0.09	150
112	hf ctrl	toe	0.95	boots	0.3	0.44	cure	1.45	0.12	
112	lf hom	heal	0.3	boots	0.3	0.08	cure	1.45	0.47	

112	lf ctrl	**clinic**	0.48	**boots**	0.3	0.05	cure	1.45	0.38	450
113	hf hom	heroine	0.7	courage	1.51	0.24	inject	0.78	-0.01	
113	hf ctrl	patriot	0	courage	1.51	0.4	inject	0.78	-0.01	
113	lf hom	heroin	0.3	courage	1.51	0.03	inject	0.78	0.2	
113	lf ctrl	addict	0	courage	1.51	0.06	inject	0.78	0.22	
114	hf hom	high	2.7	platform	1.86	0.22	visit	0	0.16	
114	hf ctrl	above	2.47	platform	1.86	0.32	visit	0	0.19	
114	lf hom	hi	0.78	platform	1.86	0.08	visit	0	0.25	
114	lf ctrl	hello	0	platform	1.86	0.05	visit	0	0.34	
115	hf hom	**high**	2.70	visit	2.04	0.16	**platform**	1.86	0.22	450
115	hf ctrl	top	2.31	visit	2.04	0.18	platform	1.86	0.23	
115	lf hom	hi	0.78	visit	2.04	0.15	platform	1.86	0.38	
115	lf ctrl	**greet**	0.85	**visit**	2.04	0.12	platform	1.86	0.37	150
116	hf hom	higher	1.2	steep	1.11	0.32	boss	0.3	0.06	
116	hf ctrl	top	0.3	steep	1.11	0.42	boss	0.3	0.15	
116	lf hom	hire	1.18	steep	1.11	0.04	boss	0.3	0.41	
116	lf ctrl	quit	1.18	steep	1.11	0.02	boss	0.3	0.41	
117	hf hom	**him**	3.42	**father**	2.26	0.35	music	2.33	0.11	1350
117	hf ctrl	her	0.48	father	2.26	0.31	music	2.33	0.11	
117	lf hom	hymn	0.95	father	2.26	0.14	music	2.33	0.35	
117	lf ctrl	**anthem**	0	father	2.26	0.02	**music**	2.33	0.29	2000
118	hf hom	hole	1.76	dig	0	0.51	preacher	1.04	0.02	
118	hf ctrl	pit	1.15	dig	0	0.52	preacher	1.04	0.07	
118	lf hom	holy	1.69	dig	0	0	preacher	1.04	0.45	
118	lf ctrl	bible	1.77	dig	0	0.07	preacher	1.04	0.5	
119	hf hom	horse	2.07	cart	0.7	0.39	husky	0.48	0.04	
119	hf ctrl	ride	1.69	cart	0.7	0.43	husky	0.48	0	
119	lf hom	hoarse	0.7	cart	0.7	0.18	husky	0.48	0.33	
119	lf ctrl	sniff	0.3	cart	0.7	0.08	husky	0.48	0.31	
120	hf hom	hose	0.95	vacuum	0.3	0.64	crop	0.3	0.06	
120	hf ctrl	pump	1.04	vacuum	0.3	0.71	crop	0.3	0.05	
120	lf hom	hoes	0	vacuum	0.3	0	crop	0.3	0.46	
120	lf ctrl	plow	0	vacuum	0.3	0.01	crop	0.3	0.66	
121	hf hom	hurts	0	afraid	1.76	0.41	frequency	1.34	0.02	
121	hf ctrl	forgotten	1.58	afraid	1.76	0.43	frequency	1.34	0	
121	lf hom	hertz	0	afraid	1.76	0.02	frequency	1.34	0.75	
121	lf ctrl	cycles	0	afraid	1.76	0.02	frequency	1.34	0.62	
122	hf hom	idle	1.11	slow	0.78	0.23	hero	1.72	0.09	
122	hf ctrl	lazy	0.95	slow	0.78	0.24	hero	1.72	0.12	
122	lf hom	idol	0.85	slow	0.78	0.08	hero	1.72	0.29	
122	lf ctrl	praise	1.23	slow	0.78	0.12	hero	1.72	0.26	
123	hf hom	instance	1.91	demonstrate	1.45	0.44	flash	1.32	0.1	
123	hf ctrl	mention	0.7	demonstrate	1.45	0.34	flash	1.32	0.13	
123	lf hom	instant	1.58	demonstrate	1.45	0.17	flash	1.32	0.5	
123	lf ctrl	minute	1.72	demonstrate	1.45	0.14	flash	1.32	0.41	
124	hf hom	intent	1.15	purpose	2.17	0.26	deep	0	0.18	
124	hf ctrl	pursue	0.3	purpose	2.17	0.28	deep	0	0.09	
124	lf hom	intense	0.6	purpose	2.17	0.19	deep	0	0.27	
124	lf ctrl	brillian	0.7	purpose	2.17	0.15	deep	0	0.29	
125	hf hom	jam	0.78	knife	1.88	0.26	frame	1.87	0.06	
125	hf ctrl	biscuit	0.3	knife	1.88	0.33	frame	1.87	0.06	

125	lf hom	jamb	0	knife	1.88	0.13	frame	1.87	0.25	
125	lf ctrl	photo	0.7	knife	1.88	0.02	frame	1.87	0.2	
126	hf hom	jewel	0	precious	1.46	0.29	physics	1.34	-0.01	
126	hf ctrl	**bracelet**	0	**precious**	1.46	0.3	physics	1.34	-0.02	1350
126	lf hom	**joule**	0	precious	1.46	-0.04	**physics**	1.34	0.28	2000
126	lf ctrl	kinetic	0.9	precious	1.46	0	physics	1.34	0.27	
127	hf hom	keys	1.53	door	2.49	0.25	ship	1.92	0.03	
127	hf ctrl	guard	1.68	door	2.49	0.27	ship	1.92	0.2	
127	lf hom	quays	0	door	2.49	-0.01	ship	1.92	0.43	
127	lf ctrl	wharf	0.6	door	2.49	0.09	ship	1.92	0.38	
128	hf hom	knot	0.9	tight	1.45	0.48	silent	1.69	0.18	
128	hf ctrl	rope	1.18	tight	1.45	0.43	silent	1.69	0.12	
128	lf hom	naught	0.3	tight	1.45	0.13	silent	1.69	0.36	
128	lf ctrl	blank	1.15	tight	1.45	0.2	silent	1.69	0.37	
129	hf hom	know	2.83	predict	0.9	0.27	antelope	0.85	0.12	
129	hf ctrl	fact	2.65	predict	0.9	0.23	antelope	0.85	0.1	
129	lf hom	gnu	0	predict	0.9	-0.03	antelope	0.85	0.25	
129	lf ctrl	beast	0.85	predict	0.9	0	antelope	0.85	0.32	
130	hf hom	know	2.83	teach	1.61	0.37	ear	1.46	0.16	
130	hf ctrl	**think**	2.64	**teach**	1.61	0.26	ear	1.46	0.15	1350
130	lf hom	**nose**	1.78	teach	1.61	0.07	**ear**	1.46	0.44	2000
130	lf ctrl	throat	1.71	teach	1.61	0	ear	1.46	0.31	
131	hf hom	lama	0	priest	1.2	0.39	hump	0.3	0.08	
131	hf ctrl	monk	1.2	priest	1.2	0.37	hump	0.3	0.08	
131	lf hom	llama	0	priest	1.2	0.12	hump	0.3	0.33	
131	lf ctrl	wild	1.75	priest	1.2	0.07	hump	0.3	0.33	
132	hf hom	lap	1.28	run	2.33	0.34	death	2.44	0.1	
132	hf ctrl	sit	1.83	run	2.33	0.3	death	2.44	0.08	
132	lf hom	lapse	0.78	run	2.33	0.11	death	2.44	0.32	
132	lf ctrl	judgment	0.78	run	2.33	0.07	death	2.44	0.25	
133	hf hom	latter	2.06	sequence	1.54	0.22	rope	1.18	0.04	
133	hf ctrl	second	2.57	sequence	1.54	0.27	rope	1.18	0.11	
133	lf hom	ladder	1.28	sequence	1.54	0.15	rope	1.18	0.39	
133	lf ctrl	hook	0.7	sequence	1.54	0.02	rope	1.18	0.35	
134	hf hom	leader	1.87	governor	1.92	0.36	song	0.85	0.09	
134	hf ctrl	chief	2.08	governor	1.92	0.33	song	0.85	0.07	
134	lf hom	lieder	0	governor	1.92	-0.02	song	0.85	0.42	
134	lf ctrl	solo	0.85	governor	1.92	0.03	song	0.85	0.44	
135	hf hom	lean	0.3	shoulder	1.79	0.53	payment	1.72	0	
135	hf ctrl	slender	1.28	shoulder	1.79	0.36	payment	1.72	0.02	
135	lf hom	lien	0.3	shoulder	1.79	-0.01	payment	1.72	0.56	
135	lf ctrl	debt	1.11	shoulder	1.79	0.06	payment	1.72	0.58	
136	hf hom	least	2.54	seldom	1.53	0.52	payment	1.72	0.12	
136	hf ctrl	best	2.55	seldom	1.53	0.43	payment	1.72	0.03	
136	lf hom	lease	0	seldom	1.53	0.09	payment	1.72	0.43	
136	lf ctrl	borrow	0.95	seldom	1.53	0.09	payment	1.72	0.45	
137	hf hom	**lesson**	1.46	text	1.78	0.3	**reduce**	1.79	0.07	450
137	hf ctrl	instruction	1.41	text	1.78	0.31	reduce	1.79	0.06	
137	lf hom	lessen	0.70	text	1.78	0.03	reduce	1.79	0.29	
137	lf ctrl	**diminish**	0.48	**text**	1.78	-0.02	reduce	1.79	0.19	150
138	hf hom	liar	0.48	honest	1.67	0.26	instrument	1.67	-0.02	

138	hf ctrl	deceit	0.3	honest	1.67	0.25	instrument	1.67	0.12	
138	lf hom	lyre	0	honest	1.67	0.06	instrument	1.67	0.32	
138	lf ctrl	harp	0	honest	1.67	0.06	instrument	1.67	0.44	
139	hf hom	lie	1.77	excuse	1.43	0.25	soap	1.34	0.17	
139	hf ctrl	guilt	1.52	excuse	1.43	0.24	soap	1.34	0.03	
139	lf hom	lye	0	excuse	1.43	0	soap	1.34	0.39	
139	lf ctrl	bath	1.41	excuse	1.43	0.16	soap	1.34	0.42	
140	hf hom	like	2.11	agree	1.71	0.3	fungus	0.3	0.14	
140	hf ctrl	same	2.84	agree	1.71	0.36	fungus	0.3	0.07	
140	lf hom	lichen	0	agree	1.71	0.05	fungus	0.3	0.65	
140	lf ctrl	algae	0.85	agree	1.71	0.03	fungus	0.3	0.54	
141	hf hom	links	0.85	connect	0.48	0.25	feline	0.3	0.08	
141	hf ctrl	attach	1.15	connect	0.48	0.26	feline	0.3	0.08	
141	lf hom	lynx	0	connect	0.48	-0.02	feline	0.3	0.2	
141	lf ctrl	soft	1.79	connect	0.48	0.13	feline	0.3	0.19	
142	hf hom	**liquor**	1.63	**drug**	1.38	0.19	kiss	1.23	0.02	2000
142	hf ctrl	whiskey	1.23	drug	1.38	0.16	kiss	1.23	0.03	
142	lf hom	lick	0.48	drug	1.38	0.06	kiss	1.23	0.4	
142	lf ctrl	**slobber**	0.00	drug	1.38	0.02	**kiss**	1.23	0.71	1350
143	hf hom	load	1.65	trailer	1.04	0.29	mineral	1.08	0.06	
143	hf ctrl	trip	1.91	trailer	1.04	0.25	mineral	1.08	0.04	
143	lf hom	lode	0	trailer	1.04	0.04	mineral	1.08	0.38	
143	lf ctrl	rock	1.88	trailer	1.04	0.04	mineral	1.08	0.47	
144	hf hom	loan	1.66	owe	0	0.36	solitary	1.15	-0.03	
144	hf ctrl	mortgage	1.23	owe	0	0.38	solitary	1.15	-0.03	
144	lf hom	lone	0.9	owe	0	0.06	solitary	1.15	0.28	
144	lf ctrl	wolf	0.78	owe	0	0.05	solitary	1.15	0.28	
145	hf hom	lock	1.36	secure	0.48	0.21	lagoon	1.18	0.03	
145	hf ctrl	bolt	0	secure	0.48	0.21	lagoon	1.18	0.05	
145	lf hom	loch	0	secure	0.48	-0.03	lagoon	1.18	0.24	
145	lf ctrl	swamp	0.7	secure	0.48	0.03	lagoon	1.18	0.23	
146	hf hom	locks	0	master	1.86	0.24	salmon	0.48	0	
146	hf ctrl	secure	0.48	master	1.86	0.22	salmon	0.48	0.04	
146	lf hom	lox	0	master	1.86	-0.01	salmon	0.48	0.43	
146	lf ctrl	eat	1.79	master	1.86	0.08	salmon	0.48	0.2	
147	hf hom	loot	0.48	robbery	0	0.39	instrument	1.67	0.04	
147	hf ctrl	thief	0.9	robbery	0	0.48	instrument	1.67	0.07	
147	lf hom	lute	0	robbery	0	0.04	instrument	1.67	0.46	
147	lf ctrl	string	1.28	robbery	0	0.1	instrument	1.67	0.45	
148	hf hom	made	3.05	build	1.93	0.41	butler	0.6	0.18	
148	hf ctrl	become	2.56	build	1.93	0.33	butler	0.6	0.18	
148	lf hom	maid	1.49	build	1.93	0.06	butler	0.6	0.29	
148	lf ctrl	slave	0.48	build	1.93	0.04	butler	0.6	0.31	
149	hf hom	magnet	0.48	electric	1.83	0.33	industry	2.23	0	
149	hf ctrl	needle	1.18	electric	1.83	0.3	industry	2.23	-0.02	
149	lf hom	magnate	0	electric	1.83	0	industry	2.23	0.32	
149	lf ctrl	shipping	1.28	electric	1.83	0.04	industry	2.23	0.38	
150	hf hom	mail	1.67	envelope	1.32	0.71	gender	0.3	0	
150	hf ctrl	address	1.89	envelope	1.32	0.77	gender	0.3	0.06	
150	lf hom	male	1.57	envelope	1.32	0.01	gender	0.3	0.55	

150	lf ctrl	sex	1.92	envelope	1.32	0.02	gender	0.3	0.67	
151	hf hom	**main**	2.08	feature	1.57	0.26	**coat**	1.63	0.09	1350
151	hf ctrl	objective	1.96	feature	1.57	0.26	coat	1.63	0	
151	lf hom	mane	0	feature	1.57	0.04	coat	1.63	0.24	
151	lf ctrl	**tangle**	0.9	**feature**	1.57	0.03	coat	1.63	0.23	2000
152	hf hom	mall	0.48	store	1.87	0.27	dog	1.88	-0.01	
152	hf ctrl	**downtown**	0	**store**	1.87	0.35	dog	1.88	0.08	1350
152	lf hom	**maul**	0	store	1.87	-0.02	**dog**	1.88	0.23	2000
152	lf ctrl	sniff	0.3	store	1.87	0.02	dog	1.88	0.41	
153	hf hom	**manner**	2.09	**routine**	1.54	0.3	palace	1.58	0.1	2000
153	hf ctrl	type	2.3	routine	1.54	0.25	palace	1.58	0.02	
153	lf hom	manor	0.7	routine	1.54	0.05	palace	1.58	0.2	
153	lf ctrl	**squire**	0.7	routine	1.54	0.09	**palace**	1.58	0.24	1350
154	hf hom	marry	1.26	single	2.24	0.2	fun	1.64	0.07	
154	hf ctrl	engage	1.15	single	2.24	0.2	fun	1.64	0.07	
154	lf hom	merry	0.9	single	2.24	0.15	fun	1.64	0.21	
154	lf ctrl	cheer	0.9	single	2.24	0.08	fun	1.64	0.24	
155	hf hom	mass	1.04	element	1.72	0.25	flag	1.2	0.03	
155	hf ctrl	common	2.35	element	1.72	0.22	flag	1.2	0.12	
155	lf hom	mast	0.78	element	1.72	0	flag	1.2	0.24	
155	lf ctrl	sailor	0.7	element	1.72	0.01	flag	1.2	0.29	
156	hf hom	maze	0.78	passage	1.69	0.24	grain	1.43	-0.04	
156	hf ctrl	obstacle	0	passage	1.69	0.32	grain	1.43	0.03	
156	lf hom	maize	0	passage	1.69	0.03	grain	1.43	0.34	
156	lf ctrl	potato	1.18	passage	1.69	0.09	grain	1.43	0.37	
157	hf hom	meat	1.65	sausage	0	0.47	comet	0.3	0.01	
157	hf ctrl	pork	0	sausage	0	0.47	comet	0.3	-0.04	
157	lf hom	meteor	0.48	sausage	0	0.02	comet	0.3	0.59	
157	lf ctrl	star	1.4	sausage	0	0.04	comet	0.3	0.53	
158	hf hom	meet	2.17	attend	1.73	0.3	cattle	1.99	0.03	
158	hf ctrl	**challenge**	1.56	**attend**	1.73	0.34	cattle	1.99	0.05	2000
158	lf hom	**meat**	1.65	attend	1.73	-0.01	**cattle**	1.99	0.39	1350
158	lf ctrl	beef	1.51	attend	1.73	0	cattle	1.99	0.64	
159	hf hom	metal	1.79	iron	1.63	0.32	courage	1.51	0.03	
159	hf ctrl	pipe	0.3	iron	1.63	0.3	courage	1.51	0.02	
159	lf hom	mettle	0.3	iron	1.63	0.05	courage	1.51	0.33	
159	lf ctrl	badge	0.7	iron	1.63	0.05	courage	1.51	0.29	
160	hf hom	mind	2.51	blank	1.15	0.32	dig	0	0.14	
160	hf ctrl	remember	2.14	blank	1.15	0.33	dig	0	0.15	
160	lf hom	mine	1.77	blank	1.15	0.15	dig	0	0.44	
160	lf ctrl	tunnel	0	blank	1.15	0.1	dig	0	0.51	
161	hf hom	**mine (r**	1.77	mineral	1.08	0.28	**delinquent**	0.78	0.01	1350
161	hf ctrl	coal	1.51	mineral	1.08	0.3	delinquent	0.78	-0.02	
161	lf hom	minor	1.76	mineral	1.08	0.01	delinquent	0.78	0.29	
161	lf ctrl	**severe**	1.59	**mineral**	1.08	0.07	delinquent	0.78	0.2	2000
162	hf hom	mist	1.15	mountain	1.52	0.22	lose	1.76	0.12	
162	hf ctrl	**haze**	0.85	mountain	1.52	0.22	**lose**	1.76	0.1	2000
162	lf hom	**missed**	0	**mountain**	1.52	0.05	lose	1.76	0.25	1350
162	lf ctrl	skip	0.7	mountain	1.52	0.09	lose	1.76	0.22	

163	hf hom	mode	1.32	computer	1.11	0.32	lawn	1.18	-0.01	
163	hf ctrl	**routine**	1.54	computer	1.11	0.32	**lawn**	1.18	0.14	2000
163	lf hom	**mowed**	0.00	**computer**	1.11	0.02	lawn	1.18	0.65	1350
163	lf ctrl	yard	1.54	computer	1.11	0	lawn	1.18	0.9	
164	hf hom	mood	1.57	angry	1.65	0.43	milk	1.69	0.06	
164	hf ctrl	emotion	1.53	angry	1.65	0.46	milk	1.69	0.05	
164	lf hom	moo	0	angry	1.65	0.03	milk	1.69	0.37	
164	lf ctrl	pasture	1.15	angry	1.65	0.1	milk	1.69	0.34	
165	hf hom	more	3.35	excess	1.62	0.23	boat	1.86	0.14	
165	hf ctrl	than	3.25	excess	1.62	0.23	boat	1.86	0.12	
165	lf hom	moor	0	excess	1.62	0.04	boat	1.86	0.21	
165	lf ctrl	marsh	0.6	excess	1.62	0.06	boat	1.86	0.19	
166	hf hom	morning	2.32	stretch	1.41	0.24	tragedy	1.69	0.08	
166	hf ctrl	afternoon	0	stretch	1.41	0.26	tragedy	1.69	0.18	
166	lf hom	mourning	0.9	stretch	1.41	0.06	tragedy	1.69	0.32	
166	lf ctrl	regret	0.95	stretch	1.41	0.15	tragedy	1.69	0.3	
167	hf hom	morning	2.32	early	2.56	0.4	death	2.44	0.09	
167	hf ctrl	today	2.45	early	2.56	0.48	death	2.44	0.16	
167	lf hom	mourn	0.3	early	2.56	0.07	death	2.44	0.45	
167	lf ctrl	sorrow	0.95	early	2.56	0.13	death	2.44	0.46	
168	hf hom	muscle	1.62	flex	0.3	0.43	oyster	0.78	0.01	
168	hf ctrl	leg	1.76	flex	0.3	0.42	oyster	0.78	0.08	
168	lf hom	mussel	0	flex	0.3	0.06	oyster	0.78	0.31	
168	lf ctrl	clam	0.48	flex	0.3	0.12	oyster	0.78	0.37	
169	hf hom	must	0	important	2.57	0.37	mess	1.34	0.14	
169	hf ctrl	necessary	2.35	important	2.57	0.43	mess	1.34	0.07	
169	lf hom	mussed	0	important	2.57	0.02	mess	1.34	0.17	
169	lf ctrl	slop	0.3	important	2.57	0.1	mess	1.34	0.25	
170	hf hom	naval	1.52	patrol	1.4	0.21	belly	1.36	0.08	
170	hf ctrl	submarine	1.43	patrol	1.4	0.24	belly	1.36	0.13	
170	lf hom	navel	0.3	patrol	1.4	0.15	belly	1.36	0.28	
170	lf ctrl	orange	1.36	patrol	1.4	0.09	belly	1.36	0.24	
171	hf hom	night	2.61	shade	1.45	0.26	medieval	1.26	0.03	
171	hf ctrl	light	2.52	shade	1.45	0.23	medieval	1.26	0.01	
171	lf hom	knight	1.26	shade	1.45	0.07	medieval	1.26	0.26	
171	lf ctrl	armor	0.6	shade	1.45	0.13	medieval	1.26	0.29	
172	hf hom	oh	2.08	surprise	1.71	0.56	payment	1.72	0.01	
172	hf ctrl	**yes**	2.16	**surprise**	1.71	0.56	payment	1.72	0	450
172	lf hom	**owe**	0	surprise	1.71	0.2	**payment**	1.72	0.43	150
172	lf ctrl	borrow	0.95	surprise	1.71	0.06	payment	1.72	0.45	
173	hf hom	one	3.52	unique	1.76	0.4	election	1.89	0.14	
173	hf ctrl	single	2.24	unique	1.76	0.41	election	1.89	0.13	
173	lf hom	won	1.83	unique	1.76	0.08	election	1.89	0.3	
173	lf ctrl	defeat	1.49	unique	1.76	0.06	election	1.89	0.35	
174	hf hom	oral	1.43	ability	1.87	0.23	listen	1.71	0.19	
174	hf ctrl	verbal	1.32	ability	1.87	0.37	listen	1.71	0.17	
174	lf hom	aural	0	ability	1.87	0.01	listen	1.71	0.37	
174	lf ctrl	ear	1.46	ability	1.87	0.12	listen	1.71	0.35	
175	hf hom	ore	0.48	mineral	1.08	0.57	raft	0.6	0	
175	hf ctrl	**granite**	0.48	mineral	1.08	0.61	**raft**	0.6	0	1350
175	lf hom	**oar**	0	**mineral**	1.08	-0.04	raft	0.6	0.58	2000

175	lf ctrl	paddle	0	mineral	1.08	0.04	raft	0.6	0.58	
176	hf hom	our	3.1	possess	1.2	0.22	twilight	0.6	0.08	
176	hf ctrl	us	2.83	possess	1.2	0.2	twilight	0.6	0.14	
176	lf hom	hour	2.16	possess	1.2	0.1	twilight	0.6	0.35	
176	lf ctrl	twelve	1.68	possess	1.2	0.14	twilight	0.6	0.35	
177	hf hom	owed	1.00	debt	1.11	0.47	verse	1.45	0.12	
177	hf ctrl	**borrow**	0.95	**debt**	1.11	0.65	verse	1.45	0.01	450
177	lf hom	**ode**	0.00	debt	1.11	0.14	**verse**	1.45	0.61	150
177	lf ctrl	poem	1.68	debt	1.11	0.12	verse	1.45	0.61	
178	hf hom	**pace (d)**	1.63	stride	1.2	0.39	**plaster**	1.36	0.03	2000
178	hf ctrl	quick	1.83	stride	1.2	0.47	plaster	1.36	0.06	
178	lf hom	paste	0	stride	1.2	0	plaster	1.36	0.33	
178	lf ctrl	**glue**	0.9	**stride**	1.2	0	plaster	1.36	0.48	1350
179	hf hom	pain	1.94	neck	1.91	0.33	window	2.08	0.13	
179	hf ctrl	**injury**	1.43	**neck**	1.91	0.23	window	2.08	0.07	1350
179	lf hom	**pane**	0.48	neck	1.91	0.17	**window**	2.08	0.34	2000
179	lf ctrl	sill	0.60	neck	1.91	0.07	window	2.08	0.04	
180	hf hom	pale	1.76	white	2.56	0.37	water	2.65	0.14	
180	hf ctrl	**faint**	1.40	white	2.56	0.23	**water**	2.65	0.12	450
180	lf hom	**pail**	0.60	**white**	2.56	0.14	water	2.65	0.33	150
180	lf ctrl	mop	0.48	white	2.56	0.07	water	2.65	0.22	
181	hf hom	palette	0.7	picture	2.21	0.27	mouth	0	-0.02	
181	hf ctrl	paint	1.57	picture	2.21	0.27	mouth	0	0.06	
181	lf hom	palate	0.3	picture	2.21	0.02	mouth	0	0.32	
181	lf ctrl	nasal	0.3	picture	2.21	-0.02	mouth	0	0.42	
182	hf hom	parish	1.04	attend	1.73	0.23	terrible	1.65	0.2	
182	hf ctrl	belong	1.57	attend	1.73	0.28	terrible	1.65	0.13	
182	lf hom	perish	0.3	attend	1.73	0.08	terrible	1.65	0.23	
182	lf ctrl	spoil	0.48	attend	1.73	0.07	terrible	1.65	0.27	
183	hf hom	patient	1.93	operation	2.05	0.22	stay	2.05	0.03	
183	hf ctrl	hospital	1.04	operation	2.05	0.24	stay	2.05	0.18	
183	lf hom	patience	1.34	operation	2.05	0.14	stay	2.05	0.26	
183	lf ctrl	calm	1.54	operation	2.05	0.08	stay	2.05	0.31	
184	hf hom	pause	1.32	consider	2.1	0.23	dog	1.88	0.04	
184	hf ctrl	hesitate	0	consider	2.1	0.27	dog	1.88	0	
184	lf hom	paws	0	consider	2.1	0.02	dog	1.88	0.38	
184	lf ctrl	cat	1.36	consider	2.1	0.03	dog	1.88	0.36	
185	hf hom	peace	2.3	justice	2.06	0.31	section	2.28	0.07	
185	hf ctrl	**freedom**	2.11	justice	2.06	0.28	**section**	2.28	0.05	1350
185	lf hom	**piece**	2.11	**justice**	2.06	0.03	section	2.28	0.22	2000
185	lf ctrl	unit	0	justice	2.06	0.04	section	2.28	0.31	
186	hf hom	peak	1.2	hill	1.86	0.28	watch	1.91	0.11	
186	hf ctrl	mountain	1.52	hill	1.86	0.3	watch	1.91	0.11	
186	lf hom	peek	0	hill	1.86	0.05	watch	1.91	0.34	
186	lf ctrl	observe	1.18	hill	1.86	0.09	watch	1.91	0.31	
187	hf hom	pear	0.78	fruit	1.54	0.28	double	1.75	0.12	
187	hf ctrl	**peach**	0.48	**fruit**	1.54	0.26	double	1.75	0.12	450
187	lf hom	**pair**	1.70	fruit	1.54	0.05	**double**	1.75	0.42	150
187	lf ctrl	couple	2.09	fruit	1.54	0.02	double	1.75	0.31	
188	hf hom	peck	0.7	kiss	1.23	0.26	muscle	1.62	-0.02	
188	hf ctrl	smack	0.6	kiss	1.23	0.28	muscle	1.62	-0.02	

188	lf hom	pectoral	0	kiss	1.23	-0.02	muscle	1.62	0.28	
188	lf ctrl	cavity	1.08	kiss	1.23	0.02	muscle	1.62	0.25	
189	hf hom	peel	0.48	onion	1.18	0.36	loud	0.3	0.07	
189	hf ctrl	lemon	1.26	onion	1.18	0.3	loud	0.3	0.1	
189	lf hom	peal	0	onion	1.18	0.02	loud	0.3	0.29	
189	lf ctrl	ring	1.67	onion	1.18	0.11	loud	0.3	0.36	
190	hf hom	peer	0.9	companion	1.28	0.2	water	2.65	0.04	
190	hf ctrl	mate	1.32	companion	1.28	0.25	water	2.65	0.15	
190	lf hom	pier	0.48	companion	1.28	0.03	water	2.65	0.26	
190	lf ctrl	boat	1.86	companion	1.28	0.07	water	2.65	0.27	
191	hf hom	pennant	0.95	champion	1.36	0.42	sin	1.72	0.09	
191	hf ctrl	baseball	0	champion	1.36	0.46	sin	1.72	0.04	
191	lf hom	penance	0.7	champion	1.36	0.12	sin	1.72	0.58	
191	lf ctrl	sacrament	0	champion	1.36	0.09	sin	1.72	0.58	
192	hf hom	pie	1.15	apple	0.95	0.47	radius	0.95	0.06	
192	hf ctrl	**lunch**	1.52	**apple**	0.95	0.28	radius	0.95	0	150
192	lf hom	**pi**	0.48	apple	0.95	0.12	**radius**	0.95	0.3	450
192	lf ctrl	ratio	1.56	apple	0.95	0.1	radius	0.95	0.38	
193	hf hom	pistol	1.43	rifle	1.8	0.44	plant	2.1	0.01	
193	hf ctrl	weapon	1.62	rifle	1.8	0.43	plant	2.1	0.04	
193	lf hom	pistil	0	rifle	1.8	0.01	plant	2.1	0.35	
193	lf ctrl	stigma	0	rifle	1.8	0.03	plant	2.1	0.27	
194	hf hom	**plane**	2.06	**luggage**	0	0.29	fancy	1.2	0.03	1350
194	hf ctrl	train	1.91	luggage	0	0.34	fancy	1.2	0.15	
194	lf hom	plain	1.68	luggage	0	0.13	fancy	1.2	0.23	
194	lf ctrl	**ordinary**	1.86	luggage	0	0.15	**fancy**	1.2	0.34	2000
195	hf hom	plate	1.34	tin	1.08	0.24	lace	0.85	0.1	
195	hf ctrl	dish	1.2	tin	1.08	0.24	lace	0.85	0.16	
195	lf hom	plait	0	tin	1.08	0.01	lace	0.85	0.25	
195	lf ctrl	twist	1.26	tin	1.08	0.13	lace	0.85	0.2	
196	hf hom	plumb	0.7	depth	1.72	0.2	tree	1.77	0.01	
196	hf ctrl	sounding	0.48	depth	1.72	0.23	tree	1.77	0.05	
196	lf hom	plum	0	depth	1.72	0.02	tree	1.77	0.26	
196	lf ctrl	tart	0.85	depth	1.72	0.05	tree	1.77	0.26	
197	hf hom	**pole**	1.26	**south**	1.38	0.47	popular	1.99	0.03	1350
197	hf ctrl	compass	1.11	south	1.38	0.27	popular	1.99	0.04	
197	lf hom	poll	0.95	south	1.38	0.08	popular	1.99	0.36	
197	lf ctrl	**elect**	0.9	south	1.38	0.12	**popular**	1.99	0.34	2000
198	hf hom	pond	1.4	turtle	0.9	0.49	payment	1.72	-0.01	
198	hf ctrl	**duck**	0.95	**turtle**	0.9	0.55	payment	1.72	0.01	150
198	lf hom	**pawned**	0	turtle	0.9	0.01	**payment**	1.72	0.31	450
198	lf ctrl	borrow	0.95	turtle	0.9	0.03	payment	1.72	0.45	
199	hf hom	poor	2.05	fine	2.21	0.37	body	2.44	0.09	
199	hf ctrl	**rich**	1.87	fine	2.21	0.37	**body**	2.44	0.08	450
199	lf hom	**pore**	0.30	**fine**	2.21	0.05	body	2.44	0.5	150
199	lf ctrl	sweat	1.36	fine	2.21	0	body	2.44	0.49	
200	hf hom	pop	0.9	burst	1.52	0.32	pity	1.15	0.13	
200	hf ctrl	explode	0.78	burst	1.52	0.38	pity	1.15	0.02	
200	lf hom	pauper	0	burst	1.52	0.09	pity	1.15	0.2	
200	lf ctrl	poverty	0.3	burst	1.52	0.11	pity	1.15	0.22	
201	hf hom	praise	1.23	condemn	0.6	0.21	hawk	1.15	0.07	

201	hf ctrl	glory	1.32	condemn	0.6	0.24	hawk	1.15	0.16	
201	lf hom	prey	0.85	condemn	0.6	0.06	hawk	1.15	0.24	
201	lf ctrl	watch	1.91	condemn	0.6	0.08	hawk	1.15	0.25	
202	hf hom	**pray**	1.08	worship	1.56	0.59	**animal**	1.83	0.02	150
202	hf ctrl	temple	1.58	worship	1.56	0.42	animal	1.83	0.02	
202	lf hom	prey	0.85	worship	1.56	0.05	animal	1.83	0.24	
202	lf ctrl	**predator**	0.00	**worship**	1.56	0.11	animal	1.83	0.32	450
203	hf hom	present	2.58	shop	1.8	0.11	attend	1.73	0.22	
203	hf ctrl	money	2.42	shop	1.8	0.22	attend	1.73	0.16	
203	lf hom	presence	1.88	shop	1.8	0.1	attend	1.73	0.22	
203	lf ctrl	exist	1.77	shop	1.8	0.08	attend	1.73	0.22	
204	hf hom	pride	1.62	patriot	0	0.24	lever	1.15	-0.01	
204	hf ctrl	honor	1.82	patriot	0	0.22	lever	1.15	-0.02	
204	lf hom	pry	0.78	patriot	0	-0.01	lever	1.15	0.32	
204	lf ctrl	effort	2.16	patriot	0	0.11	lever	1.15	0.32	
205	hf hom	prince	1.52	queen	1.61	0.58	copy	1.58	0.03	
205	hf ctrl	palace	1.58	queen	1.61	0.57	copy	1.58	0.04	
205	lf hom	print	1.26	queen	1.61	0.02	copy	1.58	0.53	
205	lf ctrl	photo	0.7	queen	1.61	0.02	copy	1.58	0.38	
206	hf hom	principa	1.96	chief	2.08	0.22	idea	2.29	0.05	
206	hf ctrl	rule	1.86	chief	2.08	0.27	idea	2.29	0.17	
206	lf hom	principl	0	chief	2.08	0.18	idea	2.29	0.27	
206	lf ctrl	basis	2.26	chief	2.08	0.19	idea	2.29	0.23	
207	hf hom	prize	1.45	win	1.74	0.36	difficult	2.21	0.09	
207	hf ctrl	trophy	0.9	win	1.74	0.4	difficult	2.21	0.11	
207	lf hom	pry	0.78	win	1.74	0.04	difficult	2.21	0.2	
207	lf ctrl	inquire	0.78	win	1.74	0	difficult	2.21	0.24	
208	hf hom	pro	1.2	sport	1.23	0.32	translation	1.2	0.02	
208	hf ctrl	amateur	1.4	sport	1.23	0.35	translation	1.2	0.07	
208	lf hom	prose	1.15	sport	1.23	0.05	translation	1.2	0.42	
208	lf ctrl	verse	1.45	sport	1.23	0.04	translation	1.2	0.37	
209	hf hom	profit	1.45	benefit	1.8	0.38	divine	1.53	0.04	
209	hf ctrl	advance	0.78	benefit	1.8	0.41	divine	1.53	0.14	
209	lf hom	prophet	0.7	benefit	1.8	-0.03	divine	1.53	0.45	
209	lf ctrl	muhammad	0	benefit	1.8	-0.01	divine	1.53	0.37	
210	hf hom	quart	0.48	measure	1.96	0.31	rock	1.88	0.02	
210	hf ctrl	ounce	0.48	measure	1.96	0.29	rock	1.88	-0.01	
210	lf hom	quartz	0	measure	1.96	0.01	rock	1.88	0.65	
210	lf ctrl	mineral	1.08	measure	1.96	0.03	rock	1.88	0.47	
211	hf hom	rabbit	1.04	turtle	0.9	0.49	cut	2.28	0.06	
211	hf ctrl	hop	0.3	turtle	0.9	0.55	cut	2.28	0.06	
211	lf hom	rabbet	0	turtle	0.9	-0.03	cut	2.28	0.65	
211	lf ctrl	groove	0.3	turtle	0.9	-0.03	cut	2.28	0.5	
212	hf hom	**rain**	1.85	thunder	1.15	0.55	**whip**	1.28	0.1	450
212	hf ctrl	wind	1.80	thunder	1.15	0.52	whip	1.28	0.14	
212	lf hom	rein	0.48	thunder	1.15	0.06	whip	1.28	0.44	
212	lf ctrl	**ride**	1.69	**thunder**	1.15	0.13	whip	1.28	0.62	150
213	hf hom	raise	1.72	pay	2.24	0.3	sharp	1.86	0.15	
213	hf ctrl	bonus	0.3	pay	2.24	0.5	sharp	1.86	0.02	

213	lf hom	razor	1.18	pay	2.24	0.06	sharp	1.86	0.46	
213	lf ctrl	blade	1.11	pay	2.24	0.02	sharp	1.86	0.51	
214	hf hom	raise	1.72	fall	2.17	0.24	light	2.52	0.05	
214	hf ctrl	**lift**	1.36	fall	2.17	0.22	**light**	2.52	0.08	2000
214	lf hom	**rays**	1.28	**fall**	2.17	0.04	light	2.52	0.3	1350
214	lf ctrl	beam	1.32	fall	2.17	0.09	light	2.52	0.41	
215	hf hom	rapture	0.48	blame	1.53	0.22	knock	1.18	0.19	
215	hf ctrl	strike	0.78	blame	1.53	0.2	knock	1.18	0.12	
215	lf hom	rap	0.3	blame	1.53	0.06	knock	1.18	0.27	
215	lf ctrl	thump	0.48	blame	1.53	0.15	knock	1.18	0.21	
216	hf hom	read	2.24	review	1.75	0.36	instrument	1.67	0.13	
216	hf ctrl	book	2.29	review	1.75	0.32	instrument	1.67	0.06	
216	lf hom	reed	0.7	review	1.75	0.07	instrument	1.67	0.32	
216	lf ctrl	vibrate	0	review	1.75	0	instrument	1.67	0.34	
217	hf hom	ride	1.69	bus	1.53	0.37	canoe	0.85	0.05	
217	hf ctrl	taxi	1.2	bus	1.53	0.45	canoe	0.85	0.06	
217	lf hom	row	1.54	bus	1.53	0.17	canoe	0.85	0.2	
217	lf ctrl	boat	1.86	bus	1.53	0.02	canoe	0.85	0.57	
218	hf hom	right	2.79	perfect	1.76	0.37	ritual	1.4	0.1	
218	hf ctrl	left	1.68	perfect	1.76	0.4	ritual	1.4	0.14	
218	lf hom	rite	0.9	perfect	1.76	0.06	ritual	1.4	0.27	
218	lf ctrl	liturgy	0	perfect	1.76	0.06	ritual	1.4	0.31	
219	hf hom	**ring**	1.67	**alarm**	1.2	0.32	towel	0.78	0.1	1350
219	hf ctrl	phone	1.73	alarm	1.2	0.32	towel	0.78	0.09	
219	lf hom	wring	0.3	alarm	1.2	0.14	towel	0.78	0.3	
219	lf ctrl	**squeeze**	1.04	alarm	1.2	0.15	**towel**	0.78	0.32	2000
220	hf hom	roll	1.54	shake	1.23	0.37	theatre	1.46	0.09	
220	hf ctrl	**jelly**	0.48	**shake**	1.23	0.35	theatre	1.46	-0.03	150
220	lf hom	**role**	2.02	shake	1.23	-0.02	**theatre**	1.46	0.14	450
220	lf ctrl	character	2.07	shake	1.23	0.09	theatre	1.46	0.28	
221	hf hom	**rose**	1.93	love	2.37	0.24	**line**	2.47	0.06	2000
221	hf ctrl	garden	0.78	love	2.37	0.24	line	2.47	0.07	
221	lf hom	row	1.54	love	2.37	0.11	line	2.47	0.25	
221	lf ctrl	**column**	1.85	**love**	2.37	0.02	line	2.47	0.23	1350
222	hf hom	row	1.54	chair	1.82	0.34	female	0.7	0.01	
222	hf ctrl	seat	1.73	chair	1.82	0.33	female	0.7	0.01	
222	lf hom	roe	0	chair	1.82	0.04	female	0.7	0.42	
222	lf ctrl	caviar	0	chair	1.82	0.06	female	0.7	0.33	
223	hf hom	rumor	0	secret	1.89	0.27	lot	2.1	0.07	
223	hf ctrl	gossip	1.11	secret	1.89	0.3	lot	2.1	0.16	
223	lf hom	roomer	0	secret	1.89	0.05	lot	2.1	0.2	
223	lf ctrl	rent	1.32	secret	1.89	0.1	lot	2.1	0.21	
224	hf hom	**sale**	1.64	item	1.73	0.7	**captain**	1.93	0	450
224	hf ctrl	purchase	1.67	item	1.73	0.62	captain	1.93	0.03	
224	lf hom	sail	1.08	item	1.73	0.01	captain	1.93	0.69	
224	lf ctrl	**voyage**	1.23	**item**	1.73	-0.01	captain	1.93	0.54	150
225	hf hom	save	1.79	cost	2.36	0.27	feeling	2.24	0.12	
225	hf ctrl	spend	1.72	cost	2.36	0.27	feeling	2.24	0.16	
225	lf hom	savor	0	cost	2.36	-0.01	feeling	2.24	0.21	

225	lf ctrl	sip	0.3	cost	2.36	0.01	feeling	2.24	0.2	
226	hf hom	saw	2.55	bench	1.54	0.32	tractor	1.38	0.2	
226	hf ctrl	cut	2.28	bench	1.54	0.29	tractor	1.38	0.16	
226	lf hom	sod	0.48	bench	1.54	0.07	tractor	1.38	0.21	
226	lf ctrl	rake	1.04	bench	1.54	0.17	tractor	1.38	0.26	
227	hf hom	sea	1.98	deep	0	0.34	escape	1.81	0.19	
227	hf ctrl	ocean	1.53	deep	0	0.46	escape	1.81	0.05	
227	lf hom	seize	0.78	deep	0	0.1	escape	1.81	0.29	
227	lf ctrl	capture	1.23	deep	0	0.15	escape	1.81	0.37	
228	hf hom	**see**	2.89	**glance**	0.6	0.41	harbor	1.57	0.17	2000
228	hf ctrl	look	2.6	glance	0.6	0.39	harbor	1.57	0.11	
228	lf hom	sea	1.98	glance	0.6	0.04	harbor	1.57	0.45	
228	lf ctrl	**boat**	1.86	glance	0.6	0.11	**harbor**	1.57	0.42	1350
229	hf hom	seed	1.61	tiny	0.7	0.2	victory	1.79	0.01	
229	hf ctrl	flower	1.36	tiny	0.7	0.25	victory	1.79	0.01	
229	lf hom	cede	0	tiny	0.7	0.04	victory	1.79	0.2	
229	lf ctrl	admit	1.57	tiny	0.7	0.09	victory	1.79	0.21	
230	hf hom	seed	1.61	tiny	0.7	0.2	shrub	0	0.11	
230	hf ctrl	flower	1.36	tiny	0.7	0.25	shrub	0	0.06	
230	lf hom	cedar	0	tiny	0.7	0.13	shrub	0	0.33	
230	lf ctrl	tree	1.77	tiny	0.7	0.13	shrub	0	0.39	
231	hf hom	seen	2.45	reflect	1.4	0.28	photo	0.7	0.2	
231	hf ctrl	view	2.27	reflect	1.4	0.32	photo	0.7	0.08	
231	lf hom	scene	0	reflect	1.4	0.11	photo	0.7	0.25	
231	lf ctrl	picture	2.21	reflect	1.4	0.1	photo	0.7	0.44	
232	hf hom	sell	1.61	pay	2.24	0.36	window	2.08	0.08	
232	hf ctrl	credit	1.81	pay	2.24	0.24	window	2.08	0.02	
232	lf hom	cellar	1.41	pay	2.24	0.05	window	2.08	0.56	
232	lf ctrl	basement	1.49	pay	2.24	0.08	window	2.08	0.52	
233	hf hom	sense	2.49	meaning	2.1	0.34	official	1.88	0.13	
233	hf ctrl	perceive	1.11	meaning	2.1	0.32	official	1.88	0.13	
233	lf hom	censor	0	meaning	2.1	0.17	official	1.88	0.21	
233	lf ctrl	supervise	0.7	meaning	2.1	0.03	official	1.88	0.23	
234	hf hom	sense	2.49	tongue	1.54	0.4	registration	1.36	0.04	
234	hf ctrl	touch	1.94	tongue	1.54	0.43	registration	1.36	0	
234	lf hom	census	1.04	tongue	1.54	0.02	registration	1.36	0.21	
234	lf ctrl	estate	1.71	tongue	1.54	0.03	registration	1.36	0.25	
235	hf hom	sense	2.49	taste	1.77	0.61	dollar	1.66	0.07	
235	hf ctrl	touch	1.94	taste	1.77	0.7	dollar	1.66	0.1	
235	lf hom	cent	2.2	taste	1.77	0.05	dollar	1.66	0.37	
235	lf ctrl	money	2.42	taste	1.77	0.02	dollar	1.66	0.65	
236	hf hom	session	0.9	assembly	0.7	0.37	territory	1.49	0.11	
236	hf ctrl	meeting	2.2	assembly	0.7	0.39	territory	1.49	0.13	
236	lf hom	cession	0	assembly	0.7	-0.01	territory	1.49	0.54	
236	lf ctrl	treaty	0.3	assembly	0.7	0.19	territory	1.49	0.59	
237	hf hom	sew	0.78	fabric	1.18	0.27	grain	1.43	0.12	
237	hf ctrl	**hem**	0.60	fabric	1.18	0.3	**grain**	1.43	0.07	450
237	lf hom	**sow**	0.48	**fabric**	1.18	0.15	grain	1.43	0.2	150
237	lf ctrl	hog	0.48	fabric	1.18	0.16	grain	1.43	0.22	

238	hf hom	**shoot**	1.43	fox	1.11	0.2	**slope**	1.28	0.14	1350
238	hf ctrl	kill	1.8	fox	1.11	0.29	slope	1.28	0.06	
238	lf hom	chute	0.3	fox	1.11	0.05	slope	1.28	0.2	
238	lf ctrl	**descend**	0.6	**fox**	1.11	0.11	slope	1.28	0.2	2000
239	hf hom	side	1.58	bottom	1.94	0.37	secret	1.89	0.14	
239	hf ctrl	line	2.47	bottom	1.94	0.22	secret	1.89	0.05	
239	lf hom	sigh	1.04	bottom	1.94	0.13	secret	1.89	0.27	
239	lf ctrl	grin	1.11	bottom	1.94	0.1	secret	1.89	0.26	
240	hf hom	sight	1.93	perceive	1.11	0.35	construct	1.08	0.13	
240	hf ctrl	touch	1.94	perceive	1.11	0.35	construct	1.08	0.07	
240	lf hom	site	1.81	perceive	1.11	0.11	construct	1.08	0.46	
240	lf ctrl	location	1.8	perceive	1.11	0.15	construct	1.08	0.4	
241	hf hom	**sign**	1.97	notice	1.77	0.22	**tangent**	1.41	0.08	150
241	hf ctrl	stop	1.08	notice	1.77	0.27	tangent	1.41	0.05	
241	lf hom	sine	0.6	notice	1.77	0.09	tangent	1.41	0.31	
241	lf ctrl	**geometry**	0.95	**notice**	1.77	0.11	tangent	1.41	0.38	450
242	hf hom	size	2.14	portion	1.79	0.33	relief	1.82	0.1	
242	hf ctrl	length	2.06	portion	1.79	0.34	relief	1.82	0.13	
242	lf hom	sigh	1.04	portion	1.79	0.05	relief	1.82	0.36	
242	lf ctrl	grin	1.11	portion	1.79	0.03	relief	1.82	0.31	
243	hf hom	skull	0.48	bone	1.52	0.66	stern	1.36	0.07	
243	hf ctrl	spine	0.78	bone	1.52	0.63	stern	1.36	0.05	
243	lf hom	scull	0	bone	1.52	-0.01	stern	1.36	0.63	
243	lf ctrl	paddle	0	bone	1.52	0.03	stern	1.36	0.54	
244	hf hom	so	3.3	anyway	1.66	0.58	yarn	1.15	0.19	
244	hf ctrl	what	1.28	anyway	1.66	0.51	yarn	1.15	0.16	
244	lf hom	sew	0.78	anyway	1.66	0.15	yarn	1.15	0.43	
244	lf ctrl	fabric	1.18	anyway	1.66	0.08	yarn	1.15	0.52	
245	hf hom	some	3.21	trace	1.36	0.39	net	1.53	0.1	
245	hf ctrl	most	2.06	trace	1.36	0.32	net	1.53	0.09	
245	lf hom	sum	1.65	trace	1.36	0.1	net	1.53	0.26	
245	lf ctrl	equal	0.95	trace	1.36	0.07	net	1.53	0.25	
246	hf hom	son	2.22	brother	1.86	0.41	heat	1.99	0.03	
246	hf ctrl	mother	2.33	brother	1.86	0.41	heat	1.99	0.03	
246	lf hom	sun	2.05	brother	1.86	0.08	heat	1.99	0.33	
246	lf ctrl	energy	2	brother	1.86	0	heat	1.99	0.47	
247	hf hom	**sore**	0	hurt	1.57	0.42	**fly**	1.52	0.04	1350
247	hf ctrl	ache	0.6	hurt	1.57	0.47	fly	1.52	0.05	
247	lf hom	soar	0	hurt	1.57	0.06	fly	1.52	0.54	
247	lf ctrl	**glide**	0.3	**hurt**	1.57	0.19	fly	1.52	0.58	2000
248	hf hom	sorry	1.68	fault	1.34	0.24	silk	1.08	0.1	
248	hf ctrl	mistake	1.53	fault	1.34	0.27	silk	1.08	0.1	
248	lf hom	sari	0	fault	1.34	-0.01	silk	1.08	0.24	
248	lf ctrl	adorn	0	fault	1.34	-0.04	silk	1.08	0.22	
249	hf hom	**soul**	1.67	brother	1.86	0.21	**foot**	1.85	0.09	2000
249	hf ctrl	heaven	1.63	brother	1.86	0.22	foot	1.85	0.14	
249	lf hom	sole	1.26	brother	1.86	0.06	foot	1.85	0.35	
249	lf ctrl	**sock**	0.60	**brother**	1.86	0.09	foot	1.85	0.24	1350
250	hf hom	spectacle	1.26	vision	1.75	0.3	bit	0	0.18	

250	hf ctrl	lens	1.08	vision	1.75	0.36	bit	0	0.04	
250	lf hom	speck	0.85	vision	1.75	0.16	bit	0	0.26	
250	lf ctrl	dash	1.04	vision	1.75	0.14	bit	0	0.26	
251	hf hom	spore	0	plant	2.1	0.26	animal	1.83	0.04	
251	hf ctrl	algae	0.85	plant	2.1	0.2	animal	1.83	0.11	
251	lf hom	spoor	0	plant	2.1	0.05	animal	1.83	0.26	
251	lf ctrl	hunt	0	plant	2.1	0.08	animal	1.83	0.39	
252	hf hom	**stake**	1.30	claim	1.99	0.36	**pepper**	1.11	0.03	2000
252	hf ctrl	condemn	0.60	claim	1.99	0.38	pepper	1.11	0.02	
252	lf hom	steak	1.00	claim	1.99	0.07	pepper	1.11	0.38	
252	lf ctrl	**beef**	1.51	**claim**	1.99	0.06	pepper	1.11	0.16	1350
253	hf hom	stare	1.15	blank	1.15	0.27	basement	1.49	0.05	
253	hf ctrl	**glance**	1.60	blank	1.15	0.26	**basement**	1.49	0.1	1350
253	lf hom	**stair**	0.30	**blank**	1.15	0.07	basement	1.49	0.37	2000
253	lf ctrl	rail	1.20	blank	1.15	0.05	basement	1.49	0.38	
254	hf hom	stationery	0.3	pen	1.26	0.33	fixed	1.94	0.06	
254	hf ctrl	envelope	1.32	pen	1.26	0.32	fixed	1.94	0.06	
254	lf hom	stationary	0.3	pen	1.26	0.03	fixed	1.94	0.28	
254	lf ctrl	stable	0.48	pen	1.26	0.11	fixed	1.94	0.21	
255	hf hom	**steel**	1.65	**concrete**	1.68	0.28	crime	1.53	-0.02	2000
255	hf ctrl	stone	1.76	concrete	1.68	0.28	crime	1.53	0.04	
255	lf hom	steal	0.7	concrete	1.68	0.02	crime	1.53	0.36	
255	lf ctrl	**fraud**	0.9	concrete	1.68	-0.02	**crime**	1.53	0.3	1350
256	hf hom	step	2.12	skip	0.7	0.28	prairie	1.32	0.03	
256	hf ctrl	walk	2	skip	0.7	0.3	prairie	1.32	0.11	
256	lf hom	steppe	0	skip	0.7	0.02	prairie	1.32	0.25	
256	lf ctrl	frontier	0.48	skip	0.7	0.02	prairie	1.32	0.23	
257	hf hom	stock	2.17	bond	1.66	0.21	celery	0.6	0.03	
257	hf ctrl	share	1.99	bond	1.66	0.23	celery	0.6	0.04	
257	lf hom	stalk	0	bond	1.66	0.01	celery	0.6	0.39	
257	lf ctrl	bean	0.7	bond	1.66	0.01	celery	0.6	0.35	
258	hf hom	sucker	0	baby	1.79	0.26	comfort	1.63	0.08	
258	hf ctrl	candy	1.2	baby	1.79	0.22	comfort	1.63	0.13	
258	lf hom	succor	0	baby	1.79	-0.04	comfort	1.63	0.24	
258	lf ctrl	assist	1.41	baby	1.79	0.04	comfort	1.63	0.33	
259	hf hom	suite	1.43	apartment	1.91	0.35	taste	1.77	0.08	
259	hf ctrl	furnitur	1.59	apartment	1.91	0.34	taste	1.77	0.12	
259	lf hom	sweet	0.85	apartment	1.91	0.07	taste	1.77	0.54	
259	lf ctrl	bitter	1.72	apartment	1.91	0.05	taste	1.77	0.38	
260	hf hom	suite	1.43	apartment	1.91	0.35	bitter	1.72	0.13	
260	hf ctrl	**lounge**	0.95	apartment	1.91	0.28	**bitter**	1.72	0.14	150
260	lf hom	**sweet**	1.85	**apartment**	1.91	0.15	bitter	1.72	0.44	450
260	lf ctrl	taste	1.77	apartment	1.91	0.14	bitter	1.72	0.32	
261	hf hom	summer	2.13	camp	1.88	0.32	analysis	0	0	
261	hf ctrl	spring	2.1	camp	1.88	0.28	analysis	0	0.03	
261	lf hom	summary	1.32	camp	1.88	0.01	analysis	0	0.31	
261	lf ctrl	outline	1.08	camp	1.88	0.07	analysis	0	0.27	
262	hf hom	surf	0	ocean	1.53	0.25	master	1.86	0.02	
262	hf ctrl	swim	1.18	ocean	1.53	0.32	master	1.86	0.05	

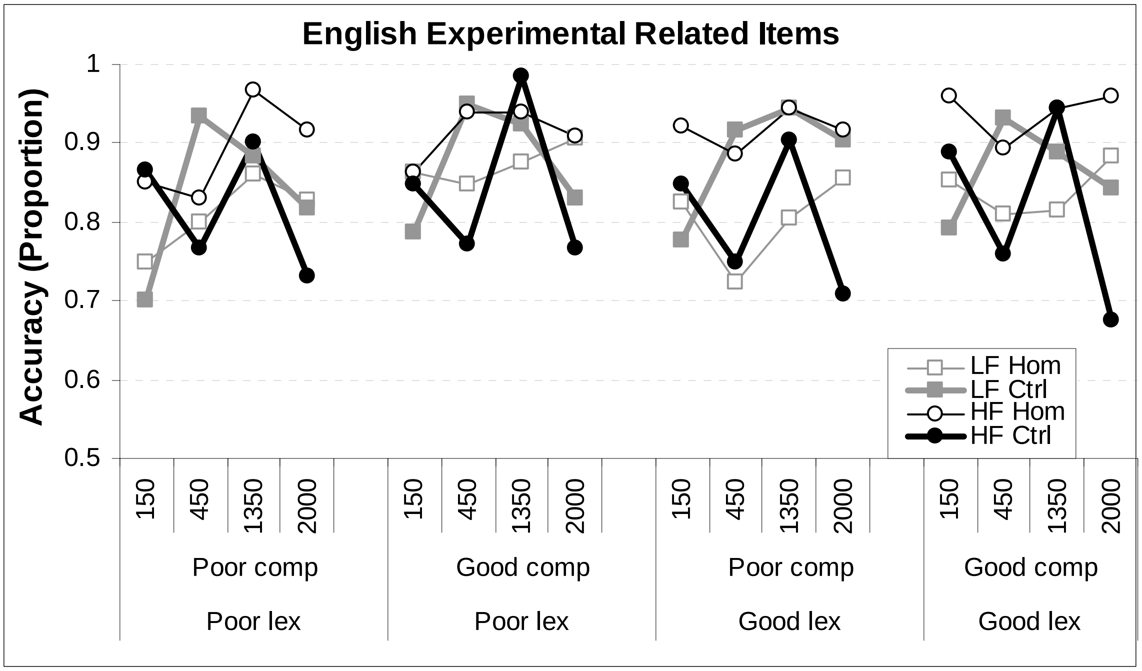
262	lf hom	serf	0	ocean	1.53	0	master	1.86	0.31	
262	lf ctrl	prisoner	0.85	ocean	1.53	0.02	master	1.86	0.33	
263	hf hom	sway	0.7	vote	1.88	0.21	boot	1.11	0.09	
263	hf ctrl	decision	2.08	vote	1.88	0.22	boot	1.11	0.08	
263	lf hom	suede	0	vote	1.88	0.03	boot	1.11	0.24	
263	lf ctrl	velvet	0.6	vote	1.88	0.01	boot	1.11	0.28	
264	hf hom	sword	0.85	knife	1.88	0.23	sky	1.76	0.17	
264	hf ctrl	spike	0.3	knife	1.88	0.31	sky	1.76	0.06	
264	lf hom	soared	0	knife	1.88	0.13	sky	1.76	0.32	
264	lf ctrl	eagle	0.7	knife	1.88	0.16	sky	1.76	0.33	
265	hf hom	tail	1.38	watch	1.91	0.27	suit	1.68	0.07	
265	hf ctrl	observe	1.4	watch	1.91	0.31	suit	1.68	0.1	
265	lf hom	tailor	0.3	watch	1.91	0.09	suit	1.68	0.27	
265	lf ctrl	hem	0.6	watch	1.91	0.2	suit	1.68	0.3	
266	hf hom	**tail**	1.38	**paw**	0.48	0.52	legend	1.41	0.07	1350
266	hf ctrl	cat	1.36	paw	0.48	0.42	legend	1.41	0.04	
266	lf hom	tale	1.32	paw	0.48	0.07	legend	1.41	0.32	
266	lf ctrl	**fable**	0.30	paw	0.48	0.09	**legend**	1.41	0.38	2000
267	hf hom	**taut**	0.90	**grip**	1.30	0.45	lesson	1.46	0.07	150
267	hf ctrl	tight	1.45	grip	1.30	0.56	lesson	1.46	0.13	
267	lf hom	taught	1.70	grip	1.30	0.03	lesson	1.46	0.33	
267	lf ctrl	**explain**	1.81	grip	1.30	0.06	**lesson**	1.46	0.37	450
268	hf hom	tax	2.29	luxury	1.32	0.23	tie	1.36	0	
268	hf ctrl	**income**	2.04	**luxury**	1.32	0.25	tie	1.36	0	150
268	lf hom	**tacks**	0.60	luxury	1.32	0.12	**tie**	1.36	0.35	450
268	lf ctrl	thumb	1.00	luxury	1.32	0.01	tie	1.36	0.27	
269	hf hom	tea	1.45	kettle	0.48	0.44	cry	1.68	0.17	
269	hf ctrl	cup	1.65	kettle	0.48	0.48	cry	1.68	0.14	
269	lf hom	tease	0.78	kettle	0.48	0.04	cry	1.68	0.28	
269	lf ctrl	rag	0	kettle	0.48	0.14	cry	1.68	0.32	
270	hf hom	tea	1.45	drink	1.91	0.25	ball	1.04	0.05	
270	hf ctrl	lemon	1.26	drink	1.91	0.23	ball	1.04	0.02	
270	lf hom	tee	0.7	drink	1.91	0.09	ball	1.04	0.2	
270	lf ctrl	swing	1.38	drink	1.91	0.06	ball	1.04	0.34	
271	hf hom	ten	2.22	worth	1.97	0.41	opera	1.67	0.06	
271	hf ctrl	coin	0	worth	1.97	0.53	opera	1.67	-0.02	
271	lf hom	tenor	0.78	worth	1.97	0.07	opera	1.67	0.57	
271	lf ctrl	sing	1.53	worth	1.97	0.07	opera	1.67	0.6	
272	hf hom	tense	1.18	relax	1.28	0.2	hut	1.11	0.04	
272	hf ctrl	nervous	1.38	relax	1.28	0.21	hut	1.11	0.03	
272	lf hom	tent	0.3	relax	1.28	0.08	hut	1.11	0.32	
272	lf ctrl	camp	1.88	relax	1.28	0.08	hut	1.11	0.39	
273	hf hom	throne	0.70	worship	1.56	0.25	drop	1.77	0.02	
273	hf ctrl	**crown**	1.28	**worship**	1.56	0.21	drop	1.77	0.08	450
273	lf hom	**thrown**	1.60	worship	1.56	0.15	**drop**	1.77	0.36	150
273	lf ctrl	toss	0.95	worship	1.56	0.38	drop	1.77	0.22	
275	hf hom	tie	1.36	neck	1.91	0.38	bay	1.76	0.03	
275	hf ctrl	shirt	1.43	neck	1.91	0.46	bay	1.76	0.05	
275	lf hom	tide	1.04	neck	1.91	0.09	bay	1.76	0.31	

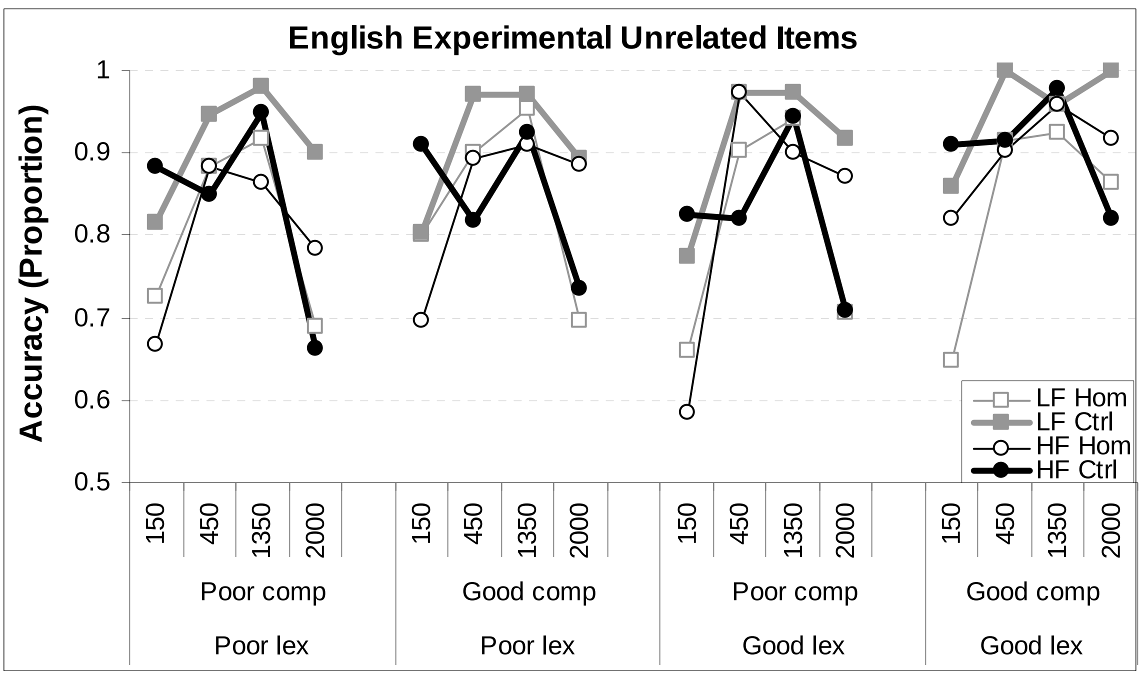
275	lf ctrl	ocean	1.53	neck	1.91	0.04	bay	1.76	0.31	
276	hf hom	time	3.2	spare	1.36	0.5	flavor	0	0.14	
276	hf ctrl	long	2.88	spare	1.36	0.44	flavor	0	0.13	
276	lf hom	thyme	0	spare	1.36	0.12	flavor	0	0.41	
276	lf ctrl	cook	1.67	spare	1.36	0.19	flavor	0	0.44	
277	hf hom	toad	0.6	jump	1.38	0.39	truck	1.76	-0.05	
277	hf ctrl	pond	1.4	jump	1.38	0.35	truck	1.76	0.11	
277	lf hom	tow	0	jump	1.38	0.14	truck	1.76	0.46	
277	lf ctrl	tractor	1.38	jump	1.38	0.08	truck	1.76	0.43	
278	hf hom	told	2.62	secret	1.89	0.43	pay	2.24	0.12	
278	hf ctrl	admit	1.57	secret	1.89	0.43	pay	2.24	0.14	
278	lf hom	toll	1.2	secret	1.89	0.13	pay	2.24	0.3	
278	lf ctrl	levy	0.85	secret	1.89	0.12	pay	2.24	0.41	
279	hf hom	trust	1.72	promise	1.65	0.38	crowd	1.72	0.17	
279	hf ctrl	honest	1.67	promise	1.65	0.31	crowd	1.72	0.2	
279	lf hom	trussed	0	promise	1.65	0.08	crowd	1.72	0.2	
279	lf ctrl	gather	0.3	promise	1.65	0.16	crowd	1.72	0.24	
280	hf hom	turn	2.37	twist	1.26	0.35	wing	1.26	0.17	
280	hf ctrl	move	2.23	twist	1.26	0.34	wing	1.26	0.14	
280	lf hom	tern	0	twist	1.26	0.06	wing	1.26	0.38	
280	lf ctrl	marsh	0.6	twist	1.26	0.13	wing	1.26	0.36	
281	hf hom	use	2.77	seldom	1.53	0.29	graze	0	0.09	
281	hf ctrl	purpose	2.17	seldom	1.53	0.32	graze	0	0.03	
281	lf hom	ewes	0	seldom	1.53	0.14	graze	0	0.4	
281	lf ctrl	wool	0	seldom	1.53	0.11	graze	0	0.34	
282	hf hom	vain	0	pride	1.62	0.46	weather	1.84	0.08	
282	hf ctrl	confident	1.2	pride	1.62	0.4	weather	1.84	0	
282	lf hom	vane	0	pride	1.62	0.06	weather	1.84	0.4	
282	lf ctrl	wind	1.8	pride	1.62	0.12	weather	1.84	0.46	
283	hf hom	veil	0.9	funeral	1.52	0.26	valley	1.86	0.11	
283	hf ctrl	disguise	0.7	funeral	1.52	0.24	valley	1.86	0.04	
283	lf hom	vale	0.6	funeral	1.52	0.13	valley	1.86	0.23	
283	lf ctrl	meadow	1.23	funeral	1.52	0.06	valley	1.86	0.34	
284	hf hom	vile	0.7	hell	1.98	0.4	doctor	2	-0.02	
284	hf ctrl	nasty	0.7	hell	1.98	0.41	doctor	2	0.14	
284	lf hom	vial	0	hell	1.98	0.19	doctor	2	0.31	
284	lf ctrl	drug	1.38	hell	1.98	0	doctor	2	0.22	
285	hf hom	**wail**	0.48	**weep**	1.15	0.44	mammal	0	0.05	150
285	hf ctrl	grief	0	weep	1.15	0.51	mammal	0	-0.01	
285	lf hom	whale	0	weep	1.15	-0.01	mammal	0	0.52	
285	lf ctrl	**blubber**	0	weep	1.15	0.03	**mammal**	0	0.53	450
286	hf hom	wait	1.97	usual	1.98	0.44	gain	1.87	0.09	
286	hf ctrl	**stay**	2.05	usual	1.98	0.3	**gain**	1.87	0.15	2000
286	lf hom	**weight**	1.96	**usual**	1.98	0.09	gain	1.87	0.42	1350
286	lf ctrl	heavy	2.04	usual	1.98	0.03	gain	1.87	0.28	
287	hf hom	war	2.67	weapon	1.62	0.27	uniform	1.71	0.12	
287	hf ctrl	death	2.44	weapon	1.62	0.31	uniform	1.71	0.05	
287	lf hom	wore	1.81	weapon	1.62	0.13	uniform	1.71	0.35	
287	lf ctrl	dress	1.83	weapon	1.62	0.02	uniform	1.71	0.32	

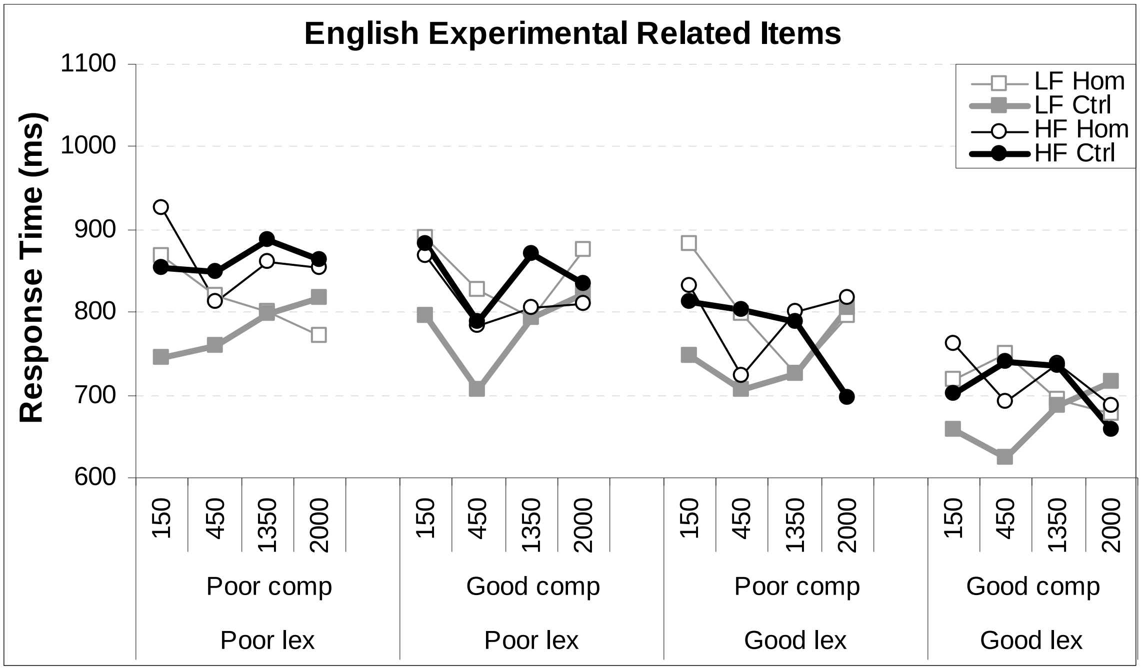
288	hf hom	**waste**	1.54	**hazard**	1.08	0.32	belt	1.46	0.09	150
288	hf ctrl	pollution	0.78	hazard	1.08	0.4	belt	1.46	0.01	
288	lf hom	waist	1.04	hazard	1.08	0.09	belt	1.46	0.39	
288	lf ctrl	**pants**	0.95	hazard	1.08	0.06	**belt**	1.46	0.38	450
289	hf hom	wave	1.66	tide	1.04	0.34	void	0	0.02	
289	hf ctrl	ripple	0.7	tide	1.04	0.25	void	0	0.08	
289	lf hom	waive	0	tide	1.04	-0.01	void	0	0.26	
289	lf ctrl	deny	1.67	tide	1.04	0.03	void	0	0.28	
290	hf hom	wax	1.15	melt	0.6	0.29	slam	0.48	0.05	
290	hf ctrl	burn	1.18	melt	0.6	0.26	slam	0.48	0.07	
290	lf hom	whack	0	melt	0.6	-0.02	slam	0.48	0.21	
290	lf ctrl	slap	0.3	melt	0.6	0.01	slam	0.48	0.23	
291	hf hom	**way**	2.96	**sidewalk**	0.00	0.36	ounce	0.48	0.13	450
291	hf ctrl	under	2.85	sidewalk	0.00	0.2	ounce	0.48	0.09	
291	lf hom	weigh	0.60	sidewalk	0.00	0.17	ounce	0.48	0.29	
291	lf ctrl	**obese**	0.00	sidewalk	0.00	0.06	**ounce**	0.48	0.29	150
292	hf hom	week	2.44	end	1.61	0.3	faint	1.4	0.16	
292	hf ctrl	**month**	1.11	**end**	1.61	0.35	faint	1.4	0.09	2000
292	lf hom	**weak**	1.51	end	1.61	0.19	**faint**	1.4	0.22	1350
292	lf ctrl	courage	1.51	end	1.61	0.15	faint	1.4	0.22	
293	hf hom	weigh	0.6	size	2.14	0.41	water	2.65	0.17	
293	hf ctrl	pound	1.45	size	2.14	0.29	water	2.65	0.09	
293	lf hom	wade	0.3	size	2.14	0.03	water	2.65	0.23	
293	lf ctrl	plunge	0.7	size	2.14	0.1	water	2.65	0.27	
294	hf hom	well	2.95	rise	0	0.23	fuse	0.7	0.06	
294	hf ctrl	surface	2.3	rise	0	0.22	fuse	0.7	0.05	
294	lf hom	weld	0.6	rise	0	0.03	fuse	0.7	0.29	
294	lf ctrl	torch	0.3	rise	0	0.11	fuse	0.7	0.27	
295	hf hom	whether	2.46	vague	1.4	0.46	storm	1.41	0.05	
295	hf ctrl	doubt	2.06	vague	1.4	0.53	storm	1.41	0.1	
295	lf hom	weather	1.84	vague	1.4	0.02	storm	1.41	0.6	
295	lf ctrl	rain	0.85	vague	1.4	0.1	storm	1.41	0.56	
296	hf hom	which	3.55	magazine	1.59	0.22	wart	1.04	0.13	
296	hf ctrl	who	3.35	magazine	1.59	0.25	wart	1.04	0.13	
296	lf hom	witch	0.7	magazine	1.59	0.08	wart	1.04	0.23	
296	lf ctrl	wicked	0.95	magazine	1.59	0.03	wart	1.04	0.24	
297	hf hom	whole	2.49	slice	1.11	0.23	plug	1.36	0.06	
297	hf ctrl	**half**	2.44	**slice**	1.11	0.29	plug	1.36	0.07	1350
297	lf hom	**hole**	1.76	slice	1.11	0	**plug**	1.36	0	2000
297	lf ctrl	drill	1.52	slice	1.11	0	plug	1.36	0	
298	hf hom	**wine**	1.86	**barrel**	1.38	0.22	utter	1.11	0.14	2000
298	hf ctrl	bottle	1.88	barrel	1.38	0.32	utter	1.11	0.09	
298	lf hom	whine	0.6	barrel	1.38	0.17	utter	1.11	0.22	
298	lf ctrl	**complain**	1.04	barrel	1.38	0.11	**utter**	1.11	0.29	1350
299	hf hom	wit	0.3	intelligent	1.41	0.34	bit	0	0.17	
299	hf ctrl	brain	1.65	intelligent	1.41	0.2	bit	0	0.05	
299	lf hom	whit	0	intelligent	1.41	0.02	bit	0	0.25	
299	lf ctrl	shred	0.48	intelligent	1.41	0.09	bit	0	0.23	
300	hf hom	word	2.44	clue	1.18	0.47	spin	0.7	0.06	
300	hf ctrl	tell	2.43	clue	1.18	0.35	spin	0.7	0.16	
300	lf hom	whir	0.48	clue	1.18	0.02	spin	0.7	0.38	

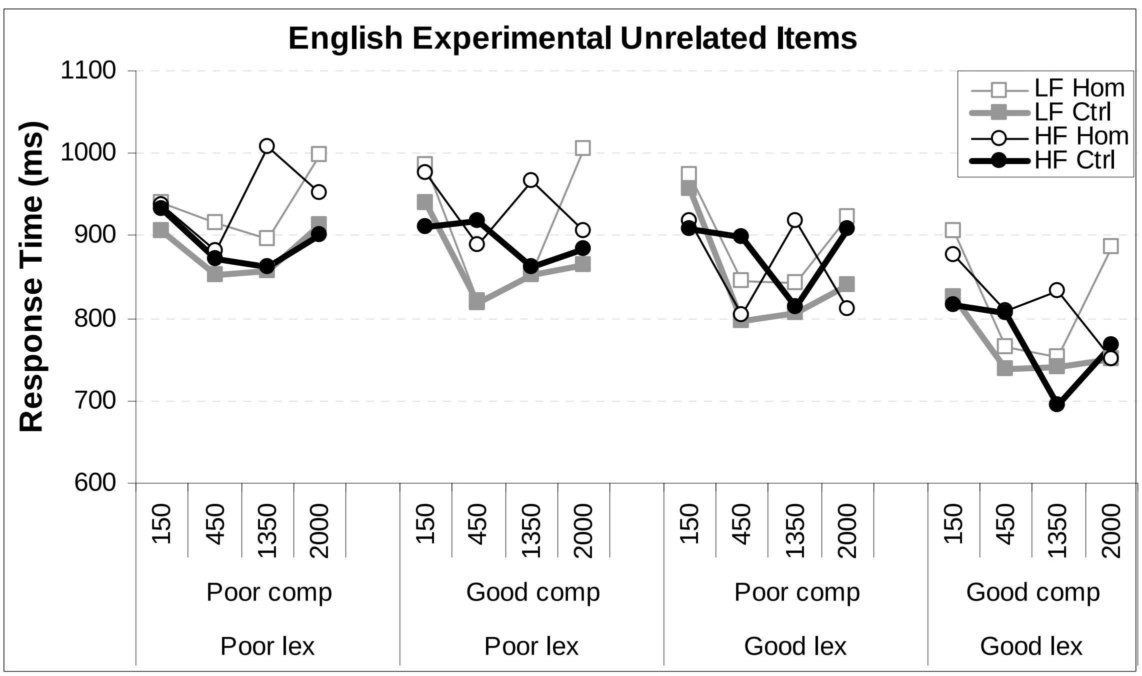
300	lf ctrl	revolve	0	clue	1.18	0.03	spin	0.7	0.29	
301	hf hom	world	2.9	nation	2.14	0.38	pool	2.05	0.1	
301	hf ctrl	people	2.93	nation	2.14	0.38	pool	2.05	0.16	
301	lf hom	whirled	0	nation	2.14	-0.02	pool	2.05	0.24	
301	lf ctrl	dizzy	0.7	nation	2.14	0.01	pool	2.05	0.29	
302	hf hom	worn	1.36	cloth	1.63	0.34	traffic	1.83	0.08	
302	hf ctrl	shirt	1.43	cloth	1.63	0.37	traffic	1.83	0.05	
302	lf hom	warn	1.04	cloth	1.63	0.05	traffic	1.83	0.34	
302	lf ctrl	halt	0	cloth	1.63	0.06	traffic	1.83	0.34	
303	hf hom	would	3.43	need	1.56	0.31	fireplace	0.78	0.18	
303	hf ctrl	will	3.35	need	1.56	0.43	fireplace	0.78	0.08	
303	lf hom	wood	1.74	need	1.56	0.11	fireplace	0.78	0.4	
303	lf ctrl	cabin	1.36	need	1.56	0.09	fireplace	0.78	0.4	
304	hf hom	wrap	0.7	package	0.3	0.33	knock	1.18	0.2	
304	hf ctrl	plastic	1.49	package	0.3	0.26	knock	1.18	0.16	
304	lf hom	rap	0.3	package	0.3	0.13	knock	1.18	0.27	
304	lf ctrl	bum	0.85	package	0.3	0.04	knock	1.18	0.23	
305	hf hom	wrapper	0.3	paper	2.2	0.26	prison	1.62	0.01	
305	hf ctrl	package	0.3	paper	2.2	0.24	prison	1.62	0.1	
305	lf hom	rap	0.3	paper	2.2	0.04	prison	1.62	0.23	
305	lf ctrl	punish	0.48	paper	2.2	0.03	prison	1.62	0.31	
306	hf hom	wrote	2.26	pen	1.26	0.35	comprehend	0.7	0.06	
306	hf ctrl	letter	2.16	pen	1.26	0.4	comprehend	0.7	0.05	
306	lf hom	rote	0	pen	1.26	0.01	comprehend	0.7	0.24	
306	lf ctrl	repeat	1.41	pen	1.26	0.14	comprehend	0.7	0.22	
307	hf hom	yawn	0.3	fatigue	1.04	0.28	retreat	1.15	0.09	
307	hf ctrl	drowsy	0	fatigue	1.04	0.29	retreat	1.15	0.15	
307	lf hom	yon	0	fatigue	1.04	0.06	retreat	1.15	0.26	
307	lf ctrl	yonder	0	fatigue	1.04	0.06	retreat	1.15	0.19	
308	hf hom	add	1.94	math	0.6	0.21	slogan	0.85	0.19	
308	hf ctrl	plus	1.86	math	0.6	0.2	slogan	0.85	0.09	
308	lf hom	ad	1.04	math	0.6	0.04	slogan	0.85	0.27	
308	lf ctrl	announce	1.26	math	0.6	-0.02	slogan	0.85	0.32	
309	hf hom	you	3.52	blame	1.53	0.41	sheep	1.36	0.11	
309	hf ctrl	who	3.35	blame	1.53	0.48	sheep	1.36	0.18	
309	lf hom	ewe	0	blame	1.53	0.15	sheep	1.36	0.48	
309	lf ctrl	pasture	1.15	blame	1.53	0.04	sheep	1.36	0.53	
310	hf hom	**course**	2.67	lecture	1.20	0.35	**sand**	1.45	0.08	2000
310	hf ctrl	school	2.69	lecture	1.20	0.22	sand	1.45	0.03	
310	lf hom	coarse	1.00	lecture	1.20	0.02	sand	1.45	0.39	
310	lf ctrl	**cement**	1.04	**lecture**	1.20	0.06	sand	1.45	0.23	1350
311	hf hom	**dawn**	1.45	**awaken**	0.85	0.42	glove	0.95	0.02	150
311	hf ctrl	sunrise	1.00	awaken	0.85	0.26	glove	0.95	0.05	
311	lf hom	don	1.36	awaken	0.85	0.08	glove	0.95	0.39	
311	lf ctrl	**trousers**	0.85	awaken	0.85	0.07	**glove**	0.95	0.32	450

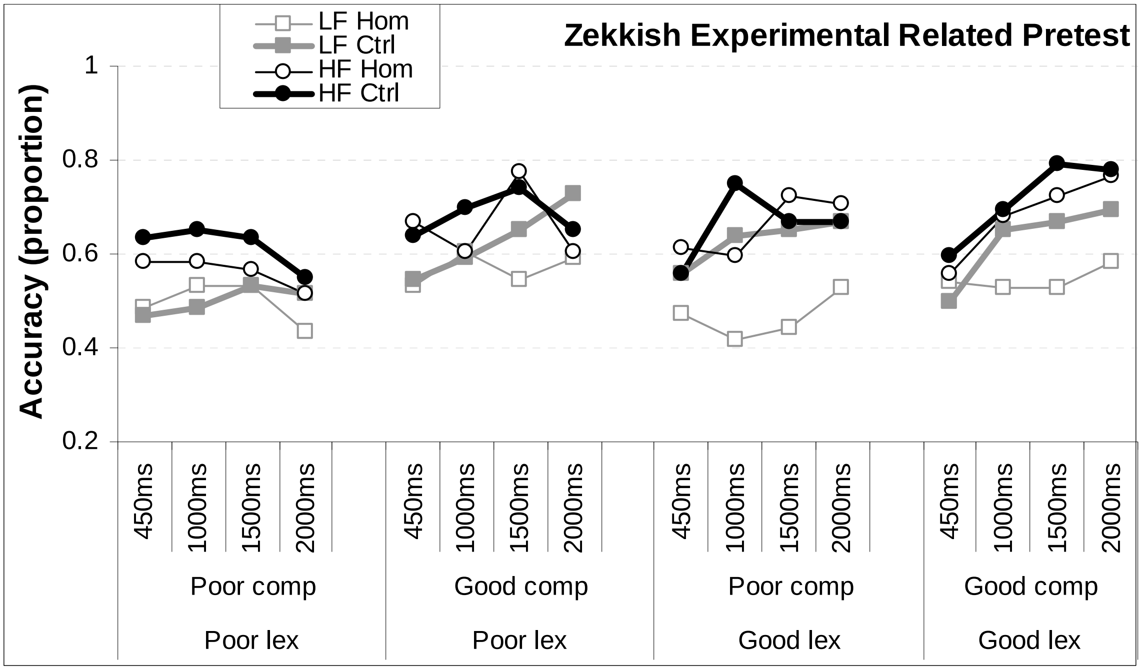
APPENDIX K: Homophone (Gernsbacher) Task Interactions

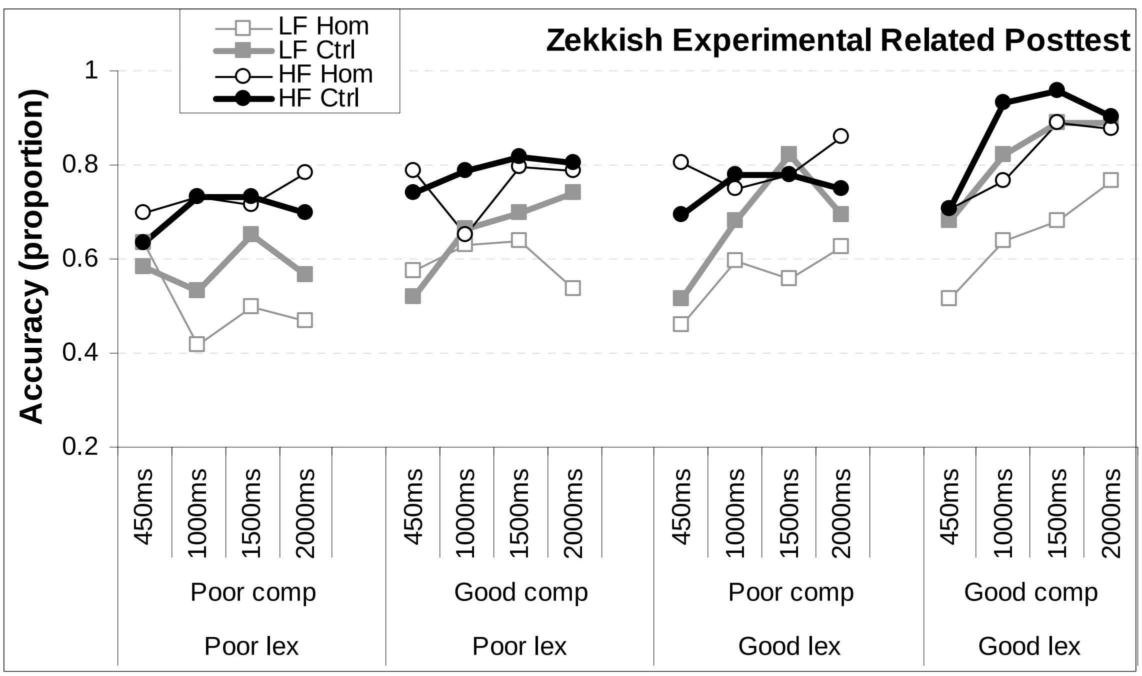


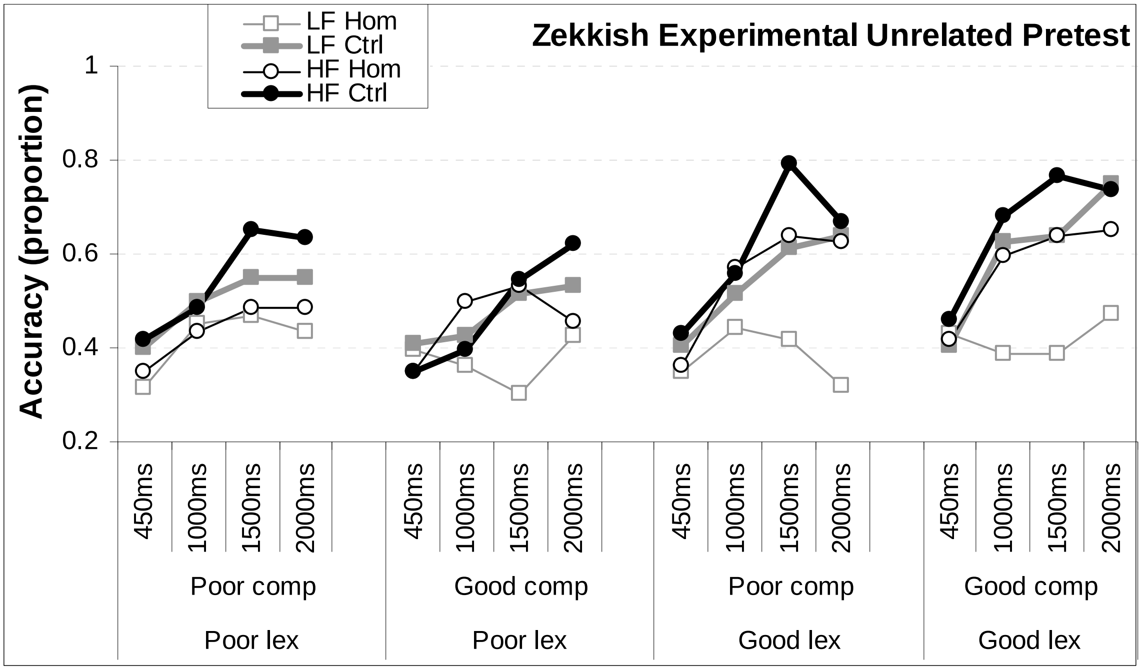



English Experimental Related Items
Response Time (ms)
1100
1000
900
800
700
600
LF Hom
LF Ctrl
HF Hom
HF Ctrl
150
450
1350
2000
Poor comp
Poor lex
Good comp
Poor lex
Poor comp
Good lex
Good comp
Good lex

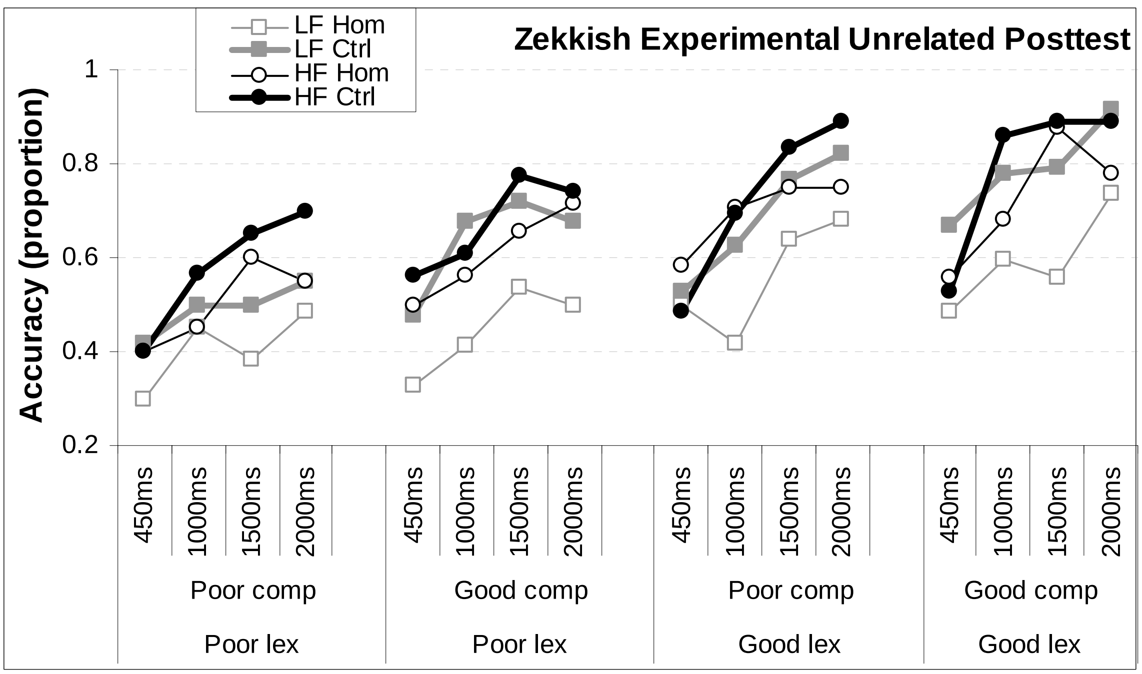

English Experimental Unrelated Items
Response Time (ms)
1100
1000
900
800
700
600
LF Hom
LF Ctrl
HF Hom
HF Ctrl
150
450
1350
2000
Poor comp
Poor lex
Good comp
Poor lex
Poor comp
Good lex
Good comp
Good lex


Zekkish Experimental Related Pretest
LF Hom
LF Ctrl
HF Hom
HF Ctrl
Accuracy (proportion)
1
0.8
0.6
0.4
0.2
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor lex
Good lex

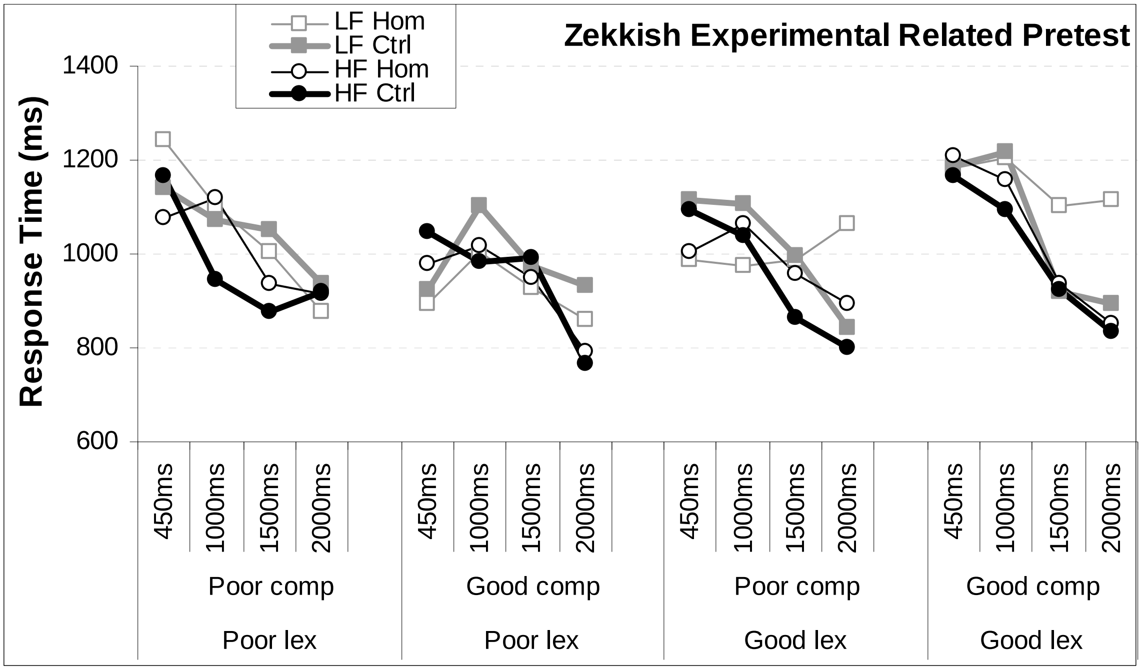

Zekkish Experimental Related Posttest
LF Hom
LF Ctrl
HF Hom
HF Ctrl
Accuracy (proportion)
1
0.8
0.6
0.4
0.2
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor lex
Good lex

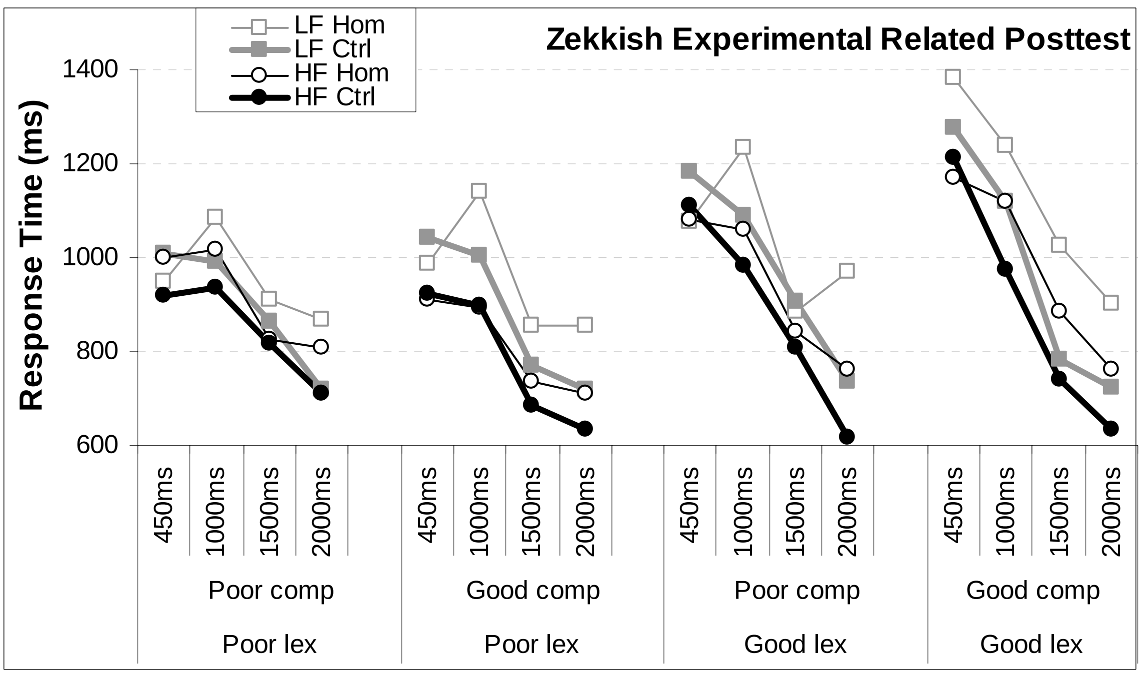


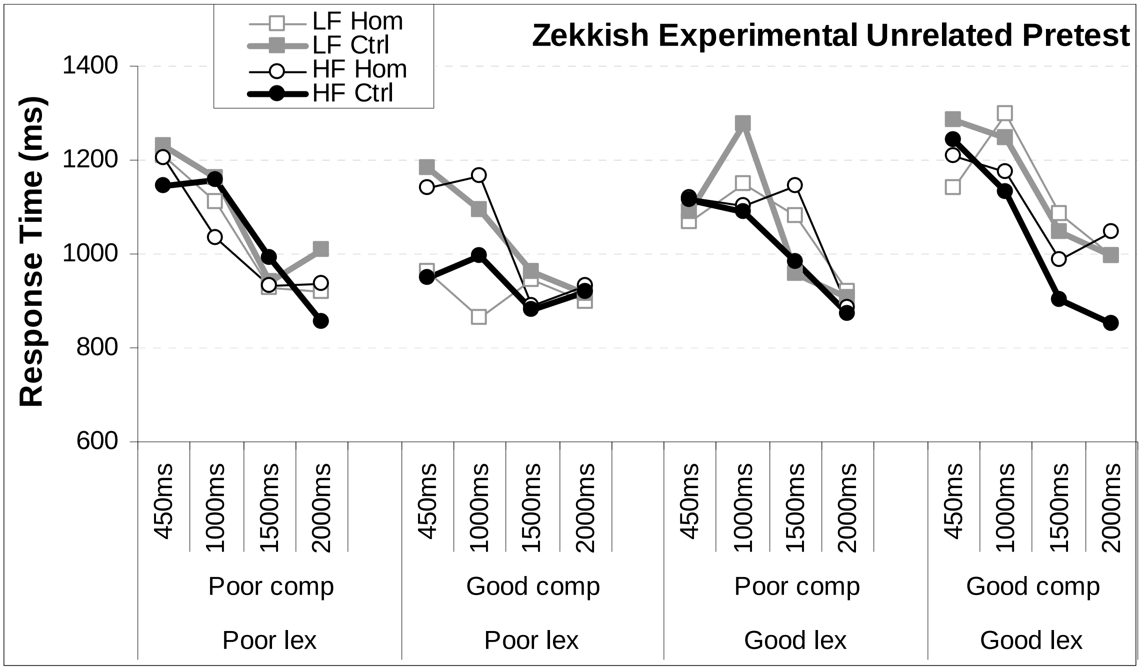
LF Hom
LF Ctrl
HF Hom
HF Ctrl
Zekkish Experimental Unrelated Pretest
Accuracy (proportion)
1
0.8
0.6
0.4
0.2
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor lex
Good lex

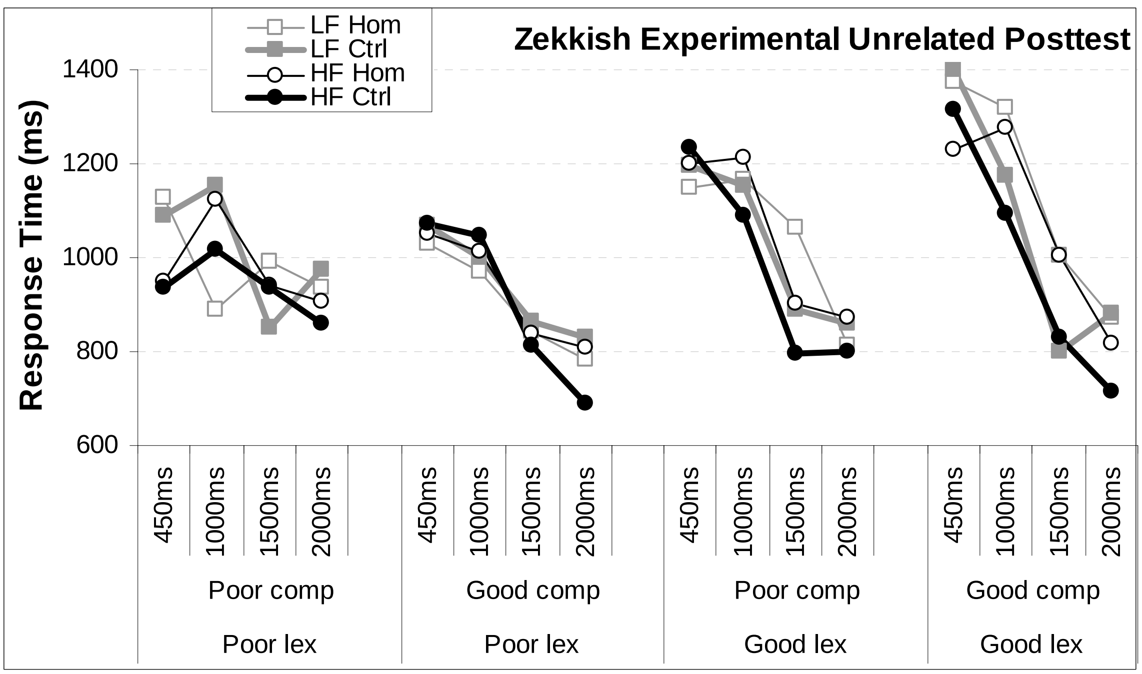


LF Hom
LF Ctrl
HF Hom
HF Ctrl
Zekkish Experimental Unrelated Posttest
Accuracy (proportion)
1
0.8
0.6
0.4
0.2
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor lex
Good lex


Zekkish Experimental Related Pretest
LF Hom
LF Ctrl
HF Hom
HF Ctrl
Response Time (ms)
1400
1200
1000
800
600
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor lex
Good lex


Zekkish Experimental Related Posttest
LF Hom
LF Ctrl
HF Hom
HF Ctrl
Response Time (ms)
1400
1200
1000
800
600
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor lex
Good lex


LF Hom
LF Ctrl
HF Hom
HF Ctrl
Zekkish Experimental Unrelated Pretest
Response Time (ms)
1400
1200
1000
800
600
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor comp
Good comp
Poor lex
Poor lex
Good lex
Good lex


LF Hom
LF Ctrl
HF Hom
HF Ctrl
Zekkish Experimental Unrelated Posttest
Response Time (ms)
1400
1200
1000
800
600
450ms
1000ms
1500ms
2000ms
Poor comp
Good comp
Poor comp
Good comp
Poor lex
Poor lex
Good lex
Good lex

APPENDIX L: Data trimming

Training

Letter learning: Forty percent of the letter learning trials had no answer. This was due to participants not knowing the answer, to microphone insensitivity, and to the tendency for some letter sounds on their own to not trigger the microphone (/m/, in particular). (This is the first task in which participants used the microphone.) After round four (out of eight to 12), answered trials outnumbered trials with no answer, suggesting that early no-response trials were due to inaccuracy. Because participants had the ability to score themselves as correct even when the microphone was not triggered, response times were deleted for these trials, but accuracies were retained (This is true of all the training phases). There was a limit of 2000 ms for a response, so no trials at the upper end of the distribution were eliminated. Response times below 350 ms were deleted (1% of the data), but accuracies were retained. When data were averaged over trial, retaining the within-participants variable of round, there were 13 missing response times due to six participants' inaccuracy. These times were replaced with cell means. There were 63 missing response times due to eight participants' incompetence with the microphone or due to microphone failure. These participants were dropped for the current analysis. This left 8 participants with poor lexical skill and poor comprehension skill, 11 participants with poor lexical skill and good comprehension skill, 9 participants with good lexical skill and poor comprehension skill, and 8 participants with good lexical skill and good comprehension skill (more participants in the good/good group just happened to come in during the week that three microphones failed).

Decoding. Only 16.8% of the trials had no answer. Of these, most were due to participants experiencing microphone difficulties. In seven cases out of ten, the participants were the same as the ones who had difficulty during letter learning. These participants were dropped from further analysis. Even though there was a limit of 6000 ms for a response, the response time distribution had both a positive and a negative tail. Trials with response times below 400 ms and trials with response times above 5550 ms were deleted (1% of the data at each end of the distribution), but accuracies were retained.

Vocabulary learning. Data from all four sets of 12 vocabulary words were analyzed together. Only 16.9% of word identification responses and only 13.2% of meaning identification responses had response times indicating a microphone error or no verbal response given. There was a limit of 4000 ms for the word identification response and a limit of 6000 ms for the meaning identification response. This eliminated the positive tail of the word identification response time distribution. Response times (but not accuracies) for word identification responses below 440 ms were removed (2% of the data). Meaning data were skewed in the opposite direction, as participants had more time to think about their response before being asked to generate it. Response times (but not accuracies) above 4440 ms were removed (2% of the data). Data were averaged over trial, retaining the within-participants variables of homophony, frequency, and round (with four levels: rounds1-2, rounds 3-4, rounds 5-6, and last 2 rounds). Due to low accuracy, 2.8% of the word identification trials and 9.6% of the meaning identification trials had missing response times. These data were replaced by cell means.

Vocabulary competence. Only 14.8% of word identification responses and only 10.5% of meaning identification responses had response times indicating a microphone error or no verbal response given. Because participants had the ability to score themselves as correct even when the microphone was not triggered, RTs were deleted for these trials, but accuracies were retained. There was a limit of 4000 ms for the word identification response and a limit of 6000 ms for the meaning identification response. However, because participants had become so skilled at Zekkish decoding by this time, the 4000 ms cutoff did not completely eliminate the positive tail of the word identification response time distribution. Response times (but not accuracies) for word identification responses below 480 ms and above 3750 ms were removed (2% of the data in each tail). Meaning data were skewed in the opposite direction, as participants had more time to think about their response before being asked to generate it. Response times (but not accuracies) above 5640 ms were removed (2% of the data). Data were averaged over trial, retaining within-participants variables of homophony, frequency, and day. For purposes of analysis, if participants reached 85% accuracy in less than 4 days, their data were duplicated for the remaining days – as if they maintained a constant level of performance.

Grammar training: Only 13.8% of word identification responses and only 8.4% of meaning identification responses had response times indicating a microphone error or no verbal response given. Because participants had the ability to score themselves as correct even when the microphone was not triggered, RTs were deleted for these trials, but accuracies were retained. There was a limit of 4000 ms for the word identification response and a limit of 6000 ms for the meaning identification response. However, because participants had become so skilled at Zekkish decoding by this time, the 4000 ms cutoff did not completely eliminate the positive tail of the word identification response time distribution. Response times (but not accuracies) for word identification responses below 260 ms and above 3810 ms were removed (2% of the data in each tail). Meaning data were skewed in the opposite direction, as participants had more time to think about their response before being asked to generate it. Response times (but not accuracies) above 5300 ms were removed (2% of the data). Overall accuracy was 78.7% for word identification, and 86.7% for meaning identification. This is the reverse pattern to that of the vocabulary consolidation data. This is because participants were focused on reading the words in sentences (word, character name). The pattern reversal indicates that participants were following directions and scoring their data appropriately. Data were averaged over trial, retaining within-participants variables of homophony, frequency, and round. After aggregating, the response times for the 0.4% of word identification trials and the 2.8% of meaning identification trials with missing data were replaced with cell means.

Acquisition of experience: Only 2.6% of word identification responses and only 3.6% of meaning identification responses had response times indicating a microphone error or no verbal response given. Because participants had the ability to score themselves as correct even when the microphone was not triggered, RTs were deleted for these trials, but accuracies were retained. There was a limit of 4000 ms for the word identification response and a limit of 6000 ms for the meaning identification response. However, because participants had become so skilled at Zekkish decoding by this time, the 4000 ms cutoff did not completely eliminate the positive tail of the word identification response time distribution. Response times (but not accuracies) for word identification responses below 250 ms and above 3440 ms were removed (2% of the data in each tail). Meaning data were skewed in the opposite direction, as participants had more time to think about their response before being asked to generate it. Response times (but not accuracies) above 4750 ms were removed (2% of the data). Overall accuracy was 94.7% for word identification, and 93.7% for meaning identification. One participant was missing data from one session, due to computer errors. These data were replaced by cell means. Data were averaged over trial, retaining within-participants variables of homophony, frequency, and day of testing.

Testing

Zekkish word identification: Good data were obtained for all participants after partial training, and for 44 participants after complete training. The remaining participant (a reader with poor lexical skill and good comprehension skill) was not given the task after complete training because of an experimenter error. Mean accuracy was 93.3%, and mean response time (RT) for correct trials was 1507.5 ms, with a standard deviation of 623.8 ms. Response time and accuracy were eliminated for trials with RTs <= 680 ms.; the microphone was probably triggered by an extraneous noise or movement rather than a true response. These trials accounted for 2% of the total data. Response time was deleted for trials with RTs >=3250 ms.; the microphone was probably not triggered by a subthreshold response. However, such responses could be heard by the examiner and were scored appropriately. Thus, accuracy data was retained. These trials accounted for 2% of the total data. Data were then collapsed over trials, retaining within-participants variables of test time (partial/complete), homophony (homophone/control) and frequency (low/high). The missing data for the single participant after complete training were replaced by cell means.

English word identification: Good data were obtained for all participants on the tests after partial training, and for 44 participants on the tests after complete training (experience). The remaining participant (a reader with poor lexical skills and good comprehension skills) was not given the task at the second test point because of an experimenter error. Mean accuracy was 90%, and mean response time (RT) for correct trials was 703.4 ms, with a standard deviation of 503.8 ms. Response time and accuracy were eliminated for trials with RTs <= 364 ms.; the microphone was probably triggered by an extraneous noise or movement rather than a true response. These trials accounted for 2% of the total data. Response time was deleted for trials with RTs >=2220 ms.; the microphone was probably not triggered by a subthreshold response. However, such responses could be heard by the examiner and were scored appropriately. Thus, accuracy data was retained. These trials accounted for 2% of the total data. In addition, the first five trials were deleted as practice trials; this was the first task that required a microphone response that was given during testing. The last five trials were deleted as too difficult to provide stable data. The last five words tended to be foreign in origin, very low frequency, and/or exception words. In addition to the general instability of the data for these items, the fact that skilled readers tended to be more accurate on these final words than less skilled readers would artificially slow the mean response times for skilled readers. The data were then collapsed over trial, retaining the within-participant variable of test time. The single missing data point was replaced by the cell mean.

Zekkish pseudoword identification: Good data were obtained for all participants after partial training, and for 44 participants after complete training. The remaining participant (a reader with poor lexical skills and good comprehension skills) was not given the task after complete training because of an experimenter error. Mean accuracy was 76%, and mean response time (RT) for correct trials was 4596 ms, with a standard deviation of 3090 ms. Response time and accuracy were eliminated for trials with RTs <= 850 ms.; the microphone was probably triggered by an extraneous noise or movement rather than a true response. These trials accounted for 2% of the total data. Response time was deleted for trials with RTs >=14400 ms.; the microphone was probably not triggered by a subthreshold response. However, such responses could be heard by the examiner and were scored appropriately. Thus, accuracy data was retained. These trials accounted for 2% of the total data. The data were then collapsed over trial, retaining the within-participants variable of test time. The single missing data point was replaced by the cell mean.

English pseudoword identification: Good data were obtained for all participants after partial training, and for 44 participants after complete training. The remaining participant (a reader with poor lexical skills and good comprehension skills) was not given the task after complete training because of an experimenter error. Mean accuracy was 83%, and mean response time (RT) for correct trials was 910.0 ms, with a standard deviation of 589.9 ms. Several trials were deleted from each list because they were not actually pseudowords. For example, "gat" was removed because it is a low frequency word, "dee," "nan" and "poe" were removed because they are names, and "pog" was removed because it has become a word since the original list of pseudowords was created (it is a children's trading card game). Two items were removed because of the examiner's inconsistency in scoring the items. Sixteen items were retained on each list. Response time and accuracy were eliminated for trials with RTs <= 415 ms.; the microphone was probably triggered by an extraneous noise or movement rather than a true response. These trials accounted for 2% of the total data. Response time was deleted for trials with RTs >=2600 ms.; the microphone was probably not triggered by a subthreshold response. However, such responses could be heard by the examiner and were scored appropriately. Thus, accuracy data was retained. These trials accounted for 2% of the total data. The data were then collapsed over trial, retaining the within-participant variable of test time. The single missing data point was replaced by the cell mean.

Zekkish phonological awareness: Good data were obtained for all participants after partial training, and for 44 participants after complete training. The remaining participant (a reader with poor lexical skills and poor comprehension skills) was not given the task after complete training because of an experimenter error. This single data point was replaced by the cell mean. Overall score was 11.43 out of 12.

English phonological awareness: Good data were obtained for all participants at both test times. Average score was 11.23 out of 12.

Zekkish working memory: Good data were obtained for all participants at both test times. Two different measures of working memory were obtained; number of correct responses given, and length of longest word list correctly repeated. Each was collected for lists repeated forward and lists repeated backward. Average scores were 3.88 total forward, 3.29 length forward, 2.59 total backward, and 2.62 length backward. These four scores were standardized across test time, and averaged together to provide a single, stable working memory score.

English working memory - words: Good data were obtained for all participants after partial training and for 44 participants after complete training. The remaining participant (a reader with good lexical skills and poor comprehension skills) was not given the task after complete training because of an experimenter error. Data were replaced by the cell means. Two different measures of working memory were obtained; number of correct responses given, and length of longest word list correctly repeated. Each was collected for lists repeated forward and lists repeated backward. Average scores were 5.06 total forward, 4.02 length forward, 4.30 total backward, and 3.32 length backward. These four scores were standardized across test time, and averaged together to provide a single, stable working memory score.

English working memory – digits: Good data were obtained for 44 participants after partial training and for 44 participants after complete training. The participant missing data after partial training had poor comprehension and poor lexical skill (only digits backward data were missing). The participant missing data after complete training had poor comprehension and good lexical skill. These participants were not given the task because of an experimenter error. Data were replaced by the cell means. Two different measures of working memory were obtained; number of correct responses given, and length of longest word list correctly repeated. Each was collected for lists repeated forward and lists repeated backward. Average scores were 11.64 total forward, 7.31 length forward, 8.79 total backward, and 6.04 length backward. These four scores were standardized across test time, and averaged together to provide a single, stable working memory score.

Zekkish word spelling: Good data were obtained for all participants after partial training and after complete training. Average score was 9.66 out of 10.

English word spelling: Good data were obtained for all participants after partial training and for 43 participants after complete training. The two participants with missing data (one with good comprehension and one with poor comprehension; both with good lexical skill) were not given the task because of experimenter error. Data were replaced by cell means. Average score was 15.57 out of 21.

Zekkish pseudoword spelling: Good data were obtained for all participants after partial training and after complete training. Average score was 8.34 out of 10.

Zekkish spelling – ease: In addition to total correct for Zekkish spelling of words and pseudowords, some other markers of spelling ease were collected. Each measures some ability to maneuver through the testing efficiently and with a sensitivity to and understanding of the underlying spelling-sound structure. Each variable alone had little variance, so they were standardized and averaged for a single stable variable of spelling ease. The variables were: (a) frequency with which the /u/ sound was represented by the same letter in words, (b) frequency with which the /u/ sound was represented by the same letter in pseudowords, (c) repetition of same letter for /u/ sound for homophones presented one after another, (d) frequency of three-letter units constructed in pseudowords (some pseudowords could be correctly spelled more than one way), (e) whether letters were always in canonical orientation, and (f) whether one sound, which would probably be a schwa in English was represented with the correct (and emphasized by the examiner) /u/ sound in Zekkish.

English pseudoword spelling: Good data were obtained for all participants after partial training and for 43 participants after complete training. The two participants with missing data (one with good comprehension and one with poor comprehension; both with good lexical skill) were not given the task because of experimenter error. Data were replaced by cell means. Average score was 88% for overall accuracy, and 57% for accuracy sensitive to position, stress, and grapheme frequency.

Zekkish category inferencing: Good data were obtained for all participants at both the test point after partial training and the test point after complete training. Average score was 5.72 out of 8.

English category inferencing: Good data were obtained for all participants after partial training and for 44 participants after complete training one participant, with good lexical skills and good comprehension skills, was not given the test because of experimenter error. This single data point was replaced by the cell mean. Average score was 5.52 out of 8.

MLAT: Good data were obtained for 44 participants. The participant with missing data, who had good lexical skill and poor comprehension skill, forgot to turn the tape recorder on at the beginning of the test period. He only did the sections of the test that were supplemented by a test booklet, and he took them untimed. Consequently, all his MLAT data were discarded. Missing data points were replaced by cell means. Average scores for the five sections and for the total score were 91%, 86%, 49%, 52%, 80%, and 69%, respectively. The total score of 134/194 places this sample at the 70 to 75th percentile of college freshmen, the closest normative sample in the MLAT manual. Norms are provided only for the total score; however, for the purposes of the current study, subtest scores are analyzed as well to capitalize on the specific skills they tap.

ERP Behavioral Data

Zekkish word classification: Good data were obtained for all participants after both partial training and complete training. Overall, participants performed at 62% accuracy, with a mean response time of 2532 ms (SD 693.0) for accurate trials. No data trimming was necessary at the upper bound of 4000 ms, as response times were very long and exceeded the limit 10% of the time.

At the lower bound, trials with response times under 830 ms were removed. This only excludes .5% of the data; less than in other tasks, because visual inspection showed few trials that appear to be outliers

Zekkish Picture Classification: Good data were obtained for all participants after both partial training and complete training. Overall, participants performed at 97% accuracy, with a mean response time of 727.79 ms (SD = 205.89) for accurate trials. Some data trimming was necessary even at the upper bound; response times were nearly always within the 2000 ms response time limit (0.6% exceeded the limit). Trials below 440 ms and above 1700 ms were removed (.5% at each end of the distribution). Much less data is cut in this task because of the extreme positive kurtosis.

Zekkish Name Recognition: Good data were obtained for 44 participants after partial training and for all participants after complete training. One participant has missing data because she was sick at the test point after partial training, and the session was cut short. This one data point was replaced with the cell mean. Overall, participants performed at 98% accuracy, with a mean response time of 556.0 ms (SD 133.3) for accurate trials. Only 18 trials out of 4005 were not answered within the 2000 ms window. Trials below 350 ms and above 1000 ms were removed (2% on either end of the distribution). These data were analyzed together with Zekkish character recognition.

Zekkish Character Recognition: Good data were obtained for 44 participants after partial training and for all participants after complete training. One participant has missing data because she was sick at the test point after partial training, and the session was cut short. This one data point was replaced with the cell mean. Overall, participants performed at 99% accuracy, with a mean response time of 495.6 ms (SD 119.66) for accurate trials. Only 1 trial out of 4005 was not answered within the 2000 ms window. Trials below 315 ms and above 800 ms were removed (2% on either end of the distribution). These data were analyzed together with Zekkish name recognition.

Nonlinguistic Interferenct Effects: Good data were obtained for 44 participants after partial training and for all participants after complete training. One participant has missing data because she was sick at the test point after partial training, and the session was cut short. These two data points were replaced with the cell means. Overall, participants performed at 98% accuracy, with a mean response time of 575.7 ms (SD 169.1) for accurate trials. Only 12 trials out of 4005 were not answered within the 2000 ms window. Trials below 380 ms and above 1125 ms were removed (2% on either end of the distribution).

English word Classification: Good data were obtained for all participants after partial training, and for 44 participants after complete training. Data from the remaining participant (a reader with good lexical skills and poor comprehension skills) were lost because of computer error.

The missing data points were replaced by cell means. Overall, participants performed at 87% accuracy, with a mean response time of 927.5 ms (SD = 293.7) for accurate trials. No data trimming was necessary at the upper bound of response time, because of the 2000 ms. response time limit (2.4% of the trials exceeded this limit). Trials below 500 ms. were considered unreliable responses and were removed; this accounted for 2.5% of the total data.

Gernsbacher Homophone Experiments

English: Good data were obtained for all participants after partial training. Overall, participants performed at 85% accuracy, with a mean response time of 819.11 ms (SD = 260.84) for accurate trials. There was no need to remove outliers at the upper end of the distribution because of the response time cutoff of 2000 ms. Only 0.8% of trials exceeded the maximum response time. Accuracy stabilized by 300 ms RT, and by 400 ms accuracies in all SOA conditions were above chance, so response times below 400 ms were removed (1.6% of the trials).

Zekkish: Good data were obtained for all participants after both partial and after complete training. Overall, participants performed at 61% accuracy, with a mean response time of 979.44 ms (SD = 434.28) for accurate trials. The response time distribution shows no clear tail at either end of the distribution; however, 2% of the data were removed from each end because of the high variability in response times associated with this test. Trials with response times less than 200 ms and greater than 1890 ms were removed. Only 4.5% of trials received no response within the 2000 ms time limit.

APPENDIX M: Statistics

ANOVAs on Participant Data: Significant Effects

Experiment participation

Dependent Variable	Independent Variable	dF	F	p
Initial interest in experiment	Interaction Lex x Comp	1, 564	3.36	.068
Completed experiment	Interaction Lex x Comp	1, 564	5.05	<.05
Initial interest/no participation	Lexical Skill	1, 564	8.33	<.005
	Comprehension skill	1, 564	3.67	.056
No-show first appointment	Comprehension Skill	1, 564	3.36	.067

Reading skill

Dependent Variable	Independent Variable	dF	F	p
Comprehension Composite	Vocabulary checklist	1, 41	51.89	<.0001
	N-D comprehension	1, 41	46.95	<.0001
	Author recognition	1, 41	44.74	<.0001
	N-D vocabulary	1, 41	35.49	<.0001
Lexical Composite	Written Phonology	1, 41	35.70	<.0001
	Written Orthography	1, 41	35.08	<.0001
	Phonology checklist	1, 41	24,12	<.0001
	Orthography checklist	1, 41	14.89	<.0001
	N-D comprehension	1, 41	8.19	<.01
	N-D vocabulary	1, 41	4.04	.051

Language history

Dependent Variable	Independent Variable	dF	F	p
L2 Average Proficiency	Interaction: Lex x Comp	1, 40	3.29	.077

School history

Dependent Variable	Independent Variable	dF	F	p
Told Good Reading	Comprehension Skill	1, 40	12.40	<.005
Told Poor Math	Lexical Skill	1, 40	3.34	.075

College experience

Dependent Variable	Independent Variable	dF	F	p
Time in college	Lexical skill	1, 40	3.88	.056
	Comprehension Skill	1, 40	3.39	.073
Language as favorite class	Lexical skill	1, 40	5.03	<.05
Psychology as least favorite	Interaction: Lex x Comp	1, 40	3.48	.069

Progress through experiment

Dependent Variable	Independent Variable	dF	F	p
Length of experiment	Comprehension Skill	1, 41	6.17	<.05
Skipped weekdays	Comprehension Skill	1, 41	4.45	<.05

Skipped weekend days	Comprehension Skill	1, 41	4.45	<.05
Multiple sessions the same day	Interaction: Lex x Comp	1, 41	3.93	.054

ANOVAs on Training Data: Significant Effects

Letter Learning

Skill	Independent Variable	dF	F	p
Rounds to 85% criterion	Lexical Skill	1, 33	3.00	.091
Accuracy of spoken response	Round	8, 264	37.49	<.0001
	Lexical Skill	1, 33	4.77	<.05
	Interaction Lex x Comp	1, 33	3.91	.056
RT of spoken response	Round	8, 264	7.40	<.0001
	Comprehension Skill	1, 33	4.82	<.05

Decoding

Skill	Independent Variable	dF	F	p
Rounds to 85% criterion	Lex x Comp	1, 34	3.86	.058
Accuracy of spoken response	Round	3, 102	57.73	<.0001
	Rnd x Lex x Comp	3, 102	2.45	.068
RT of spoken response	Round	3, 102	10.00	<.0001
	Lexical Skill	1, 34	3.26	.080
	Rnd x Comp	3, 102	3.25	<.05

Vocabulary learning

Skill	Independent Variable	dF	F	p
Accuracy of spoken response	Frequency	1,37	21.10	<.0001
	Round	3,111	19.67	<.0001
	Hom x Freq	1, 37	8.42	<.01
	Freq x Rnd	3, 111	1.83	<.05
RT of spoken response	Frequency	1, 37	21.69	<.0001
	Round	3,111	16.76	<.0001
	Hom x Freq	1, 37	17.58	<.0005
	Rnd x Lex	3, 111	8.87	<.0001
	H x R x L x C	3, 111	2.71	<.05
	Hom x Lex	1, 37	3.97	.053
	Rnd x Comp	3, 111	2.42	.070
Accuracy of meaning response	Homophony	1, 37	103.32	<.0001
	Frequency	1, 37	408.48	<.0001
	Round	3, 111	491.71	<.0001
	Lexical Skill	1, 37	5.52	<.05
	Hom x Freq	1, 37	21.16	<.0001
	Hom x Rnd	3, 111	4.29	<.01
	Freq x Rnd	3, 111	13..71	<.0001
	Freq x Comp	1, 37	5.31	<.05

	Hom x Freq x Rnd	3, 111	4.73	<.005
	Freq x Rnd x Lex	3, 111	3.85	<.05
	Rnd x Lex	3, 111	2.25	.086
	Hom x Freq x Comp	1, 37	3.66	.063
RT of meaning response	Homophony	1, 37	15.77	<.0005
	Frequency	1, 37	83.69	<.0001
	Round	3, 111	39.38	<.0001
	Lexical Skill	1, 37	10.87	<.005
	Hom x Rnd	3, 111	3.68	<.05
	Hom x Freq x Rnd	3, 111	3.04	<.05
	Hom x Rnd x Lex	3, 111	4.64	<.005
	H x F x R x L	3, 111	2.76	<.05
	Hom x Lex	1, 37	2.91	.096

Vocabulary Competence

Skill	Independent Variable	dF	F	p
Accuracy of spoken response	Frequency	1, 37	4.42	<.05
	Homophony	1, 37	4.30	<.05
	Round	3, 111	9.78	<.0001
	Rnd x Lex x Comp	3, 111	6.99	<.0005
	Freq x Lex x Comp	1, 37	8.71	<.01
	F x H x L x C	1, 37	6.56	<.05
RT of spoken response	Frequency	1, 37	6.71	<.05
	Round	3, 111	4.05	<.01
	Hom x Comp	1, 37	4.98	<.05
	Hom x Lex x Comp	1, 37	4.62	<.05
	Freq x Lex x Comp	1, 37	4.65	<.05
	Freq x Rnd x Lex	3, 111	3.26	<.05
	F x H x L x C	1, 37	11.62	<.01
	Freq x Comp	1, 37	4.05	.051
	Freq x Rnd	3, 111	2.16	.097
Accuracy of meaning response	Frequency	1, 37	262.72	<.0001
	Homophony	1, 37	58.09	<.0001
	Round	3, 111	38.66	<.0001
	Freq x Hom	1, 37	25.89	<.0001
	Freq x Hom x Rnd	3, 111	2.23	.088
RT of meaning response	Frequency	1, 37	77.04	<.0001
	Homophony	1, 37	39.62	<.0001
	Round	3, 111	3.40	<.05
	Lexical Skill	1, 37	8.48	<.01
	Freq x Hom x Rnd	3, 111	3.24	<.05
	Freq x Hom	1, 37	3.91	.056
	Hom x Comp	1, 37	2.93	.095
	Rnd x Comp	3, 111	2.66	.051

Grammar Training

Skill	Independent Variable	dF	F	p
Accuracy of spoken response	Frequency	1, 37	90.59	<.0001
	Homophony	1, 37	57.57	<.0001
	Round	2, 74	24.17	<.0001
	Freq x Hom	1, 37	21.81	<.0001
	Hom x Rnd x Lex	2, 74	2.76	.07
RT of spoken response	Frequency	1, 37	11.52	<.005
	Freq x Hom	1, 37	7.31	<.01
	Hom x Lex x Comp	1, 37	4.65	<.05
	Freq x Rnd x Lex	2, 74	6.65	<.005
	H x R x L x C	2, 74	3.52	<.05
	Freq x Rnd x Comp	2, 74	3.12	.051
	F x R x H x L x C	2, 74	2.54	.086
Accuracy of meaning response	Frequency	1, 37	128.54	<.0001
	Homophony	1, 37	51.91	<.0001
	Round	2, 74	48.31	<.0001
	Lexical Skill	1, 37	10.28	<.005
	Comprehension Skill	1, 37	5.35	<.05
	Hom x Freq	1, 37	29.18	<.0001
	Rnd x Freq	2, 74	18.29	<.0001
	Hom x Rnd	2, 74	2.90	.061
RT of meaning response	Frequency	1, 37	93.37	<.0001
	Homophony	1, 37	24.76	<.0001
	Round	2, 74	34.11	<.0001
	Hom x Freq	1, 37	5.02	<.05
	Rnd x Freq	2, 74	4.65	<.05
	Freq x Rnd x Comp	2, 74	8.21	<.001
	H x R x L x C	2, 74	3.95	<.05
	F x R x L x C	2, 74	6.00	<.005
	Freq x Lex	1, 37	3.99	.053
	Freq x Lex x Comp	1, 37	3.68	.063
	Rnd x Comp	2, 74	2.67	.076
	Rnd x Lex x Comp	2, 74	3.00	.056
	Hom x Rnd x Lex	2, 74	3.08	.052
	Freq x Hom x Rnd	2, 74	2.81	.066

Acquisition of Experience

Skill	Independent Variable	dF	F	p
Accuracy of spoken response	Frequency	1, 37	70.75	<.0001
	Homophony	1, 37	36.82	<.0001
	Round	3, 111	3.58	<.05
	Hom x Freq	1, 37	7.11	<.05
	Freq x Lex	1, 37	4.18	<.05
	Hom x Freq x Lex	1, 37	7.44	<.01

	Rnd x Freq x Comp	3, 111	3.69	<.05
	Rnd x Freq x Lex	3, 111	3.33	<.05
	; R x H x L x C	3, 111	2.46	.066
RT of spoken response	Frequency	1, 37	9.67	<.005
	Round	3, 111	5.67	<.005
	Lexical Skill	1, 37	6.68	<.05
	Hom x Freq	1, 37	6.44	<.05
	Rnd x Lex	3, 111	4.09	<.01
	Rnd x Freq x Lex	3, 111	4.94	<.005
	Freq x Lex	1, 37	3.45	.071
	R x H x F x L	3, 111	2.36	.075
Accuracy of meaning response	Homophony	1, 37	19.57	<.0001
	Frequency	1, 37	70.16	<.0001
	Round	3, 111	22.51	<.0001
	Lexical Skill	1, 37	14.76	<.0005
	Comprehension Skill	1, 37	6.31	<.05
	Hom x Freq	1, 37	15.62	<.0005
	Hom x Rnd	3, 111	6.35	<.001
	Freq x Rnd	3, 111	14.04	<.0001
	Freq x Lex	1. 37	14.99	<.0005
	Freq x Comp	1, 37	5.82	<.05
	Hom x Freq x Rnd	3, 111	8.92	<.0001
	Lex x Comp	1, 37	2.97	.093
RT of meaning response	Homophony	1, 37	45.70	<.0001
	Frequency	1, 37	87.34	<.0001
	Round	3, 111	11.14	<.0001
	Lexical Skill	1, 37	13.24	<.001
	Hom x Freq	1, 37	13.73	<.001
	Freq x Rnd	3, 111	3.76	<.05
	Hom x Freq x Lex	1, 37	7.64	<.01
	F x R x L x C	3, 111	3.29	<.05
	Freq x Rnd x Comp	3.111	2.68	.051

Across Phases

Skill	Independent Variable	dF	F	p
Spoken response	Phase	5, 205	93.15	<.0001
	Test Point	1, 41	423.54	<.0001
	Lexical Skill	1, 41	6.80	<.05
	Phase x Point	5, 205	33.41	<.0001
	Point x Lex x Comp	1, 41	3.17	.082
Meaning response	Phase	3, 123	145.81	<.0001
	Test Point	1, 41	717.51	<.0001
	Lexical Skill	1, 41	18.23	<.0005
	Phase x Point	3, 123	40.56	<.0001

ANOVAs on testing data: Significant effects

Zekkish Word Identification

Test	Independent Variable	dF	F	p
Accuracy	Test Time	1, 41	8.79	$<.005$
	Hom x Freq	1, 41	5.51	$<.05$
	Hom x Lex	1, 41	3.24	.08
Response Time	Test Time	1, 41	52.11	$<.0001$
	Frequency	1, 41	9.51	$<.005$
	Homophony	1, 41	7.75	$<.01$
	Lexical Skill	1, 41	9.51	$<.005$
	Freq x Hom x Comp	1, 41	4.74	$<.05$

English Word Identification

Test	Independent Variable	dF	F	p
Accuracy	Lexical Skill	1, 37	6.27	$<.05$
	Comprehension skill	1, 37	16.01	$<.0005$
Response Time	Comprehension skill	1, 37	7.95	$<.01$
	Time x Lex x Comp	1, 37	4.83	$<.05$

Zekkish Pseudoword Identification

Test	Independent Variable	dF	F	p
Accuracy	Test Time	1, 37	48.94	$<.0001$
	Comprehension skill	1, 37	8.78	$<.01$
	Time x Comp	1, 37	5.13	$<.05$
Response Time	Test Time	1, 37	61.91	$<.0001$

English Pseudoword Identification

Test	Independent Variable	dF	F	p
Accuracy	Lexical Skill	1, 37	4.66	$<.05$
	Time x Comp	1, 37	6.37	$<.05$
Response Time	Lexical Skill	1, 37	4.54	$<.05$
	Comprehension Skill	1, 37	6.00	$<.05$

Zekkish Phonological Awareness

Test	Independent Variable	dF	F	p
	Test Time	1, 41	8.09	$<.01$
	Lexical Skill	1, 41	4.18	$<.05$
	Comprehension Skill	1, 41	9.41	$<.005$

English Phonological Awareness

Test	Independent Variable	dF	F	p
	Comprehension Skill	1, 41	7.54	<.01

Zekkish Working Memory

Test	Independent Variable	dF	F	p
	Comprehension Skill	1, 41	8.20	<.01
	Time x Lex x Comp	1, 41	4.19	<.05

English Working Memory - Words

Test	Independent Variable	dF	F	p
	Comprehension Skill	1, 41	8.73	<.01

English Working Memory - Digits

Test	Independent Variable	dF	F	p
	Comprehension Skill	1, 41	4.96	<.05

Zekkish Word Spelling

Test	Independent Variable	dF	F	p
	Test Time	1, 41	3.30	.077
	Comprehension Skill	1, 41	3.91	.055
	Time x Comp	1, 41	4.22	<.05

English Word Spelling

Test	Independent Variable	dF	F	p
	Lexical Skill	1, 37	6.30	<.05
	Comprehension Skill	1, 37	15.72	<.0005

Zekkish Pseudoword Spelling

Test	Independent Variable	dF	F	p
	Test Time	1, 37	12.73	<.001
	Comprehension Skill	1, 37	13.43	<.001
	Lexical Skill	1, 37	3.16	.084

Zekkish Spelling - Ease

Test	Independent Variable	dF	F	p
	Lexical Skill	1, 37	5.03	<.05

	Comprehension Skill	1, 37	4.57	<.05
	Lex x Comp	1, 37	4.14	<.05

English Pseudoword Spelling

Test	Independent Variable	dF	F	p
Total	Comprehension Skill	1, 37	5.91	<.05
Common	Comprehension Skill	1, 37	8.26	<.01

Zekkish Category Inferencing

Test	Independent Variable	dF	F	p
	Test Time	1, 37	7.00	<.05
	Test Mode	1, 37	100.62	<.0001
	Lexical Skill	1, 37	5.06	<.05
	Comprehension Skill	1, 37	11.27	<.005
	Mode x Comp	1, 37	9.70	<.005
	Mode x Time	1, 37	10.19	<.005
	Lex x Comp	1, 37	8.55	<.01
	Mode x Lex x Comp	1, 37	2.91	.096

English Category Inferencing

Test	Independent Variable	dF	F	p
	Test Mode	1, 37	4.75	<.05
	Comprehension Skill	1, 37	18.70	<.0001

MLAT

Test	Independent Variable	dF	F	p
MANOVA with Subtests	Comprehension Skill	5	2.75	<.05
	MLAT1	1, 41	3.87	.056
	MLAT 2	1, 41	6.95	<.05
	MLAT 3	1, 41	5.13	<.05
	MLAT 4	1, 41	3.62	.064
	Lexical Skill	5	2.43	.053
	MLAT1	1, 41	11.80	<.005
ANOVA of Total Score	Comprehension Skill	1, 41	10.31	<.005
	Lexical Skill	1, 41	7.02	<.05

ANOVAs on ERP Behavioral Data: Significant Effects

Zekkish word classification

Dependent Variable	Independent Variable	dF	F	p
Accuracy	Homophony	1, 41	107.55	<.0001
	Frequency	1, 41	122.90	<.0001
	Test Time	1, 41	163.50	<.0001
	Lexical Skill	1, 41	21.10	<.0001
	Comprehension Skill	1, 41	9.24	<.005
	Hom x Freq	1, 41	21.07	<.0001
	Freq x Comp	1, 41	6.59	<.05
	H x F x T x C	1, 41	9.06	<.005
Response Time	Homophony	1, 41	56.00	<.0001
	Frequency	1, 41	128.32	<.0001
	Test Time	1, 41	124.61	<.0001
	Hom x Lex	1, 41	5.04	<.05

Zekkish picture classification

Dependent Variable	Independent Variable	dF	F	p
Accuracy	Test Time	1, 41	8.22	<.01
	Time x Freq	1, 41	10.33	<.005
Response Time	Homophony	1, 41	8.07	<.01
	Test Time	1, 41	143.70	<.0001
	Lexical Skill	1, 41	10.59	<.005
	Hom x Freq	1, 41	13.77	<.001
	Freq x Time	1, 41	4.09	<.05
	Freq x Comp	1, 41	4.76	<.05

Written language sensitivity

Dependent Variable	Independent Variable	dF	F	p
Accuracy	Wri x Lex x Comp	1, 41	4.71	<.05
Response Time	Writing Condition	1, 41	267.41	<.0001
	Test Time	1, 41	6.02	<.05
	Lexical Skill	1, 41	6.98	<.05
	Wri x Time	1, 41	6.87	<.05

Nonlinguistic interference

Dependent Variable	Independent Variable	dF	F	p
Accuracy	Interference Condition	1, 41	25.21	<.0001
Response Time	Interference Condition	1, 41	119.56	<.0001
	Test Time	1, 41	38.83	<.0001

	Lexical Skill	1, 41	6.03	<.05

English words

Dependent Variable	Independent Variable	dF	F	p
Accuracy	Homophony	1, 41	406.27	<.0001
	Frequency	1, 41	87.66	<.0001
	Comprehension Skill	1, 41	30.11	<.0001
	Hom x Comp	1, 41	10.82	<.005
	Freq x Comp	1, 41	10.85	<.005
Response Time	Homophony	1, 41	148.83	<.0001
	Frequency	1, 41	44.86	<.0001
	Test Time	1, 41	41.63	<.0001
	Hom x Time	1, 41	5.63	<.05
	Hom x Comp	1, 41	4.83	<.05
	F x T x L x C	1, 41	4.22	<.05

ANOVAs on homophone (Gernsbacher) Tasks

English

Dependent Variable	SOA	Independent Variable	dF	F	p
Accuracy	150/450	SOA	1, 41	43.88	<.00001
		Homophony	1, 41	8.42	<.01
		Comprehension Skill	1, 41	5.33	<.05
		SOA x Hom	1, 41	9.06	<.005
		Hom x Freq	1, 41	10.87	<.005
		Hom x Rel	1, 41	20.48	<.00001
		SOA x Hom x Freq	1, 41	36.61	<.00001
		SOA x Hom x Rel	1, 41	29.65	<.00001
		Hom x Freq x Rel	1, 41	9.83	<.005
		SOA x Rel x Lex	1, 41	8.34	<.01
		S x F x L x C	1, 41	5.01	<.05
	1350/2000	SOA	1, 41	133.65	<.00001
		Comprehension Skill	1, 41	4.09	<.05
		SOA x Hom	1, 41	18.17	<.0005
		SOA x Freq	1, 41	8.54	<.01
		SOA x Rel	1, 41	10.39	<.005
		SOA x Lex	1, 41	5.56	<.05
		Hom x Freq	1, 41	72.35	<.00001
		Hom x Rel	1, 41	14.26	<.001
		Freq x Rel	1, 41	7.97	<.01
		SOA x Hom x Freq	1, 41	41.74	<.00001
		SOA x Hom x Rel	1, 41	13.37	<.001
		SOA x Freq x Rel	1, 41	7.20	<.05

		S x H x F x R	1, 41	13.40	<.001
Response Time	150/450	SOA	1, 41	78.97	<.00001
		Homophony	1, 41	35.31	<.00001
		Frequency	1, 41	9.61	<.005
		Relatedness	1, 41	184.45	<.00001
		SOA x Hom	1, 41	6.38	<.05
		SOA x Rel	1, 41	6.38	<.05
		Hom x Freq	1, 41	18.85	<.0001
		SOA x Hom x Freq	1, 41	5.41	<.05
		SOA x Freq x Rel	1, 41	8.04	<.01
		SOA x Lex x Comp	1, 41	8.26	<.01
	1350/2000	Homophony	1, 41	18.07	<.0005
		Relatedness	1, 41	57.29	<.00001
		Lexical Skill	1, 41	18.17	<.0005
		SOA x Freq	1, 41	32.27	<.00001
		SOA x Rel	1, 41	5.19	<.05
		Hom x Rel	1, 41	14.39	<.0005
		SOA x Hom x Freq	1, 41	7.30	<.01
		S x H x F x R	1, 41	18.17	<.0005

Note: Rel = relatedness, i.e. answer (yes/no)

English

Dependent Variable	SOA	Independent Variable	dF	F	p
Accuracy: Partial Tr	450/1000	SOA	1, 41	23.94	.00001
		Homophony	1, 41	6.47	<.05
		Lexical Skill	1, 41	4.74	<.05
	1500/2000	Homophony	1, 41	57.80	<.00001
		Lexical Skill	1, 41	10.80	<.005
Accuracy: Complete Tr	450/1000	SOA	1, 41	21.08	<.00001
		Homophony	1, 41	20.17	<.00001
		Lexical Skill	1, 41	13.74	<.001
		Comprehension Skill	1, 41	7.88	<.01
		SOA x Hom	1, 41	9.39	<.005
		Hom x Comp	1, 41	6.24	<.05
	1500/2000	Homophony	1, 41	42.71	<.00001
		Lexical Skill	1, 41	21.09	<.00001
		Comprehension Skill	1, 41	8.33	<.01
RT: Partial Training	1500/2000	SOA	1, 41	10.25	<.005
		Hom x Lex	1, 41	7.20	<.01
RT: Complete Training	450/1000	Lexical Skill	1, 41	7.82	<.01
		SOA x Hom	1, 41	6.56	<.05
		SOA x Hom x Lex	1, 41	4.10	<.05
	1500/2000	SOA	1, 41	22.73	<.00001
		Homophony	1, 41	29.64	<.00001

APPENDIX N: ERP Analyses

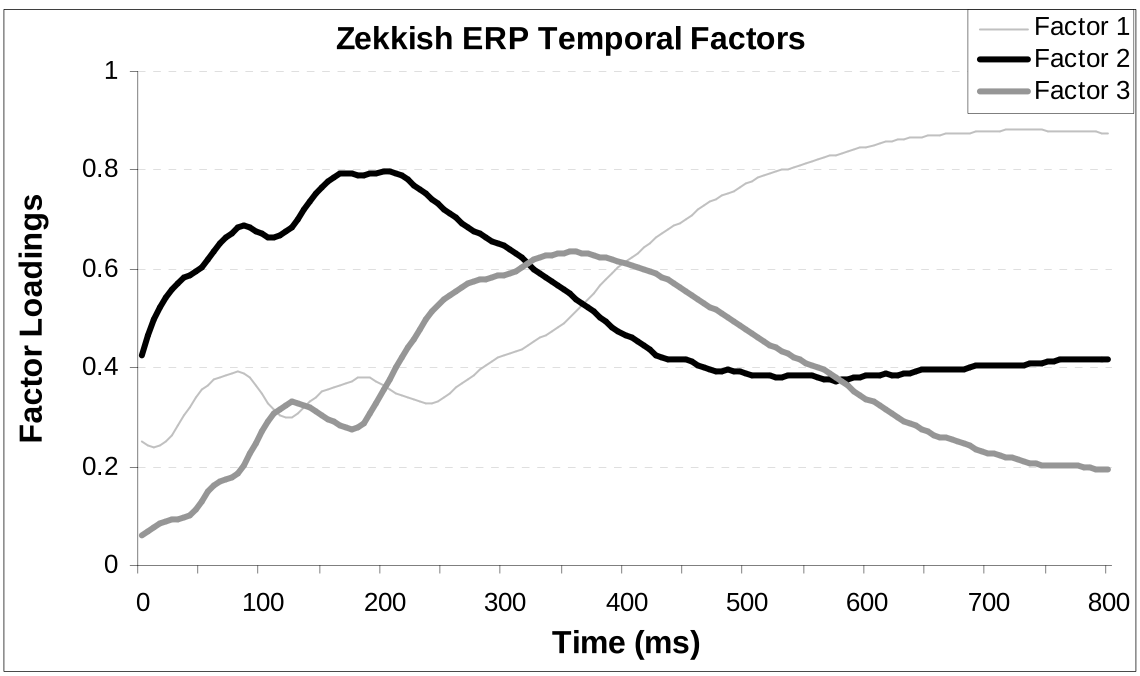
Number of trials in ERP averages:

		Mean	SD	N	Min	5%	25%	Med	75%	95%	Max
Partial Training											
Zek (Corr)	LF Hom	16.49	10.37	45	1	4	8	14	20.5	37.1	40
	HF Hom	28.80	11.89	45	7	10.6	19	27	36.5	50	51
	LF Ctrl	26.80	12.96	45	9	10.3	15	27	37	51.1	56
	HF Ctrl	32.62	12.30	45	6	11.2	23	31	43	53.7	55
Zek (Incorr)	LF Hom	30.49	8.93	45	10	15.5	22.5	31	37.5	45	46
	HF Hom	18.44	7.84	45	5	8	12.5	18	23.5	34.7	39
	LF Ctrl	20.33	9.44	45	3	6	13.5	17	27.5	37	41
	HF Ctrl	15.44	8.98	45	1	4.3	8.5	13	21	32	34
Zek Pict	LF Hom	40.69	6.72	45	21	28	38	43	46	47	48
	HF Hom	41.13	6.46	45	23	30.3	35	44	46.5	48	48
	LF Ctrl	40.69	7.09	45	22	24.6	37	44	46	48	48
	HF Ctrl	41.31	6.76	45	25	27	37.5	44	47	48	48
Wri	Names	39.30	7.67	45	0	24.5	39	41	43	45	45
	Critters	38.89	7.79	45	2	21.25	37	41	43	45	45
Interfer	Normal	42.09	6.85	45	15	25	39.5	45	46.75	47.75	48
	Interference	41.68	5.88	45	19	26.25	38.25	43.5	46	46.75	49
Eng	LF Hom	32.07	7.60	45	3	17.6	29	34	37	42.1	46
	HF Hom	33.49	8.74	45	3	13.9	29.5	35	40	44.4	45
	LF Ctrl	37.09	8.83	45	2	19.2	34	40	43	46	47
	HF Ctrl	38.09	8.85	45	7	15.5	36	41	44	46	48
Complete Training											
Zek (Corr)	LF Hom	27.49	13.22	45	4	5.3	16.5	26	39	49.8	56
	HF Hom	37.67	10.62	45	14	16.3	30	38	47	51.7	54
	LF Ctrl	36.36	11.73	45	12	14.5	29.5	35	45.5	55.7	57
	HF Ctrl	42.24	10.61	45	14	18.6	35	44	51	56	58
Zek (Incorr)	LF Hom	23.31	12.72	45	1	3.9	13	23	32.5	47.1	50
	HF Hom	12.62	7.87	45	3	4	7	11	16.5	26.7	39
	LF Ctrl	15.38	10.35	45	1	1.3	6.5	13	23	36	38
	HF Ctrl	9.04	7.95	45	0	0	3.5	7	12	28	30
Zek Pict	LF Hom	41.62	7.46	45	10	22.8	41	44	46	48	48
	HF Hom	41.82	8.45	45	11	15.9	41	45	47	48	48

	LF Ctrl	41.58	8.91	45	5	18.5	41.5	45	46.5	48	48
	HF Ctrl	42.56	7.62	45	7	23	41	45	47	48	48
Wri	Names	40.16	8.20	45	10	15.9	41	43	44	45	45
	Critters	40.11	7.41	45	14	16.2	39.5	43	44	45	45
Interfer	Normal	44.31	5.12	45	25	29.1	43	46	47	48	48
	Interference	44.38	2.97	45	34	38.6	43	44	47	48	48
Eng	LF Hom	34.42	8.16	45	9	13.8	31	37	41	43.7	45
	HF Hom	36.89	7.32	45	12	20.9	33.5	39	42	45.4	46
	LF Ctrl	38.11	7.77	45	13	18.3	36	40	43	46.7	47
	HF Ctrl	40.89	8.72	45	13	14.6	39.5	44	46	47.7	48

Zekkish words:

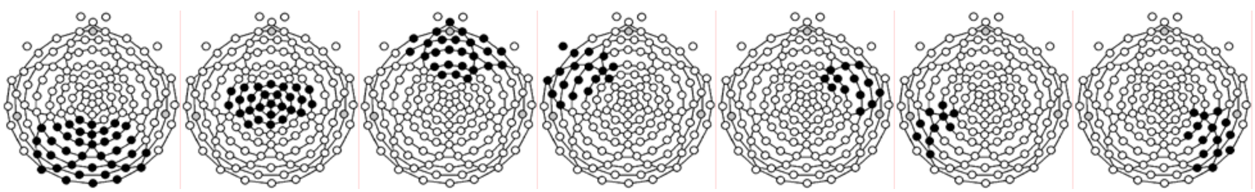
Temporal Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	66.30	41.44	41.44
Factor 2	47.83	29.89	71.33
Factor 3	27.20	17.00	88.33



Spatial Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	26.25	20.34	20.34

Factor 2	18.63	14.44	34.79
Factor 3	17.84	13.83	48.62
Factor 4	11.57	8.971	57.59
Factor 5	10.15	7.87	65.47
Factor 6	10.13	7.85	73.32
Factor 7	7.10	5.50	78.83
Factor 8	2.56	1.99	80.82
Factor 9	1.91	1.48	82.30
Factor 10	1.72	1.33	83.64
Factor 11	1.40	1.08	84.73

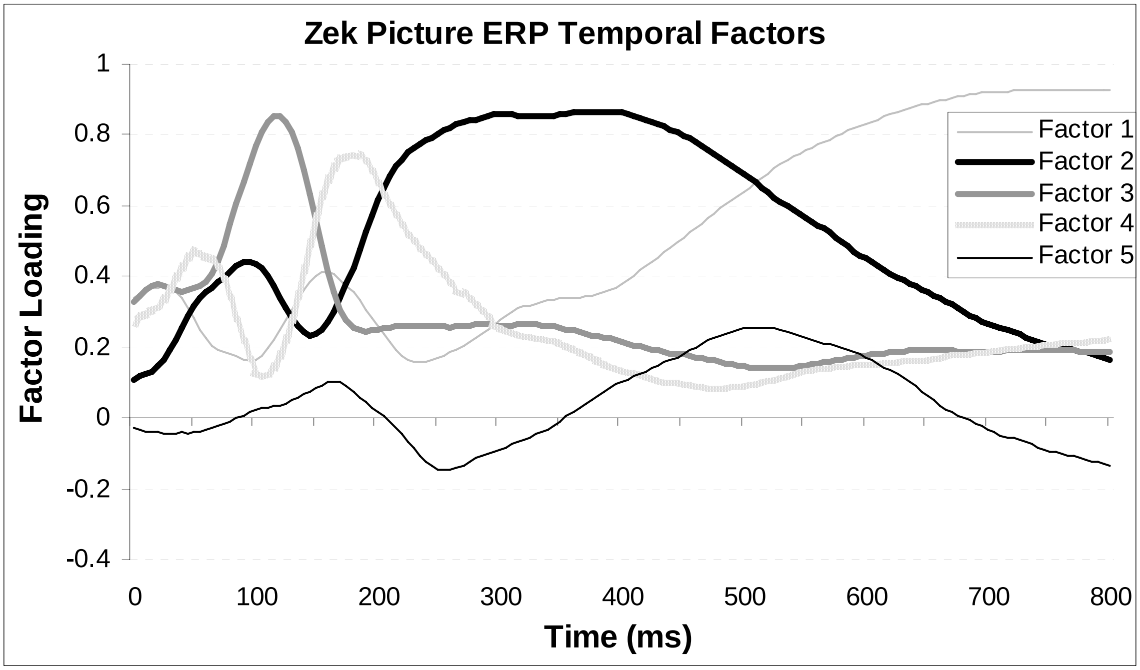
Spatial Factors



Independent Variable	dF	F	p
Test Time	1, 40	4.56	<.05
Hom x Time x Lex x Comp	6, 240	5.20	<.05
Freq x Time x Spatial x Lex x Comp	6, 240	3.50	<.005
Temporal x Spatial	6, 240	8.43	<.00001
Time x Spatial	6, 240	2.19	<.05
Time x Spatial x Lex x Comp	6, 240	2.41	<.05

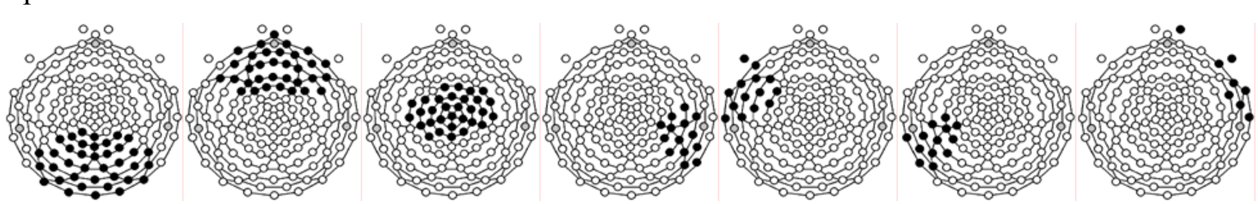
Zek Pictures

Temporal Analysis	Rescaled Eigenvalue	%Variance Explained	Cumulative Variance
Factor 1	56.73	35.23	35.23
Factor 2	54.57	33.89	69.13
Factor 3	16.63	10.33	79.46
Factor 4	15.30	9.50	88.97
Factor 5	2.48	1.54	90.51



Spatial Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	30.62	23.74	23.74
Factor 2	25.54	19.80	43.54
Factor 3	20.04	15.53	59.08
Factor 4	9.83	7.62	66.70
Factor 5	9.43	7.31	74.01
Factor 6	8.78	6.81	80.82
Factor 7	6.04	4.68	85.51
Factor 8	1.71	1.33	86.84
Factor 9	1.49	1.16	88.00

Spatial Factors

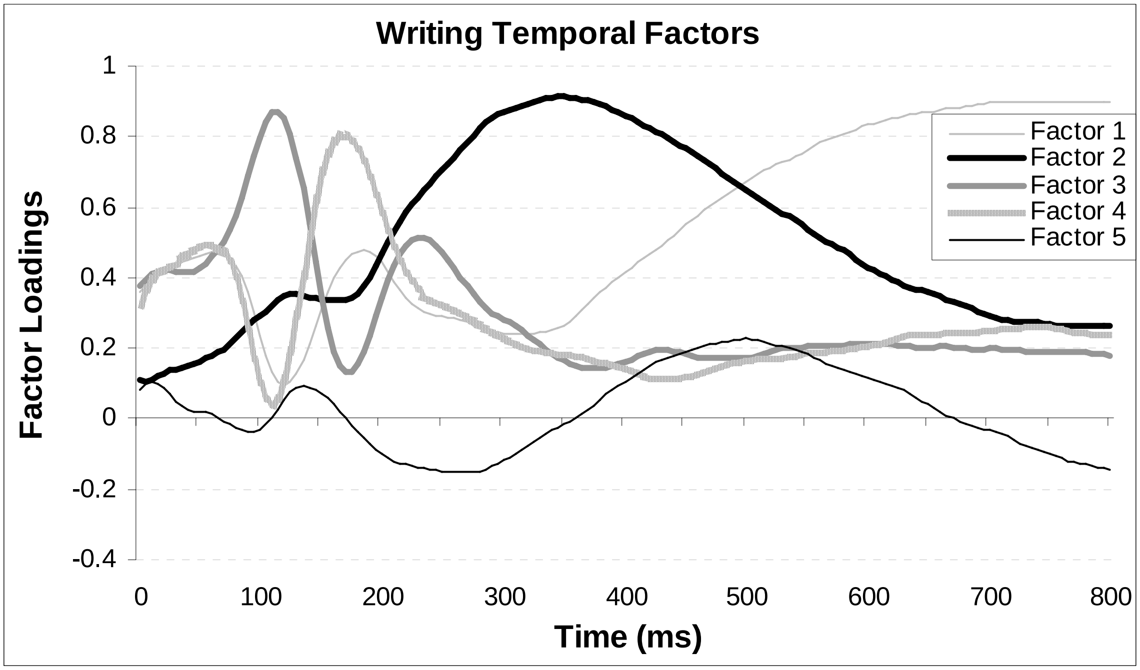


Independent Variable	dF	F	p

Temporal Factor	2, 82	25.43	<.00001
Temporal x Spatial	12, 492	13.48	<.00001
Hom x Spatial x Temporal	12, 492	4.96	<.00001
Hom x Comp x Spatial x Temporal	12, 492	2,51	<.05
Freq x Spatial	6, 246	3.86	<.0005
Freq x Temporal	2, 82	7.40	<.005
Freq x Spatial x Lex	6, 246	1.99	<.05
Freq x Spatial x Lex x Comp	6, 246	2.13	<.05
Hom x Freq x Spatial	6, 246	4.30	<.0001
Hom x Freq x Temporal	2, 82	20.69	<.00001
Hom x Freq x Spatial x Temporal	12, 492	22.00	<.00001
Hom x Freq x Lex x Spatial	6, 246	3.05	<.005
Hom x Freq x Lex x Temporal x Spatial	12, 492	2.36	<.005
Time x Lex x Comp	1, 41	7.54	<.01
Hom x Freq x Time x Lex x Temporal x Spatial	12, 492	1.86	<.05
Hom x Freq x Time x Lex x Comp	1, 41	4.42	<.04
Temporal x Comp	2, 82	5.46	<.01
Temporal x Spatial x Comp	12, 492	1.69	<.05
Spatial xLex x Comp	6, 246	2.08	<.05

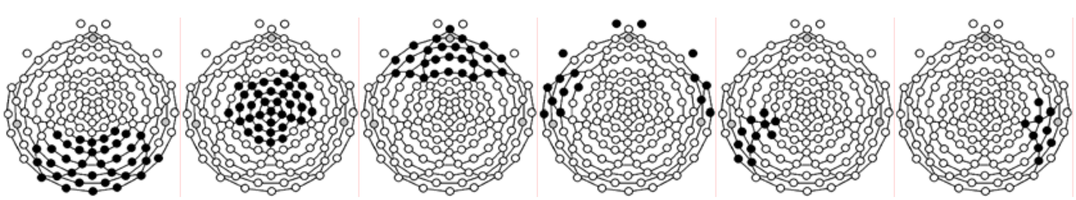
Writing

Temporal Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	58.85	36.55	36.55
Factor 2	50.81	31.56	68.11
Factor 3	18.36	11.40	79.52
Factor 4	16.88	10.48	90.014
Factor 5	2.25	1.39	91.41



Spatial Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	28.28	21.92	21.92
Factor 2	27.78	21.53	43.46
Factor 3	22.73	17.62	61.08
Factor 4	15.07	11.68	72.77
Factor 5	7.85	6.08	78.86
Factor 6	6.66	5.16	84.02
Factor 7	1.79	1.39	85.41
Factor 8	1.74	1.35	86.76
Factor 9	1.25	0.97	87.74

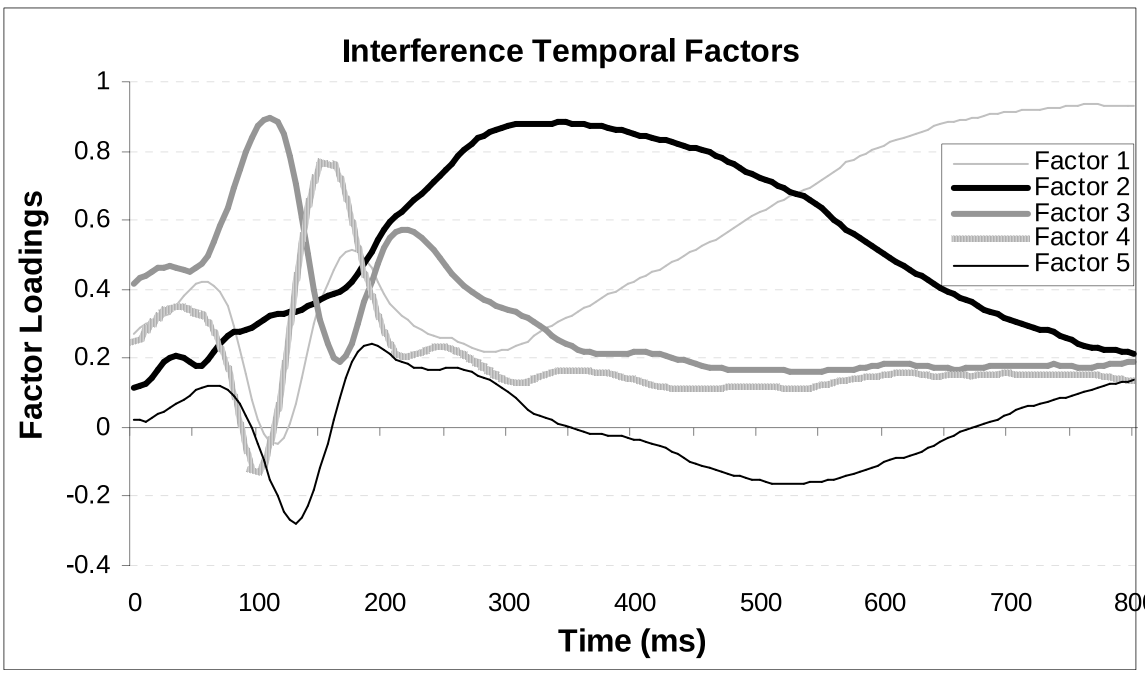
Spatial Factors



Independent Variable	dF	F	p
Temporal Factor	2, 78	10.86	<.0001
Temporal Factor x Spatial Factor	10, 390	34.20	<.00001
Writing x Spatial	5, 195	10.05	<.00001
Writing x Temporal	2, 78	20.66	<.00001
Writing x Spatial x Temporal	10, 390	6.25	<.00001
Writing x Time x Comp	1, 39	5.82	<.05
Time x Lex x Spatial	5, 195	2.87	<.05
Comp x Temporal	2, 78	4.38	<.05

Nonlinguistic interference

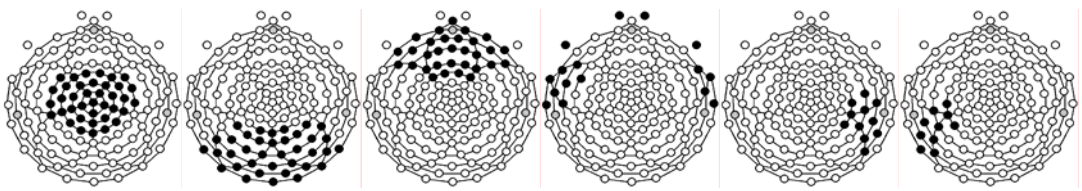
Temporal Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	57.10	35.46	35.46
Factor 2	55.79	34.65	70.12
Factor 3	21.30	13.23	83.35
Factor 4	9.77	6.07	89.42
Factor 5	2.38	1.48	90.91



Spatial Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	28.83	22.35	22.35

Factor 2	28.45	22.05	44.41
Factor 3	23.80	18.45	62.86
Factor 4	13.38	10.37	73.23
Factor 5	7.60	5.89	79.13
Factor 6	7.19	5.57	84.71
Factor 7	2.11	1.63	86.34
Factor 8	1.78	1.38	87.73

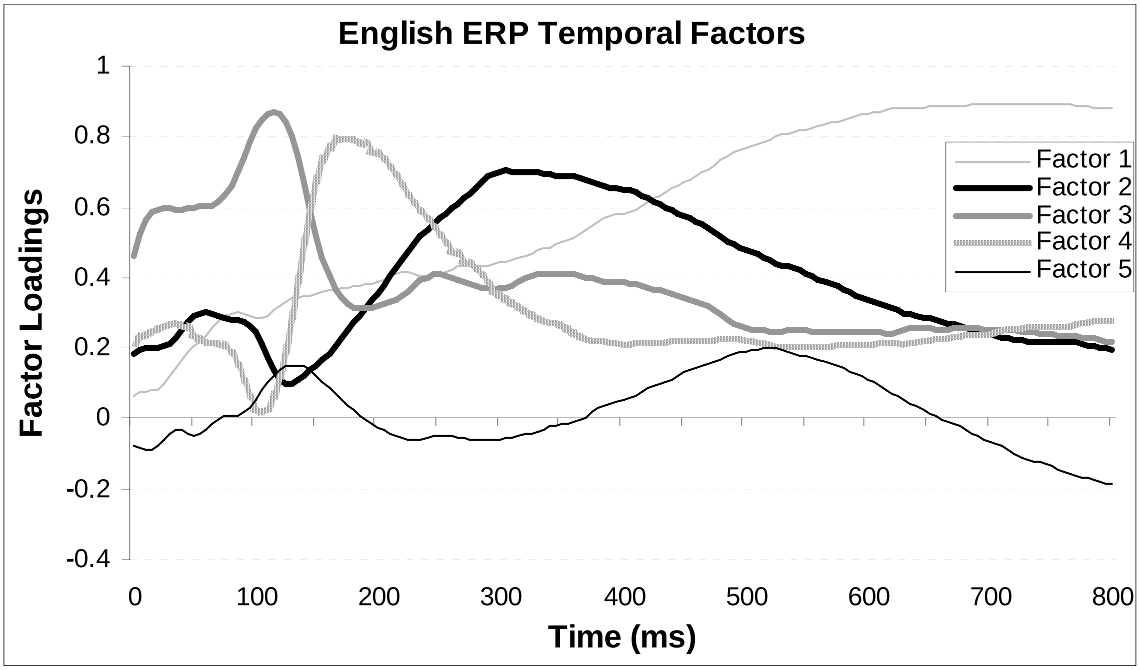
Spatial Factors



Independent Variable	dF	F	p
Temporal Factor	2, 78	10.85	<.0001
Test Time	1, 39	16.96	<.0005
Temporal x Spatial	10, 390	29.94	<.00001
Interference x Spatial	5, 195	1,91	<.05
Interference x Comp	1, 39	4.19	<.05
Interference x Time x Comp x Temporal x Spatial	10, 390	2.44	<.01
Time x Temporal x Lex	2, 78	3.43	<.05
Time x Temporal x Comp	2, 78	4.05	<.05
Time x Spatial x Comp	5, 195	3.26	<.01
Spatial x Lex x Comp	5, 195	3.25	<.01

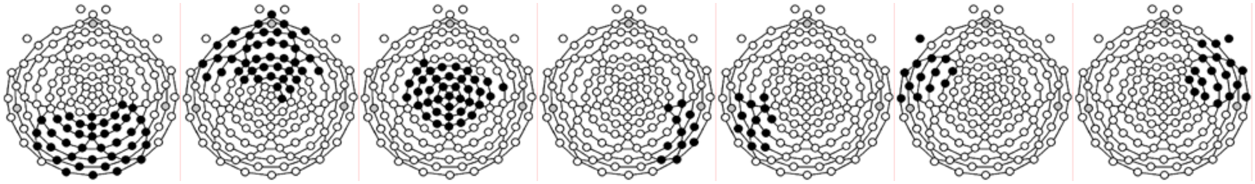
English words

Temporal Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	66.45	41.27	41.27
Factor 2	30.49	18.94	60.21
Factor 3	27.30	16.95	77.17
Factor 4	19.90	12.36	89.53
Factor 5	1.74	1.08	90.62



Spatial Analysis	Rescaled Eigenvalue	% Variance Explained	Cumulative Variance
Factor 1	25.17	19.51	19.51
Factor 2	24.03	18.63	38.15
Factor 3	20.61	15.97	54.13
Factor 4	9.45	7.33	61.46
Factor 5	8.46	6.56	68.02
Factor 6	8.15	6.31	74.34
Factor 7	7.79	6.04	80.38
Factor 8	2.33	1.81	82.19
Factor 9	1.87	1.45	83.64
Factor 10	1.80	1.40	85.04
Factor 11	1.70	1.32	86.37
Factor 12	1.42	1.10	87.47

Spatial Factors



Independent Variable	dF	F	p
Temporal x Spatial	12, 492	6.63	<.00001
Hom x Freq x Comp	1, 41	4.44	<.05
Freq x Lex x Comp x Temporal	2, 82	3.11	<.05

BIBLIOGRAPHY

Akamatsu, N. (2002). A similarity in word-recognition procedures among second language readers with different first language backgrounds. Applied Psycholinguistics, 23, 117-133.

Alvarez, R. P., Holcomb, P. J., & Grainger, J. (2003). Accessing word meanings in two languages: An event-related brain potential study of beginning bilinguals. Brain and Language, 87, 290-304.

Balass, M., & Hart, L. A. (in preparation). Training lexical quality: brain and behavioral responses.

Breznitz, Z., & Misra, M. (2003). Speed of processing of the visual-orthographic and auditory-phonological systems in adult dyslexics: The contribution of "asynchrony" to word recognition deficits. Brain and Language, 85, 486-502.

Brown, J. I., Bennett, J. M., & Hanna, G. (1981). The Nelson-Denny Reading Test: Examiner's Manual. Chicago, IL: Riverside Publishing.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. Journal of Educational Psychology, 96, 31-42.

Coltheart, M. (1981). The MRC Psycholinguistic Database. Quarterly Journal of Experimental Psychology, 33, 497-505. http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm.

Dufva, M., & Voeten, M. J. M. (1999). Native language literacy and phonological memory as prerequisites for learning English as a foreign language. Applied Psycholinguistics, 20, 329-348.

Elbaum, B., Vaughn, S., Hughes, M. T., & Moody, S. W. (2000). How effective are one-to-one tutoring programs in reading for elementary students at risk for reading failure? A meta-analysis of the intervention research. Journal of Educational Psychology, 92, 605-619.

Federico, P. A. (1984). Event-related potential (ERP) correlates of cognitive styles, abilities and aptitudes. Personality and Individual Differences, 5, 575-585.

Fender, M. (2003). English word recognition and word integration skills of native Arabic- and Japanese-speaking learners of English as a second language. Applied Psycholinguistics, 24, 289-315.

Ferree, T. C., Luu, P., Russell, G. S., & Tucker, D. M. (2001). Scalp electrode impedance, infection risk, and EEG data quality. Clinical Neurophysiology, 112, 536-544.

Gernsbacher, M.A. (1990). Language Comprehension as Structure Building. Hillsdale, NJ: Lawrence Erlbaum Asociates.

Gernsbacher, M.A., & Faust, M. (1991). The mechanism of suppression: A component of general comprehension skill. Journal of Experimental Psychology: Learning, Memory, and Cognition, 17, 245-262.

Gernsbacher, M.A., Varner, K.R., & Faust, M. (1990). Investigating differences in general comprehension skill. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 430-445.

Gough, P. B., Hoover, W. A., & Peterson, C. L (1996). Some observations on a simple view of reading. In Cornoldi, C. & Oakhill, J. (Eds). Reading Comprehension Difficulties: Processes and Intervention. Mahwah, NJ: Lawrence Erlbaum Associates.

Guyer, B. P., & Sabatino, D. (1989). The effectiveness of a multisensory alphabetic phonetic approach with college students who are learning disabled. Journal of learning disabilities, 7, 430-434.

Hanna, P. R., Hanna, J. S., Hodges, R. E., & Rudorf, E. H. (1966). Phoneme-Grapheme Correspondences ad Cues to Spelling Improvement. Washington, D. C: U.S. Department of Health, Education, & Welfare.

Hoover, W. A., & Gough P. B. (1990). The simple view of reading. Reading and Writing: An Interdisciplinary Journal, 2, 127–160.

Juel, C., Griffith, P L., & Gough, P B. (1986). Acquisition of Literacy: A longitudinal study of children in first and second grave. Journal of Educational Psychology, 78, 243-255.

Kazmerski, V. A., Blasko, D. G., & Banchiamlack, G. D. (2003). ERP and behavioral evidence of individual differences in metaphor comprehension. Memory and Cognition, 31, 673-689.

Kramer, J. H., Knee, K., & Delis, D. C. (2000). Verbal memory impairments in dyslexia. Archives of Clinical Neuropsychology, 15, 83-93.

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

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). Introduction to Latent Semantic Analysis. Discourse Processes, 25, 259-284. http://lsa.colorado.edu/.

Lehmann, D., & Skrandies, W. (1980). Reference-free identification of components of checkerboard-evoked multi-channels potential fields. Electroencephalography and Clinical Neurophysiology, 48, 609-621.

Long, D. L., Oppy, B. J., & Seely, M. R. (1997). Individual differences in readers' sentence and text-level representations. Journal of Memory and Language, 36, 129-145.

Mazur, J. E., & Hastie, R. (1978). Learning as accumulation: A re-examination of the learning curve. Psychological Bulletin, 85, 1256-1274.

McCandliss, B. D., Posner, M. I., & Givon, T. (1997). Brain plasticity in learning visual words. Cognitive Psychology, 33, 88-110.

Miller-Guron, L. & Lundberg, I. (2000). Dyslexia and second language reading: A second bite at the apple? Reading and Writing: An Interdisciplinary Journal, 12, 41-61.

Molfese, D. L., Molfese, V. J., Key, S., Modglin, A., Kelley, S., & Terrell, S. (2002). Reading and cognitive abilities: Longitudinal studies of brain and behavior changes in young children. Annals of Dyslexia, 52, 99-119.

Nassaji, H., & Geva, E. (1999). The contribution of phonological and orthographic processing skills to adult ESL reading: Evidence from native speakers of Farsi. Applied Psycholinguistics, 20, 241-267.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1998). The University of South Florida word association, rhyme, and word fragment norms. http://www.usf.edu/FreeAssociation/.

Oakhill, J., Cain, K., & Yuill, N. (1998). Individual differences in children's comprehension skill: Toward an integrated model. Mahwah: Lawrence Erlbaum Associates.

Perfetti, C. A., Beck, I., Bell, L. C., & Hughes, C. (1987). Phonemic knowledge and learning to read are reciprocal: A longitudinal study to first grade children. Merrill-Palmer Quarterly, 33, 283-319.

Perfetti, C.A., & Hart, L.A. (2002). Lexical basis of comprehension skill. In Gorfein, D. (Ed.). On the consequences of meaning selection. American Psychological Association.

Perfetti, C. A., Wlotko, E. W., & Hart, L. A. (under review). Word learning and individual differences in word learning reflected in ERPs. Submitted to Journal of Experimental Psychology: Learning, Memory and Cognition.

Pulido, D. (2003). Modeling the role of second language proficiency and topic familiarity in second language incidental vocabulary acquisition through reading. Language Learning, 53, 233-284.

Rudell, A. P., & Hua, J. (1997). The recognition potential, word difficulty, and individual reading ability: On using event-related potentials to study perception. Journal of Experimental Psychology: Human Perception and Performance, 23, 1170-1195.

Shucard, D. W., & Horn, J. L. (1973). Evoked potential amplitude change related to intelligence and arousal. Psychophysiology, 10, 445-452.

Sinai, A., & Pratt, H. (2002). Electrophysiological evidence for priming in response to words and pseudowords in first and second language. Brain and Language, 80, 240-252.

Squires, K. C., Wickens, C., Squires, N. K., & Donchin, E. (1976). The effect of stimulus sequence on the waveform of the cortical event-related potential. Science, 193, 1976, 1142-1146.

St. George, M., Mannes, S., & Hoffman, J. E. (1997). Individual differences in inference generation: An ERP analysis. Journal of Cognitive Neuroscience, 9, 776-787.

Stanovich, K. E., & Cunningham, A. E. (1993). Where does knowledge come from? Specific associations between print exposure and information acquisition. Journal of Educational Psychology, 85, 211-229.

Van Gelderen, A., Schoonen, R., de Glopper, K., Hulstijn, J., Simis, A., Snellings, P., & Stevenson, M. (2004). Linguistic knowledge, processing speed, and metacognitive knowledge in first- and second-language reading comprehension: A componential analysis. Journal of Educational Psychology, 96, 19-30.

Verhoven, L. (2000). Components in early second language reading and spelling. Scientific Studies of Reading, 4, 313-330.

Wade-Woolley, L., & Siegel, L. S. (1997). The spelling performance of ESL and native speakers of English as a function of reading skill. Reading and Writing: An Interdisciplinary Journal, 9, 387-406.

Winkler, I., Kujala, T., Titinen, H., Sivonen, P., Alku, P., Lehtokoski, A., Czigler, I., Csepe, V., Ilmoniemi, R. J., & Naatanen, R. (1999). Brain responses reveal the learning of foreign language phonemes. Psychophysiology, 36, 638-642.