DEVELOPING AN ALPHASYLLABARY FOR ENGLISH

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This research explored our predictions that a syllable-based orthography of English (i.e., an alphasyllabary) is: 1) learnable and 2) easier to read than a phoneme-based orthography of English. To examine this, we developed a novel orthography of English (called Faceabary) that utilizes face-graphemes, which correspond to syllables in the English language. We trained 16 individuals (6 males, 10 females) on how to read our new orthography. After the training phase, participants decoded words and read stories that had been transcribed into Faceabary. Reading fluency rates for this orthography were then compared to reading fluency rates for the phoneme-based orthography called FaceFont. We found that Faceabary is learnable, but that it does not appear to have an advantage over FaceFont except between Level 2 and Level 3 stories. Our findings suggest that Faceabary and FaceFont yield different decoding strategies. This research has implications for improving reading skills for individuals with dyslexia and alexia.

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PREFACE

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1.0 INTRODUCTION

1.1 ENGLISH IS A DIFFICULT ORTHOGRAPHY TO READ

The rules for representing a language in its written form vary across languages. The set of symbols that makes reading and writing possible is referred to as "orthography." Orthographies allow for reading acquisition by visually representing a language and its respective phonological mappings. The type of orthography that a language adopts is highly contingent upon both the morphological and the phonological characteristics of that language. Morphological characteristics pertain to the visual representation / structure of words in a language, while phonological characteristics pertain to the organization of speech units in a language. There are many factors that affect the ease with which one can acquire or learn a language. These factors are associated with differences in 1) the rules / structure of the written orthography itself, i.e., transparency and granularity, and 2) the spoken language, i.e., phonological complexity.

One determiner of an orthography's readability is its transparency: Any given orthography adheres to its own rules for associating graphemes with speech units. If the orthographic-phonological mappings in a language are a direct 1:1 relationship (i.e., the pronunciation of the graphemes is always the same), then that orthography is defined as shallow, or transparent. Transparent languages include Italian and Finnish. If the grapheme-phoneme mappings in a language are inconsistent, then that orthography is defined as deep, or opaque.

English, for example, is an opaque orthography, such that its graphemes do not consistently inform its pronunciation (Odisho, 2007) (e.g., there are a number of possible pronunciations of its vowels: The vowel sounds in *fair* / *fare* sound the same whereas the vowel sounds in *ton* / *con* do not) (Siegel & Faux, 1989)).

Another way in which orthographic scripts differ is in grain size. Orthographies can be alphabetic, syllabic, or logographic. The grain size of these scripts, then, refers to the size of the individual units that form words. An alphabetic orthography represents the relationship between a letter and its corresponding phoneme; a syllabic orthography between a grapheme and its corresponding syllable; a logographic orthography between a symbol and a corresponding word or morpheme, which is the smallest meaningful unit in a language. In an alphabetic language, the grain size is relatively small, or fine. In a syllabic or logographic language, the grain size is relatively large, or coarse (Katz & Frost, 1992). Orthographies that rely on smaller grain sizes are generally more inconsistent than those orthographies that rely on larger grain sizes (Pagliuca & Monaghan, 2010).

A third way in which orthographies differ is dependent on the demands of the phonological complexity of the spoken language. Languages that are phonologically simple contain syllables that are either a consonant-vowel (CV) combination or a stand-alone vowel (V). Languages with moderate phonological complexity may also contain CVC and CCV combinations. For those languages that are phonologically complex, like English, even longer combinations are common (e.g., CCCV, CCVC, CVCC, VCC, etc.). The phonological complexity of an English word may also refer to the number of consonant clusters it contains (Snowling, 1981). In a language with many clusters and blends, the visual representation of more phonologically complex words may prove difficult depending on the number of phonemic units represented.

All of these factors affect learnability across orthographies. The main way that individuals learn to read words is through decoding, i.e. producing a blend of sounds from a combination of letters (Ehri, 1998). Decoding skills, although they vary with the consistency of the orthography, are essential in reading and their mastery can make the difference between a strong reader and a weak reader (Snowling, 1981; Georgiou, Parrila, & Papadopoulos, 2008). Children learning to read consistent orthographies are likely to develop grapheme-phoneme decoding skills more quickly than children learning to read inconsistent orthographies (Goswami, 2002). Thus, the English orthography would be more difficult to learn how to read than the Italian orthography. Compared to less complex orthographies, like in Italian, both the irregularity and the phonological complexity of English make the language difficult to read (Siegel & Faux, 1989). When decoding unfamiliar words in English, the reader typically relies on prior orthographic knowledge, which allows him to successfully convert letters into sounds (Ehri, 1998).

Decoding is an especially challenging task for individuals with reading disorders like dyslexia. Dyslexia is a developmental disorder that is characterized specifically by impairments in spelling and reading (Schulte-Kome, 2010) that are not associated with poor vision or hearing, low intelligence, or a lack of educational opportunities (Wydell & Butterworth, 1999). Readers with dyslexia (and other individuals who struggle with reading) have trouble with decoding, in particular, due to both diminished phonological awareness (Dietz, 2002) and an inability to phonologically represent words in the mental lexicon (Swan & Goswami, 1997; Patel, Snowling, & de Jong, 2004). These insufficiencies lead to a deficit in grapheme-phoneme conversion (i.e., decoding) (Zaretsky, Kraljevic, Core, & Lencek, 2009). Words with multiple syllables and consonant clusters, of which English has many, are especially difficult for individuals with dyslexia to spell and read (Snowling, 1981).

It is not surprising, then, that dyslexia is more common among readers of opaque orthographies than of transparent orthographies: 10% of children have dyslexia in the United States compared to 1% of children in Japan. Dietz explains that the degree of dyslexia positively correlates to the respective orthographic system's degree of inconsistency and its demands on phonological processing (2002). These ideas are also consistent with the orthographic depth hypothesis, which suggests that "[transparent versus opaque] orthographies should be easier to read using word-recognition processes that involve the language's phonology" (Ellis, Natsume, Stavropoulou, Hoxhallari, Van Daal, Polyzoe, Tsipa, & Petalas, 2004), and with the hypothesis of granularity and transparency (Wydell & Butterworth, 1999)). This hypothesis states that 1) high incidences of phonological dyslexia will not be present in consistent orthographies and 2) high incidences of phonological dyslexia will not be present if the grain size of the orthography is coarse. The case study of AS, a sixteen-year-old Japanese-English bilingual / biscriptal with dyslexia in only English, lends support to the ideas proposed by the orthographic depth and granularity / transparency hypotheses, as he only displayed impairment in tasks in English that required phonological manipulation, but not in Kana (a transparent syllabary) or Kanji (a logographic system) (Wydell & Butterworth, 1999).

An alternative hypothesis suggests that the grain size of an orthography does not affect reading acquisition. According to the grain size theory, coarse grain sizes are not any simpler to read than fine grain sizes because smaller subunits must be accessed in order to read larger grain size orthographies. Unlike the orthographic depth and transparency hypotheses, the theory also suggests that an opaque orthography is not any more difficult to acquire than a transparent one because both require phonological sensitivity, which is crucial for reading acquisition. Thus, dyslexia is not more prevalent in one orthography or another; however, its manifestation is different for each type of orthography (Ziegler & Goswami, 2005).

All of these things considered, the English language, represented by an opaque orthography with a fine grain size and high phonological complexity, is among the hardest of languages to learn to read (Pagliuca & Monaghan, 2010; Odisho, 2007; Siegel & Faux, 1989). But must it be so difficult? Given what we know about differences in orthographies and acquisition rates, one would think that there should be a way to simplify the English orthography, thus, making it easier to learn and read.

1.2 THE VISUAL WORD FORM AREA

The visual word form area (VWFA), located in the left fusiform gyrus of the brain, is essential for reading acquisition due to its ability to recognize letters (Dehaene & Cohen, 2011; Dien, 2009) and its sensitivity to the "orthographic regularity by which letters form words" (McCandliss, Cohen, & Dehaene, 2003). When compared to typical readers, dyslexic readers exhibit less VWFA activation during phonological processing and word reading. This is thought to be due to poor grapheme-phoneme conversion skills (Desroches, Cone, Bolger, Bitan, Burman, & Booth, 2010).

Poor functioning of the VWFA is not a hallmark of only phonological dyslexia. Damage to the VWFA can also cause a reading disorder called alexia (Gaillard, Naccache, Pinel Clémenceau, Volle, Hasboun, Dupont, Baulac, Dehaene, Adam, & Cohen, 2006). This disorder is characterized by a loss of acquired advanced reading skills, coupled with a maintenance of both spelling ability and speech comprehension and production. In other words, alexic readers are unable to read whole words; rather, they employ a letter-by-letter reading strategy (Montant & Behrmann, 2000). During this strategy, it is believed that the right-hemispheric VWFA receives the visual input and transfers the letters to the left hemisphere, where the whole word can be recognized (Cohen, Henry, Dehaene, Martinaud, Lehericy, Lemer, & Ferrieux, 2004).

One unexplained phenomenon about the VWFA is that activation lateralization differs across languages, and that it is contingent upon both the writing system and the native language of the reader. English and other alphabets are mostly left lateralized, while Chinese is bilateral (Nelson, Liu, Fiez, & Perfetti, 2009). The reasons for such differences between qualitatively distinct languages like English and Chinese could lie in the languages' visual and / or linguistic characteristics. Visually, English words differ from Chinese words in that they are made up of individual letters that are processed serially, whereas Chinese words are represented by a single character symbol, thought to be processed more spatially. Linguistically, English words are formed by stringing together letters that correspond to phonemes. Conversely, Chinese characters are a combination of strokes that cannot be broken into smaller components and that do not correspond to phonemes. The whole character can stand alone: It has its own pronunciation and meaning. The pronunciation of Chinese characters operates at the syllable level rather than at the phoneme level.

There are two different accounts that attempt to explain the left lateralization of the VWFA in English and other alphabets: 1) the phonological bridge account claims that the VWFA is left-lateralized because it must connect left-lateralized language areas to visual units, and 2) the visual-perceptual account attributes orthographic processing to the fact that printed words require processing that differs for stimuli that are perceptually different (Moore, Durisko, Perfetti, & Fiez, under review).

1.3 FACEFONT STUDY

In an attempt to tease apart the phonological and perceptual influences on VWFA lateralization, the FaceFont writing system was developed by Moore et al. (under review). The visual-perceptual account of VWFA lateralization focuses on the idea that orthographic processing of printed words requires high-spatial frequency analysis, which is not necessarily limited to the left hemisphere (Moore et al., under review). Since faces tend to be processed holistically in the right hemisphere (Dien, 2009; Zhang, Li, Song, & Liu, 2012), face graphs were chosen as stimuli for the novel alphabet. The phonological bridge account claims that the VWFA is left lateralized because it must connect the left-lateralized speech / phonological language areas to visual units in order to open access to stored word knowledge. Thus, it would predict that an alphabet, requiring phonological decoding, would engage the left hemisphere even when it uses visual forms for letters that do not rely upon left-hemispheric visual perceptual processes. To pit these two hypotheses against each other, an alphabet using face-graphs was developed. The FaceFont alphabet is comprised of face images that are mapped onto English phonemes.

The study of Moore et al. suggested that, while the FaceFont graphemes activated the right fusiform, the resultant learning effects were observed only in the left fusiform (under review). The finding speaks both to the phonological bridge account of the VWFA and to the ability of the VWFA to become activated in response to varying stimuli.

The researchers were then curious as to whether training alexic individuals to read FaceFont was possible, and if so, whether the orthography might elicit more effortless reading strategies from alexic readers, who engage a letter-by-letter reading strategy due to acquired VWFA damage. A case study of AA1, a 68-year-old female with acquired alexia, was conducted to determine whether she was able to learn FaceFont. AA1 performed age-appropriately on tests of memory, general intelligence, reading comprehension, and phonological processing; however, AA1 performed poorly on the reading fluency task. AA1's alexia symptoms were confirmed upon finding a positive direct correlation between her reading latency and word length.

A previous study regarding FaceFont learnability demonstrated that healthy, young adults can learn the 35 face-phoneme pairings with 90% accuracy in two hours. Contrarily, AA1 remembered significantly fewer pairings and demonstrated subpar decoding ability compared to controls. She did not demonstrate deficits in either face recognition or phonological awareness tasks, however (Moore, Brendel, & Fiez, under review).

After an additional four months, the training protocol was changed to incorporate larger phonological units. AA1 was taught three subsets of five face-syllable pairings and could learn all 15 pairs as well as blend the pairs to make words (Moore et al., under review). This finding suggests that the VWFA is less essential when the grain size is larger (i.e., when the grapheme represents a syllable versus a phoneme).

1.4 CURRENT STUDY

The current study investigates whether reading English at the syllable versus the phoneme level is: 1) possible with a newly-developed, syllabic writing system and 2) easier since syllables are more natural and instinctive for people to produce and perceive (Goswami, 2002). Gleitman et al. suggest that a syllabary should only be used as a preliminary reading strategy to teach young children. They argue that there are far too many syllables in the English language to develop an extensive syllabary. It makes more sense, as far as memory capacity is concerned, to represent English using the 26 letters of the alphabet (Gleitman & Rozin, 1973).

Based on the results of the AA1 study, however, we predict that a face-alphasyllabary is learnable. Unlike the English alphabet, our novel "Faceabary" represents syllables rather than phonemes. Alphabets and syllabaries are similar in that they represent orthographic-phonological mappings, but a key difference is that the phoneme is abstract in comparison to the syllable (Gleitman & Rozin, 1973). For this reason, it is more challenging for children to learn alphabetic systems than it is for them to learn syllabic systems. Furthermore, children struggle with blending phonemes during reading due to their inability to separate the consonant sound from the succeeding vowel that is inherent in human speech (e.g., one cannot pronounce the phoneme *b* without saying *–uh*). In other words the consonant "cannot be isolated…it is recognizable only in the context of a vowel" (Gleitman & Rozin, 1973). Lacking the ability to separate the two sounds, children cannot access relevant stored word knowledge (Gleitman & Rozin, 1973), for it is not until later in development that an individual becomes aware of the concept of a phoneme (Goswami, 2002).

There is evidence to suggest that the syllable is also the more natural unit of speech representation. There is a very low illiteracy rate in Japan, a country that uses a syllabary and logographs. There are also reports of very low illiteracy rates among Native American tribes that use a syllabic writing system (Gleitman & Rozin, 1973). Due to the decreased decoding demands of a syllabary, we predict similar or more fluent reading in Faceabary than in FaceFont.

2.0 METHOD

2.1 PARTICIPANTS

Sixteen undergraduate students (6 males, 10 females) in the psychology subject pool at the University of Pittsburgh (*M* Age = 20.6 years, *SD* = 1.7) participated in recall and decoding tasks that would prepare them to read, in English, stories comprised of face-graphs.

All participants were native English speakers and completed initial screening, which showed that all participants were within the normal range for decoding and comprehension. All participants provided informed consent and were compensated for their time.

2.2 MATERIALS

The purpose of this study is to determine whether reading English at the syllable level is possible and whether it is easier than reading English at the phoneme level. To test this assumption, we developed a Faceabary of English. The participants learned and applied the alphasyllabary in order to decode beginner-level stories (written for young children) from the series, *Now I'm Reading!* (Gaydos, 2003).

2.3 MATERIAL DEVELOPMENT

Instead of using letters as graphemes, Faceabary utilizes pictures of human faces (*see sample face stimuli in Appendix A*). These face-graphs represent either a CV or a VC syllable, e.g. [a m] or [m a] (*see LAI-PA Tables 1.1 & 1.2*). The face identity represents the consonant component, while the expression represents the vowel component. We assigned these components to each face in a consistent fashion. For example, face identity 38 represents the /p/ phoneme; the happy-excited expression represents the /O/ phoneme. When one sees face identity 38 with the happy-excited expression, he knows that this face graph represents the syllable [p O] (*refer to Faceabary Table 2.1*).

Table 1.1. LAI-PA: Vowels

Example Word	IPA	LAI-PA
cat	æ	@
sale/say	e/eɪ	e
bed	ɛ	E
cheap	i	i
hit	ɪ	I
mile	aɪ	Y
law/father	ɔ/ɑ	a
now	aʊ	W
no	o/oʊ	o
boy	oɪ	O
gum/the	ʌ/ə	x
put	ʊ	U
soothe	u	u

Table 1.2. LAI-PA: Consonants

Example Word	LAI-PA
boot	b
cat/**k**it	k
church	C
dog	d
fog	f
get	g
hot	h
jet/**g**enre	j
lot	l
man	m
no	n
put	p
rat	r
sit	s
shirt	S
toy	t
this	T
vest	v
water	w
yellow	y
zebra	z
si**ng**	G

Table 2.1 Faceabary: Face-syllable mapping

LAI-PA	p	b	t	d	k	g	C	j	T	s	z	S	f	v	h	m	n	y	w	r	l	Facial Expression
@	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	NE_C
e	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	DI_O
E	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	SP_O
i	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	SA_O
I	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	AN_C
Y	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	AN_O
a	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	FE_O
W	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	HA_C
o	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	HA_O
O	38	39	40	41	42	43	20	28		30	31		34	36	37	21	22	23		26	33	HA_X
X	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	NE_O
U	38	39	40	41	42	43		28		30		32	34		37	21	22	23	24	26	33	CA_O
u	38	39	40	41	42	43	20	28	29	30	31	32	34	36	37	21	22	23	24	26	33	SA_C

Table 2.1. This table shows the face-grapheme that was assigned to each syllable. The vowels are listed down the y-axis; the consonants are listed across the x-axis. The numbers* (i.e., the face identity) in the boxes represent the syllable's consonant component, and the facial expressions** indicate the syllable's vowel component.
*Numbers 38, 39, 40, 41, 42, and 43 = Black male faces. Numbers 20, 28, 29, 30, 31, 32, 34, 36, and 37 = White male faces with brown eyes. Numbers 21, 22, 23, 24, 26, and 33 = White male faces with blue eyes.
*The facial expressions follow this naming method: facialexpression_mouthing.
The abbreviations for the facial expressions are defined as follows: NE = neutral, DI = disgusted, SP = surprised, SA = sad, AN = angry, FE = fear, HA = happy, CA = calm.
The abbreviations for the mouthings are defined as follows: C = closed, O = open, X = excited (i.e., wide open mouth).
E.g., NE_C = neutral facial expression, with mouth closed.

Faceabary consists of face-graphs that are organized into two tables. The first was created to represent all CV syllable of the English language (Table 2.1), with consonants listed across the x-axis and vowels listed down the y-axis. The consonants were divided into three groups: stops (consonants that involve complete closure of the vocal tract), fricatives (consonants that are produced through a narrow opening), and liquids (consonants produced with almost no blockage of the vocal tract). Only male faces were used in the first grid. We decided that the faces used for each of the three consonant groups would share a certain feature: The stops (e.g., *g*, *p*, *t*) are represented by Black American faces, the fricatives (e.g., *f*, *h*, *s*) are represented by White American faces with brown eyes, and the liquids / nasals (e.g., *l*, *r*, *w*) are represented by White American faces with blue eyes.

In the second Faceabary table (Table 2.2), we used female face identities to represent: 1) common consonant clusters (CCV; e.g., *st*-,*sk*-, *sp*-), 2) common vowel-onset syllables with complex consonant clusters (VCC; e.g., -*ft*, -*kt*, -*ng*), 3) vowels followed by a liquid or nasal (VC; i.e. -*l*, -*n*, - *r*, -*m*), 4) stand-alone vowels, and 5) tense and number markers (e.g., past tense, progressive (-ing), plural, third person singular). The first category of syllables is represented by White American females with light-colored hair and eyes, the second by Asian American females, the third and fourth by Black American females, and the fifth by White American females with darker-colored hair and eyes.

Table 2.2 Faceabary: Face-syllable mapping for complex syllables and tense / number markers

LAI-PA	st	sk	sp	ft	m	ks	ng	kt	_l	_n	_r	Stand-alone Vowels	Facial Expression	Past Tense	Plural	Tense Marker ('s')	ing	Facial Expression
@	1	10	6	15	16	18	17	19	12	13		11	NE_C	9	5	8	2	CA_C
e	1	10	6	15	16	18		19		13	14	11	DI_O					
E	1	10	6	15	16	18		19	12	13		11	SP_O					
i	1	10	6			18		19		13	14	11	SA_O					
I	1	10	6	15	16	18	17	19	12	13		11	AN_C					
Y	1	10	6			18		19	12	13		11	AN_O					
a	1	10	6	15	16	18		19	12	13	14	11	FE_O					
W	1	10	6							13		11	HA_C					
o	1	10	6	15	16	18		19	12		14	11	HA_O					
O			6							13		11	HA_X					
X	1	10	6		16		17		12	13		11	NE_O					
U	1										14		CA_O					
u	1	10	6							13		11	SA_C					

Table 2.2. This table shows the face-grapheme that was assigned to each syllable. The vowels are listed down the y-axis; the consonant clusters are listed across the x-axis (an underscore indicates that the vowel that would precede the consonant cluster). The numbers* (i.e., the face identity) in the boxes represent the syllable's consonant blend, and the facial expressions** indicate the syllable's vowel component.
All tense / number markers (last five columns in table) share one facial expression, i.e. CA_C.
*Numbers 1, 6, and 10 = White female faces with light-colored hair and eyes. Numbers 15, 16, 17, 18, and 19 = Asian female faces. Numbers 11, 12, 13, and 14 = Black female faces.
Numbers 2, 5, 8, and 9 (the tense / number markers) = White female faces with red or brown hair.
**The facial expressions follow this naming method: facialexpression_mouthing.
The abbreviations for the facial expressions are defined as follows: NE = neutral, DI = disgusted,
SP = surprised, SA = sad, AN = angry, FE = fear, HA = happy, CA = calm.
The abbreviations for the mouthings are defined as follows: C = closed, O = open, X = excited (i.e., wide open mouth).
E.g., NE_C = neutral facial expression, with mouth closed.

Determining which facial expressions would be mapped onto which vowel sounds was a more or less arbitrary process. Because some of our facial expressions were not easy to distinguish (e.g., calm versus neutral), similar expressions were not learned by participants on the same day. Expressions that were similar, like calm and neutral, were also mapped onto similar vowels (e.g., /ə/ as in *bud* and /ʊ/ as in *book*). Upon finishing both Faceabary tables, we had a total of 375 face-syllable pairings.

2.4 PILOT STUDY

We created two lists for each day of training and each day of testing: a vowel-centric list (i.e., a list that focused on only one or two vowels), and a consonant-centric list (i.e., a list that focused on a predetermined set of consonants). We then compiled a list of words of varying difficulty for participants to decode with the syllable sounds that they had learned. We generated all of the training and testing scripts as well as the vowel-centric and consonant-centric decoding scripts for each day of decoding as well. This pilot study indicated that learning Faceabary is, in fact, possible despite its relatively high number of face-graphs.

2.5 DESIGN AND PROCEDURE: CURRENT EXPERIMENT

2.5.1 Face-grapheme training

Participants completed a three-week training session that consisted of: face-grapheme testing (days 1-9), face-grapheme recap (days 2-9), and face-grapheme decoding (days 1-10). During the first two weeks of training, participants (good typical readers) learned all 375 face-graphs. In the first five days (i.e., week 1) of training, participants learned CV graphs that focused on two or three new vowel sounds per day from the first Faceabary table (Table 2.1). The face-graphs to be learned were organized by vowel sound due to the structure of our writing system. Participants learned the consonants across the vowels, versus the vowels across the consonants, because it is presumably more difficult to distinguish between the vowels (i.e., the facial expressions that varied slightly between identities) than the consonants (i.e., the face identity that did not change across expressions). The vowel sounds (*refer to Table 1.1*) were grouped as follows: Day 1) *x*, *i*; Day 2) *U*, *a*; Day 3) *I*, *O*, *e*; Day 4) *E*, *o*, *Y*; Day 5) *@*, *u*, *W*. During week 2 of training, participants learned the complex syllables (days 6-8) and the tense / number markers represented in Table 2.2 (day 9). On Day 10, participants reviewed all face-graphemes.

After learning the face-graphs each day, participants took a face-grapheme test in order to demonstrate how accurately they recalled the face-graphs. Following testing, participants decoded face words via single-word reading tests, which were scored for accuracy. Beginning on Day 2, participants also took a face-grapheme recap test each day. The recap test covered all of the faces learned on prior training days.

2.5.2 Training administration

During training, the face-graphemes were presented consecutively to the participants on a computer screen. When a grapheme appeared, the participant was to press a button on the keyboard in order to hear the pronunciation of that grapheme's corresponding syllable. There was no limit to the number of times the participant could listen to each of the graphemes, as one goal of this study is to demonstrate high accuracy, or learnability. All of the face-graphemes to be learned on any given day were referred to as a cycle. The cycle was repeated five times per day. Those participants who did not reach 75% accuracy were allowed to repeat the training.

2.5.3 Word-condition training

In week three, participants completed word tests. The participants were presented with 60 randomized words a day, 20 for each of the following conditions: new words (i.e., face words they had never seen), old words (i.e., face words they had seen on prior word testing days), and non-words (i.e., words that follow conventional English word rules but that are not actual words in English). Before decoding, participants were told from which condition of words they would be reading the corresponding face words. When a face word appeared on the computer screen, participants were instructed to read the word as quickly and as accurately as possible.

2.5.4 Reading fluency

Participants also read stories during week 3. On the first four days of this week, participants used the previously-learned face graphs to read ten stories per day from the *Now I'm Reading!* series (i.e., Levels 1-4), which was transcribed into the Faceabary orthography. Each story focuses on certain vowel sounds. The length and level of difficulty of the stories increase with each day (*see examples of stories in Appendix B*). Reading performance was measured in words read per minute for each story. After measuring the fluency rates and reading durations for each individual, we compared those measures to the measures of those who had learned the similar FaceFont script, which is phoneme-based instead of syllable-based.

3.0 RESULTS

3.1 ARE THE FACE-GRAPHEMES LEARNABLE?: TRAINING

After examining the results of the participants' face-grapheme assessments, we concluded that they were able to learn the presented graphs. Figures 1, 2, and 3 display the overall subject performance by day on the face-grapheme tests, recaps, and decoding, respectively.

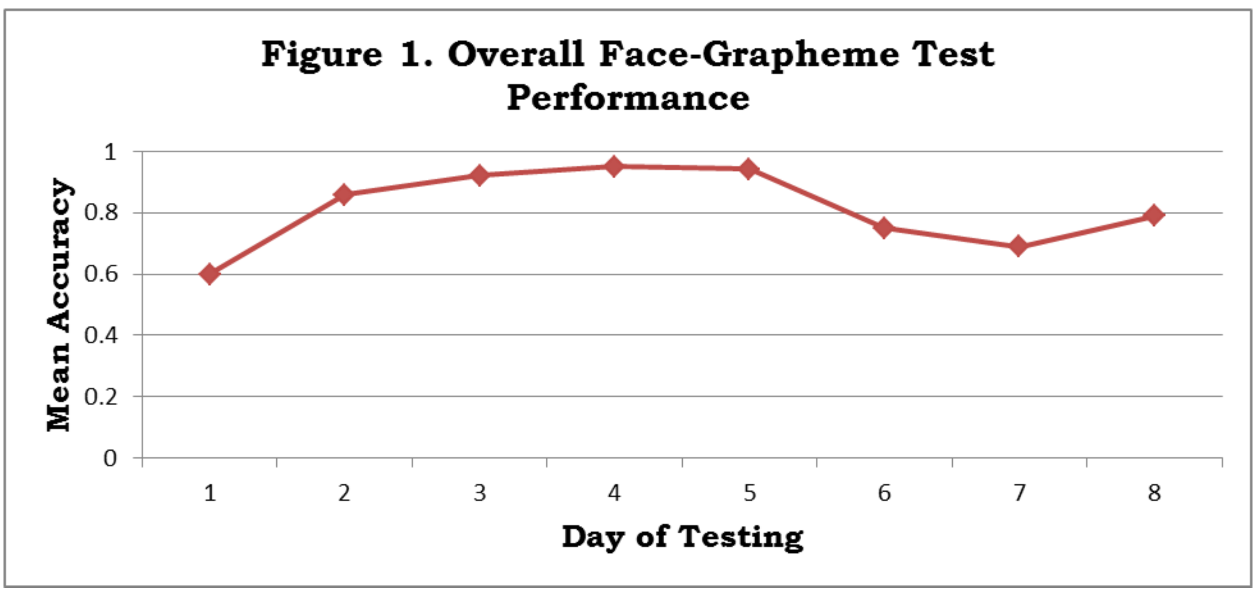

Figure 1. Overall face-grapheme test performance

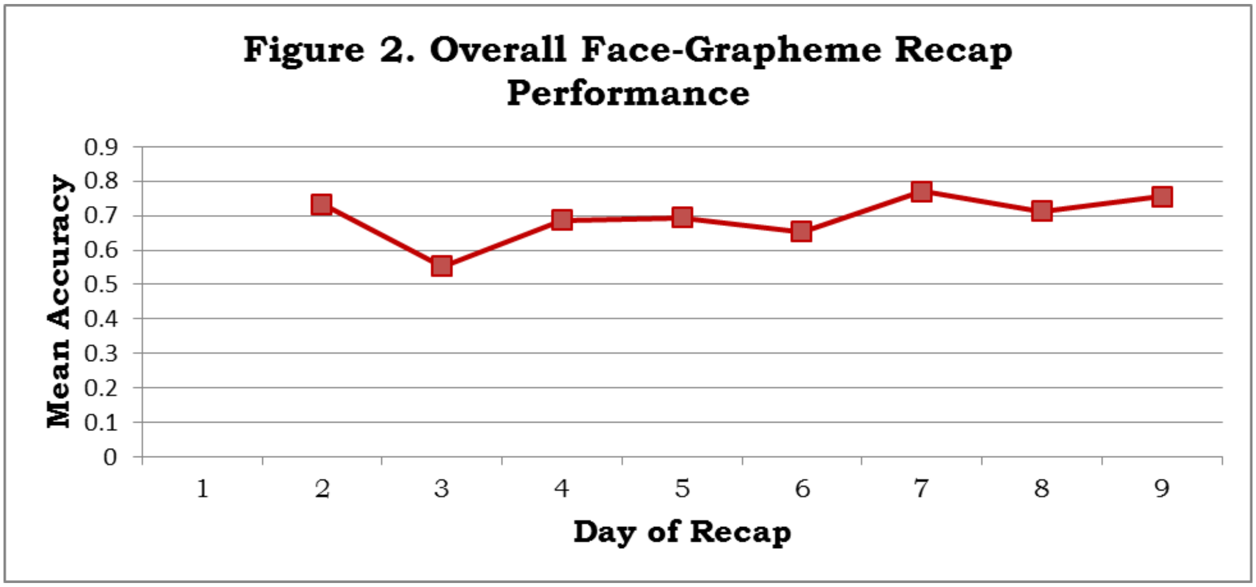

Figure 2. Overall face-grapheme recap performance

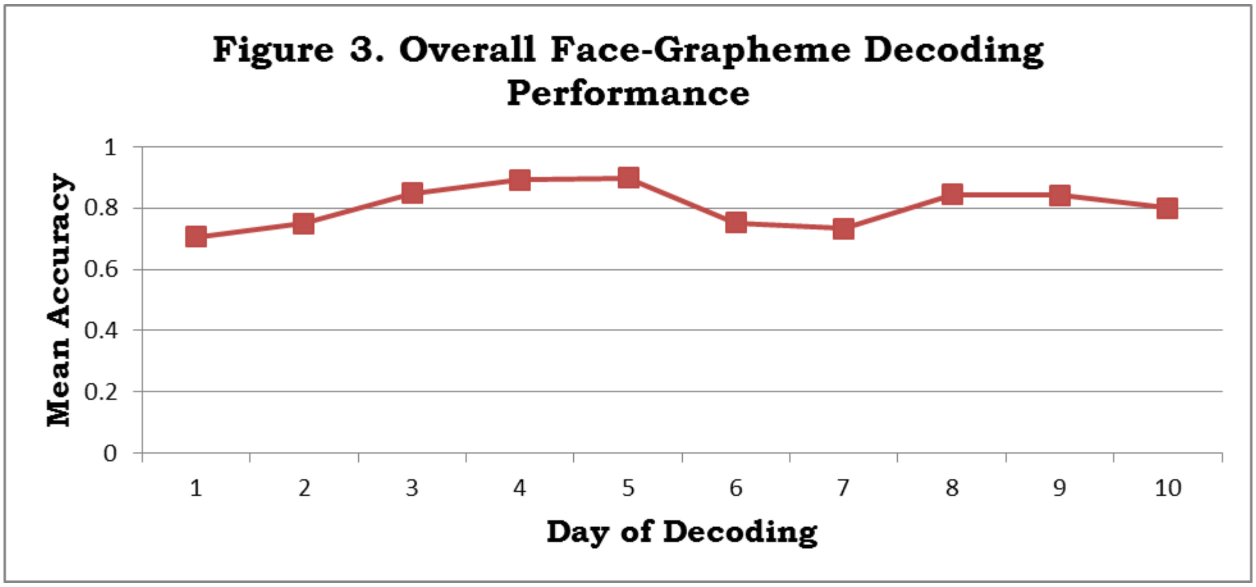

Figure 3. Overall face-grapheme decoding performance

First, in the daily face-grapheme test, there was a main effect of day, $F(7, 105) = 25.30$, $p < 0.001$. Participants' mean accuracy significantly increased on Day 2 of testing, $t(15) = -5.50$, $p < 0.001$, and again on Day 3, $t(15) = -2.27$, $p < 0.05$. Mean accuracy then significantly decreased on Day 6, $t(15) = 8.45$, $p < 0.001$, and increased on Day 8, $t(15) = -2.54$, $p < 0.05$. The increase in accuracy on Days 2 and 3 may have been the result of participants' prior exposure to the previous day's test. The decrease observed on Day 6 may be due to the fact that participants began learning the complex face-syllable pairings on that day. The increase in accuracy on Day 8, then, may have been the result of participants' increased familiarity with the complex pairings.

Similarly, there was a difference in mean performance on the face-grapheme recap by day, $F(7, 105) = 13.07$, $p < 0.001$. The mean accuracy was relatively high on Day 2 then dropped on Day 3, $t(15) = 6.29$, $p < 0.001$. It then increased on Day 4, $t(15) = -6.23$, $p < 0.001$, and again on Day 7, $t(15) = -7.16$, $p < 0.001$. Another decrease was observed on Day 8, $t(15) = 2.39$, $p < 0.05$, followed by an increase on Day 9, $t(15) = -3.02$, $p < 0.01$. The drop in mean accuracy on Day 3 of recap may have been the result of participants' having to recall two similar face-phoneme pairings (i.e., *x* and *U*). We suggest that the increase in accuracy observed on Day 4, then, was due to the participants' having to recall a fewer percentage of face-phoneme pairings that were similar and a greater percentage of face-phoneme pairings that were dissimilar. Consistent with our presumptions regarding the two-day training abeyance, the increase in mean accuracy for the grapheme recap on Day 7 may be because participants, by this time, had had a day to reacquaint themselves with the face-graphemes.

There was also a difference in mean accuracy for decoding by day, $F(9, 135) = 6.64$, $p < 0.001$. There was an increase in mean accuracy on Day 3, $t(15) = -3.33$, $p < 0.01$. On Day 6 of decoding, the mean accuracy decreased, $t(15) = 8.16$, $p < 0.001$, and then increased again by

Day 8, $t(15) = -5.05$, $p < 0.001$. The decrease observed on Day 6 may be because Day 6 of decoding fell after a weekend.

The fact that participants' overall accuracy on the three face-grapheme assessments was relatively high and did not become progressively poorer with each day indicates that the participants were recalling previously-learned faces and rules to assist them in subsequent performances.

3.2 WORD TESTS

After sufficiently learning the face-graphemes, participants were tested on whether they could read words formed by presenting faces side-by-side. Both reaction time (RT) and accuracy were measured across the three word conditions: new word, non-word, and old word. A 3x5 repeated measures ANOVA (3 conditions x 5 days) was conducted for both RT and accuracy data. There was no main effect of condition in RT, $F(2, 18) = 2.13$, $p = 0.15$. There was a significant main effect of day, $F(4, 36) = 4.69$, $p < 0.01$, such that the mean reaction time on Day 4 was faster than the mean reaction time on Day 2, $t(13) = 2.35$, $p < 0.05$. However, because words were randomly assigned to participants, the reason for this difference is unclear. There was no significant interaction between word condition and day, $F(8, 72) = 0.64$, $p = 0.74$ (Figure 4).

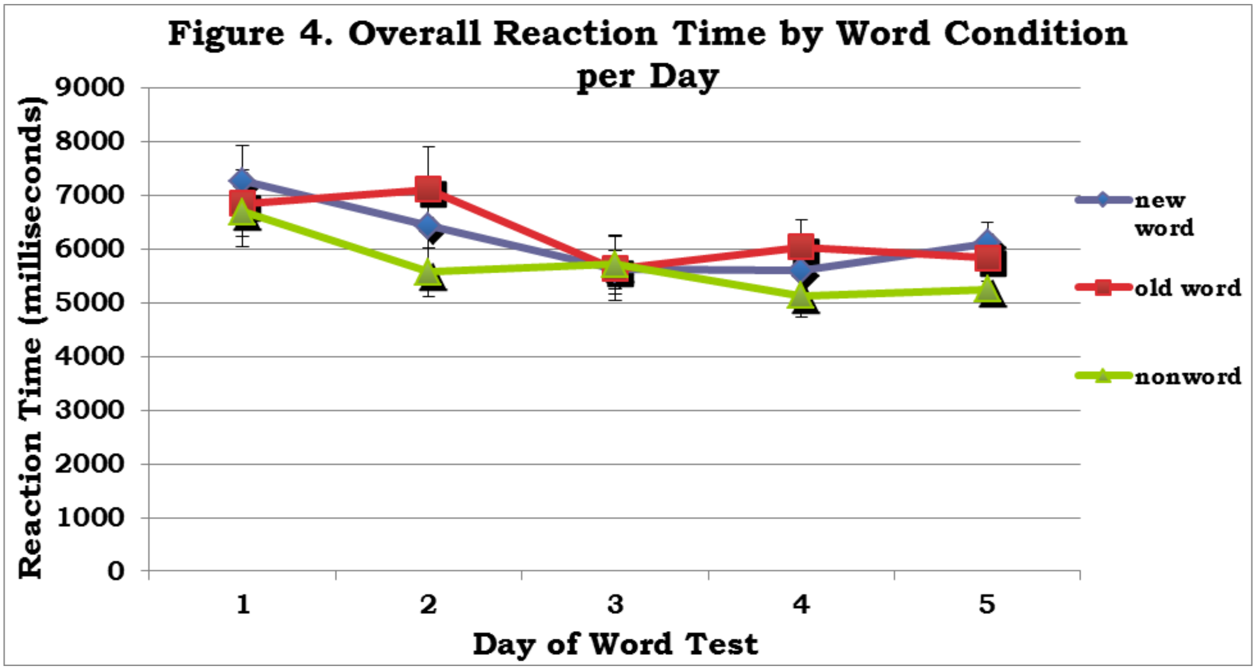

Figure 4. Overall reaction time by word condition per day

There was a main effect of condition in accuracy, $F(2, 18) = 17.24$, $p < 0.01$. Not surprisingly, participants were most accurate in the old word condition compared to both the new word and non-word conditions ($M_{old\ word} = 0.79$, $SD_{old\ word} = 0.19$; $t(15) = -4.44$, $p < 0.001$; $t(15) = -6.83$, $p < 0.001$), less accurate in the new word condition compared to both the old word and non-word conditions ($M_{new\ word} = 0.71$, $SD_{new\ word} = 0.22$; $t(15) = -4.44$, $p < 0.001$; $t(15) = 3.89$, $p = 0.001$), and the least accurate in the non-word condition compared to both the old word and new word conditions ($M_{non\text{-}word} = 0.62$, $SD_{non\text{-}word} = 0.24$; $t(15) = -6.83$, $p < 0.001$; $t(15) = 3.89$, $p = 0.001$). There was neither a significant main effect of day, $F(4, 36) = 1.24$, $p = 0.31$, nor a significant interaction, $F(8, 72) = 1.13$, $p = 0.35$ (Figure 5).

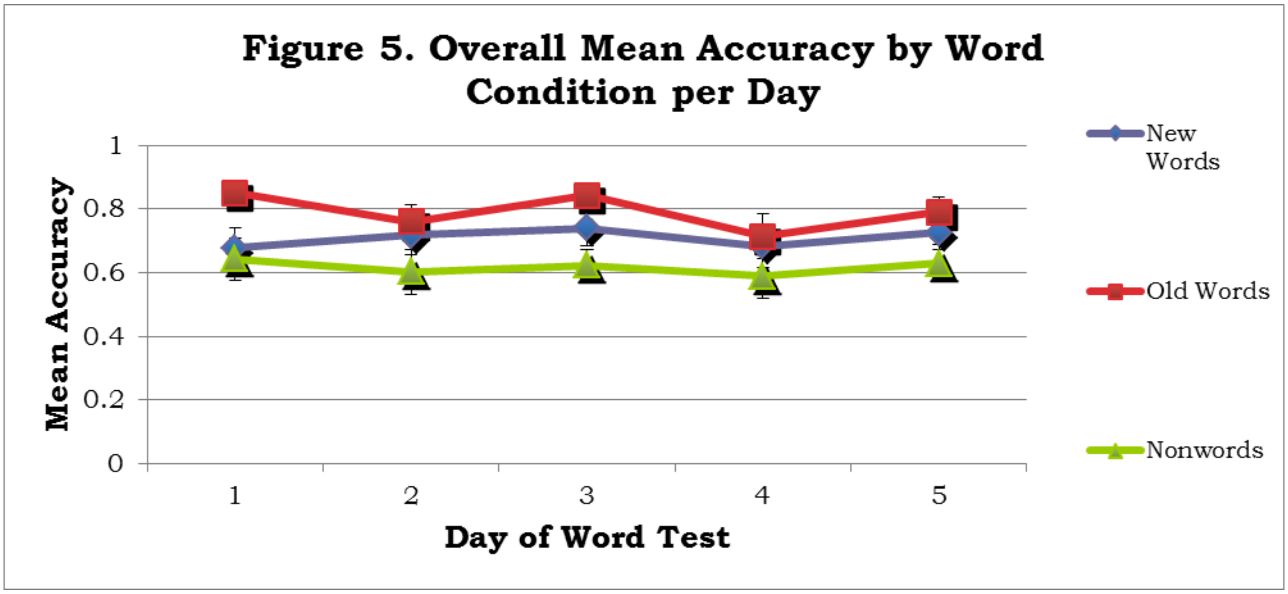

Figure 5. Overall mean accuracy by word condition per day

Non-word reading can be thought of as the purest form of decoding, as accurate reading of the presented word may be hindered by: 1) a lack of semantic information and 2) the inability to retrieve the word's phonological information from the mental lexicon. Considering this, we further examined the kinds of errors participants were making in the non-word condition. Of the 1,461 non-words counted (not all words were scored due to technical difficulties), 558 were missed among the 16 participants. About 75% of the errors in this condition were due to a vowel change, about 22% were due to a consonant change, and about 3% to an incorrect blend (Figure 6).

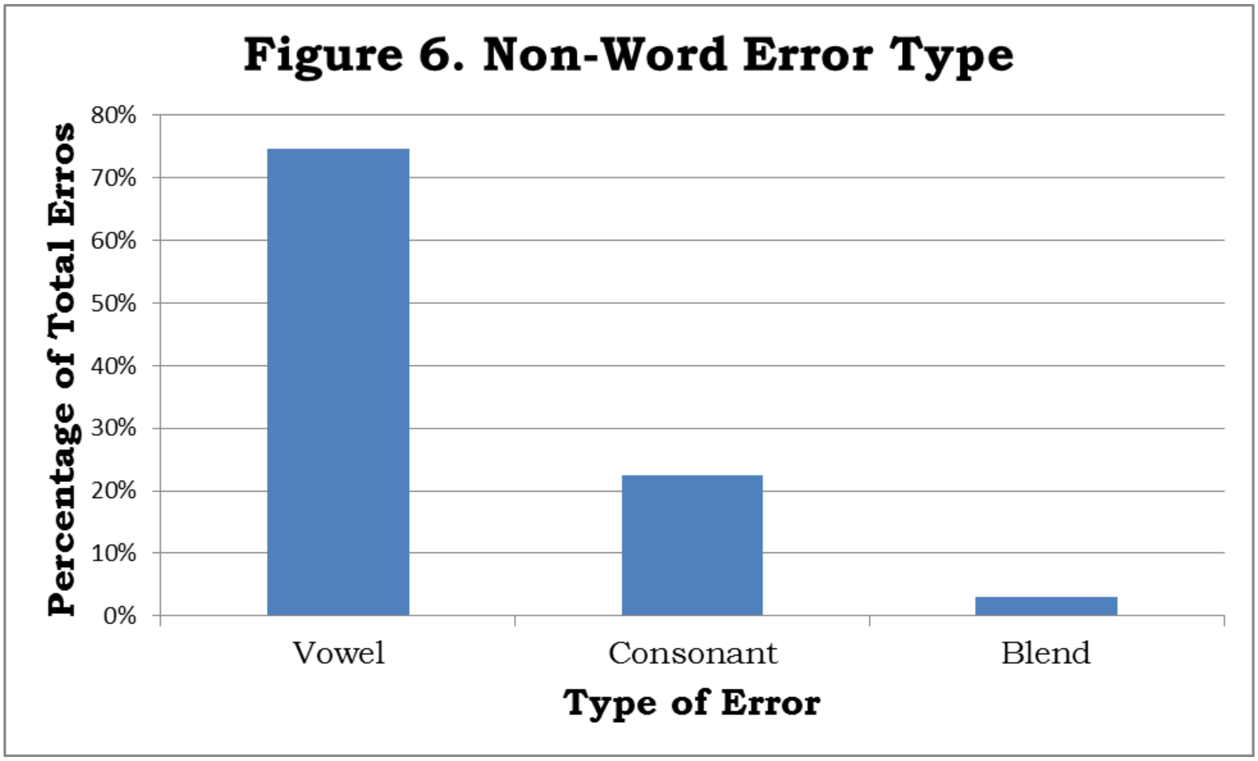

Figure 6. Percentage of non-word errors by type

Next, individual differences in grapheme recognition were examined to see how they might differentially affect accuracy in the three word conditions. An average grapheme recap score was calculated for each subject across days. We found that the accuracy of non-words yielded the highest correlation with the grapheme recap test, r = 0.80, followed by new words, r = 0.75, and then old words, r = 0.73.

3.3 READING FLUENCY

In the next phase, participants were asked to read stories written in the novel Faceabary (FB) orthography that they had already succeeded in learning. Their mean reading fluency rates (words/minute) across levels (i.e., Days 1-4) were then compared to the mean rates of participants in the previous FaceFont (FF) study conducted by Moore et al. (under review). Figure 7 shows that there was a significant main effect of level / day, $F(3, 72) = 4.07$, $p = 0.01$, and no main effect of group, $F(1, 24) = 0.005$, $p = 0.94$. There was not a significant interaction between group and day, $F(3, 72) = 2.04$, $p = 0.11$; however, there was a marginal within-group contrast interaction between group and day on Days 2 and 3, $F(1, 24) = 4.71$, $p < 0.05$ (Figure7).

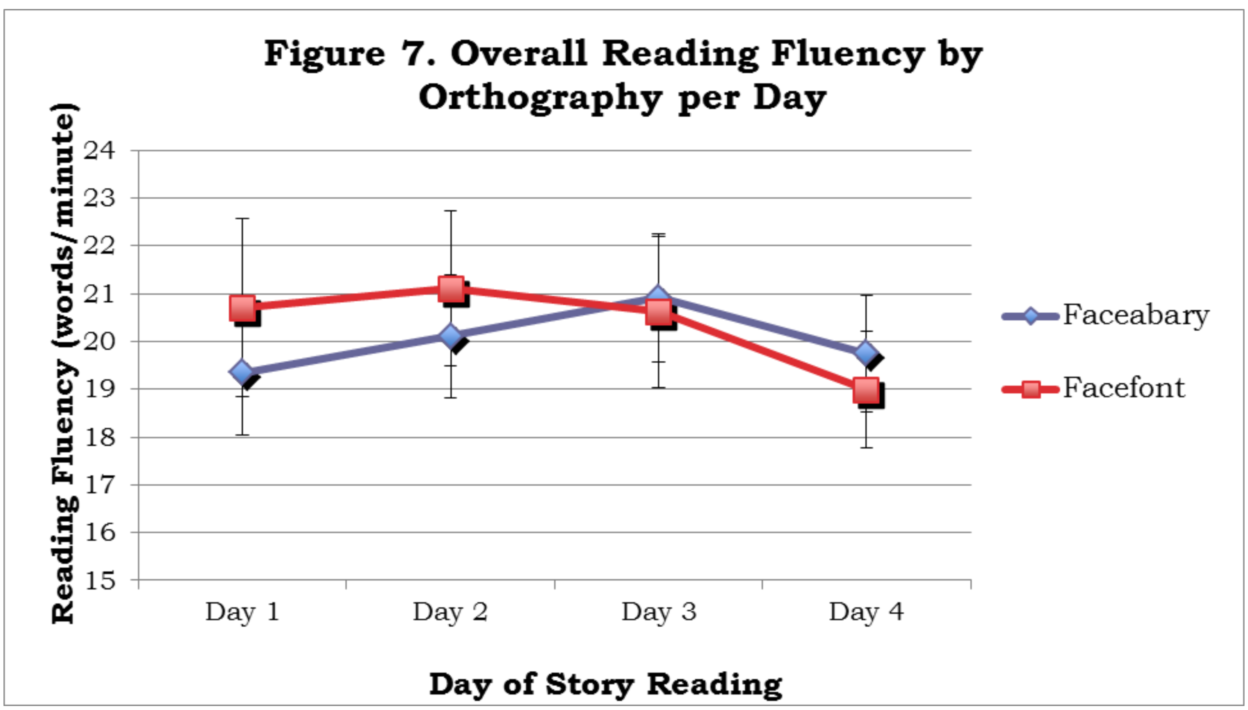

Figure 7. Overall reading fluency by orthography per day

Although there were no overall group differences in reading fluency rates, because of the moderate interaction, we wanted to explore the difference in stories across levels. One way that the stories vary between the FB and FF orthographies is in graphs per word (graphs/word). This difference is due to the fact that FB graphs combine certain syllables and phonologically-complex phonemes (e.g., blends) in a single face whereas FF graphs represent a single phoneme per graph. Hence, the number of graphs/word changes depending on the phonological complexity in each story / level. In the event that a story does include complex phonemes or blends, FB would represent that story in fewer graphs/word than would FF.

Figure 7 illustrates that both FB participants and FF participants demonstrated a similar trend in fluency rate except between Days 2 and 3. To explain this, we looked at two correlations for both the FB and FF orthographies: 1) the correlation between graphs/word and reading rate and 2) the correlation between the difference in graphs/word and the difference in reading rate. We found that the correlation between graphs/word and reading rate was not as strong in FB, $r = -0.19$, as it was in FF, $r = -0.67$ (Figures 8 and 9, respectively). FF readers, then, may be at a disadvantage compared to FB readers because the reading rate of FF is more dependent upon graphs/word.

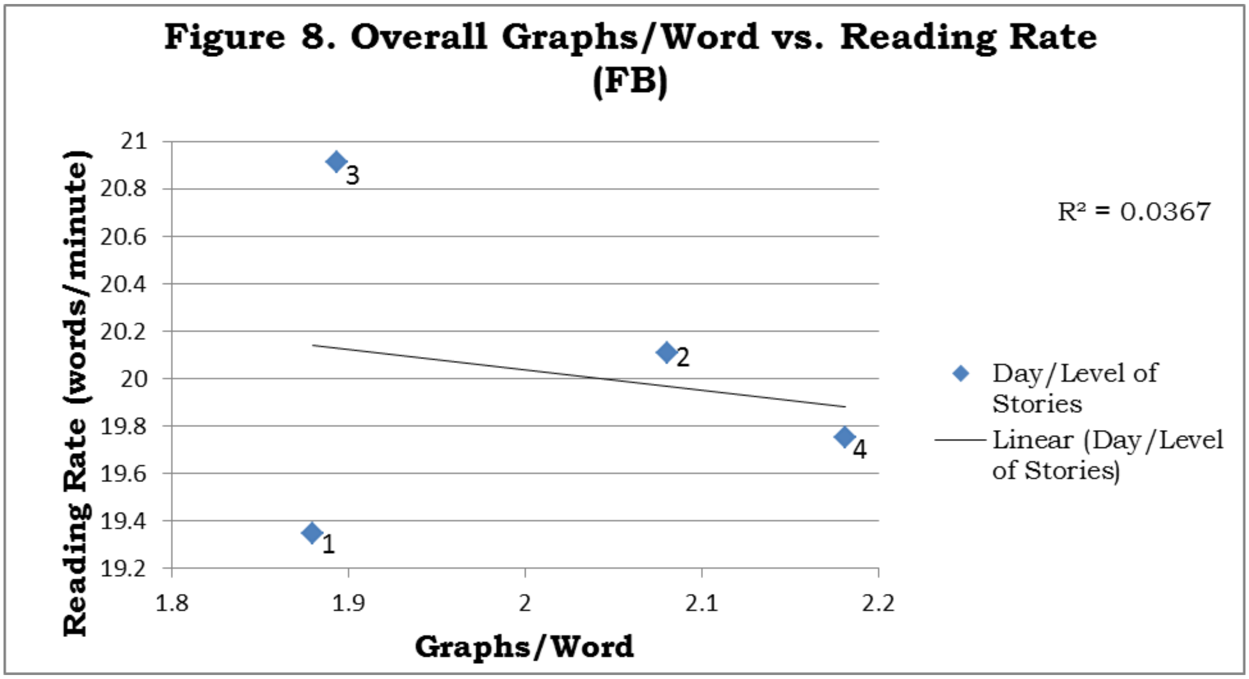

Figure 8. Overall graphs/word vs. reading rate for FB orthography

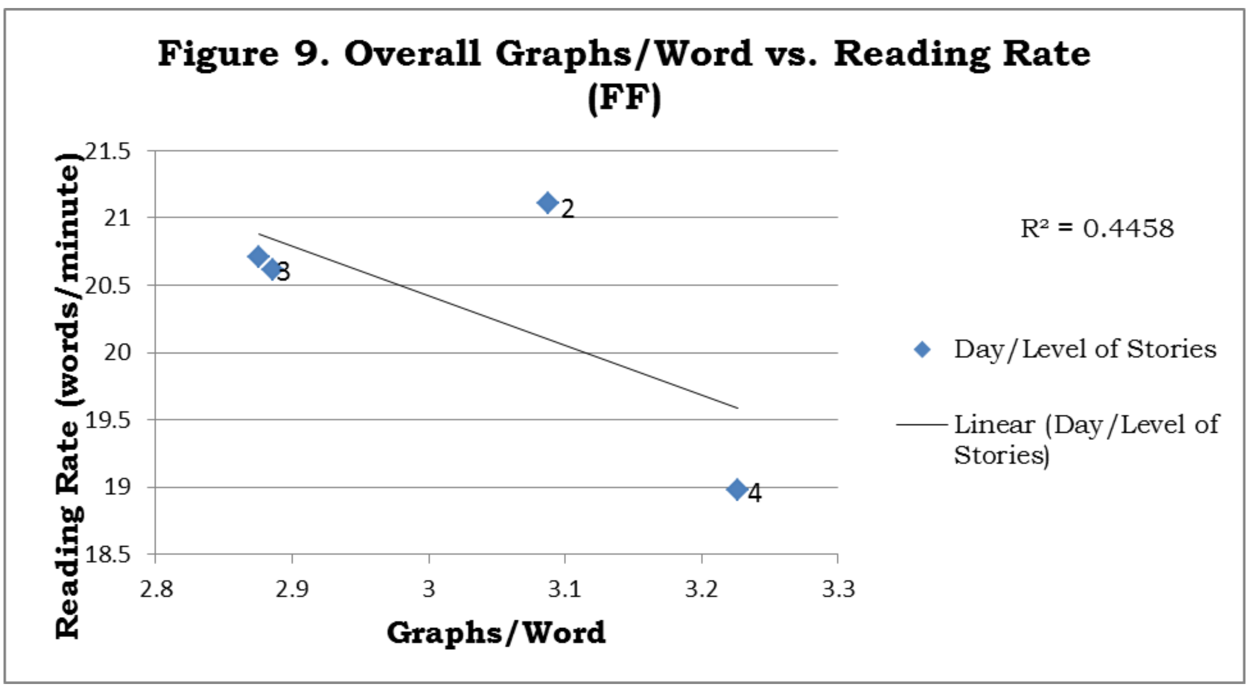

Figure 9. Overall graphs/word vs. reading rate for FF orthography

To explain the marginal interaction between group and Days 2 and 3, we looked at the overall correlation between the difference in graphs/word and the difference in reading rate between FB and FF readers, $r = 0.59$ (Figure 10). Figure 10 suggests that the greater the difference in graphs/word between the orthographies, the greater the difference in reading rate between FB and FF readers. However, this seems to only be the case once the difference in graphs/word exceeds a threshold of about 1.02. When this threshold is exceeded, FF readers read more slowly than do FB readers. This was not the case on Day 3 of stories, however. FB participants read faster on Day 3 than they had on Day 2, while FF participants read slower on Day 3 than they had on Day 2. On Day 4, reading rates of both groups had decreased in relation to the previous day. This is an indication that, while readers of FB and FF read at similar rates, the decoding strategies that they elicit may differ. The reading of FF may be a more face-by-face strategy, while the reading of FB may entail a strategy that is influenced by factors that cannot be deduced from this correlation.

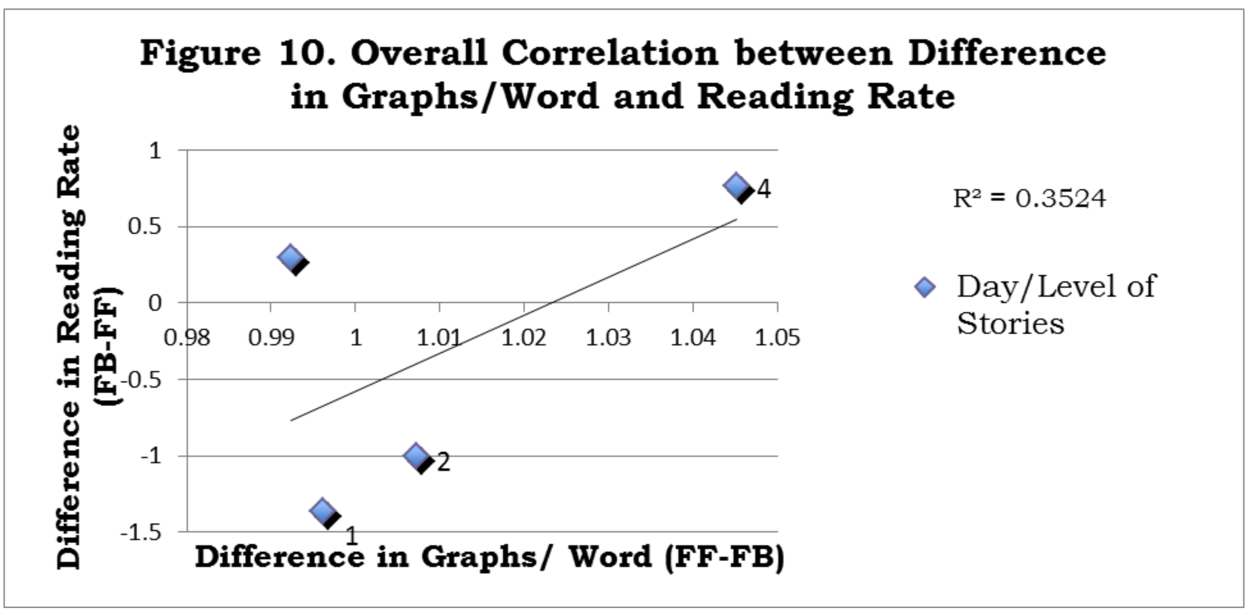

Figure 10. Overall correlation between difference in graphs/word and reading rate

Finally, individual differences in grapheme recognition were examined to see how much they affect one's reading fluency in FB. Both a mean grapheme recap score and a mean fluency rate were calculated for each subject across days. We found this correlation, $r = 0.35$, to be much weaker compared to the correlations between mean grapheme recap score and mean word accuracy by condition ($r_{non\text{-}word} = 0.80$, $r_{new\ word} = 0.75$, $r_{old\ word} = 0.73$).

4.0 DISCUSSION

4.1 ARE THE FACE-GRAPHEMES LEARNABLE?

The results of the current study indicate that the novel face-syllable/phoneme pairings are, in fact, learnable, as participants were able to accurately recognize faces that they had learned days before: Their accuracy was just as high on Day 9 as it was on Day 2 of the face-grapheme recap.

4.2 WORD TESTS

Not only were the participants able to learn the face-graphemes, but they were also able to decode words with relatively high accuracy each day by employing face-graphemes and rules they had previously learned. Participants' overall reaction time was similar across the new word, non-word, and old word conditions. The difference in their mean accuracy, however, was significant. We predict that participants were most accurate in the old word condition because they had seen those words on a prior day, and thus, were more quickly able to decode them. It follows that they may have been less accurate in the new word condition because they were not familiar with the face words in this condition. Participants were most likely the least accurate in the non-word condition both because these words were unfamiliar to them and because they could not retrieve semantic and linguistic cues regarding these non-words from their mental lexicon. Most errors that participants made in the non-word condition were vowel errors, followed by consonant and blend errors. This distribution of errors indicates that while participants may have found the expressions or the faces themselves somewhat difficult to distinguish, they applied the rules of blending the faces to form words quite well.

When the mean accuracy in each word condition was correlated with the average face-grapheme recap scores, we observed the opposite trend, which was, nonetheless, consistent with the previous finding. Non-word accuracy was the most highly correlated with the face grapheme recap, followed by new word accuracy, then old word accuracy. Accuracy of non-words may have been most highly correlated with the grapheme recap test because participants were relying more on face-grapheme knowledge when they were unfamiliar with the word than when they were familiar with the word (Ehri, 1998).

It is also possible that the word test trends we observed have nothing to do with the familiarity of the words. Instead, the trends may be the result of a phenomenon known as the speed-accuracy tradeoff. The participants' overall reaction time for each condition indicates that they may have been the most accurate in the old word condition due to the fact that they identified those words least quickly compared to the other two conditions. Taking longer to respond to these words provided participants with more time to think about what the word might be. The extra time may have improved their chances of decoding the words accurately. Similarly, participants may have been the least accurate in the non-word condition due to the fact that they identified those words the most quickly compared to the other two conditions. Because they did not take as much time decoding non-words, their accuracy may have been compromised in this condition.

4.3 READING FLUENCY

Both the FB and the FF orthographies are inherently more transparent than the English orthography. Participants in this study were to read their respective face orthographies as learned while decoding words. The fact that they were able to do so sufficiently supports our prediction that FB is, in fact, possible to learn. FB and FF are more or less the same in terms of transparency, but they differ in their representation of phonologically-complex syllables and in their granularity. In general, the FB orthography represents phonologically-complex phonemes in fewer faces than does the FF orthography. Because the FB orthography consists of face-syllable pairings (as opposed to face-phoneme pairings), it also has a grain size that is larger than that of the FF orthography.

Our results indicate that these orthographic differences only affect the reading fluency of FB and FF participants between Level 2 and 3 stories. The decrease in reading fluency that is observed only in FF readers on Day 3 suggests that there is something special about the stories presented on Day 3 that is worth investigating. To begin, Level 1 and 2 stories are both more phonologically simple and more repetitive than Level 3 and 4 stories. Level 3 and 4 stories are similar in both length and style. Compared to the first two levels of stories, stories found in the last two levels are longer. Furthermore, the style of Level 3 and 4 stories is less repetitive, and, therefore, the stories are less predictable. Because the stories are less predictable, participants are forced to rely more on face-grapheme knowledge and less on their recent memory. Level 2 and 3 stories, between which we observed a significant interaction, also have a key difference: Level 2 stories are qualitatively different from Level 3 stories in that they include fewer words that contain *st*-, *sk*-, and *sp*- consonant blends (9 occurrences versus 63 total occurrences). Each of these three consonant blends is represented as a single face graph in the second Faceabary table of complex syllables (Table 2.2). Perhaps one explanation for FF readers' slower fluency rate between Days 2 and 3 is due to the greater number of graphs/word present in Level 3 stories written in the FF orthography compared to Level 3 stories written in the FB orthography.

Given that consonant-cluster onsets are more difficult for beginning readers to recognize than are single-consonant onsets (Bruck, 1990), the FB orthography reconciles this by blending consonants into a single face. Evidence also suggests that the second consonant of a consonant pair (or blend) onset is usually the one that is lost during decoding (Stemberger, 1986). FB resolves this issue by essentially treating certain consonant clusters as a single consonant and making them easier to identify. Not only does FB simplify the representation of phonologically-complex phonemes, but it also has a larger grain size relative to FF. Morais et al. found that illiterates are better at localizing syllables than they are at localizing consonants (Morais, Bertelson, Cary, & Alegria, 1986). Because the participants in the current study were learning a novel orthography, one might consider these individuals FB illiterate. It would make sense, then, that readers of the FB orthography might have an advantage in reading compared to their FF counterparts. Both of these factors, i.e., phonological simplification and grain size, most likely contributed to FB participants' increased fluency rate on Day 3. Due to the structure of the orthography itself, FB participants were able to recruit different, perhaps more effective, reading strategies and skills than were the FF participants.

On the other hand, the interaction that we observed might be due to our small sample size. Given more participants, we may find that FB and FF participants perform similarly between Level 2 and 3 stories. We might even find that graphs/word has just as great an influence on the reading fluency in the FB orthography as it does on the reading fluency in the FF orthography. Another alternative explanation for our findings might be that the FF readers had not learned their face-graphemes as well as the FB readers had. This would have immediately put FF participants at a disadvantage – even more so for the Level 3 stories. This explanation is unlikely, however, as FB participants only had 35 graphemes to learn compared to the 375 graphemes that FF participants had to learn.

For future studies, it might be interesting to compare both the face-grapheme training results and the word test results of FF readers to those of the FB readers. In particular, if we could quantify non-word test errors in the FF group (just as we did for the FB group), I would predict that more consonant / blend errors than vowel errors would be made due to the inherent structure of the FF orthography and what we already know regarding consonant clusters and strings. What we could learn from such studies might elucidate the significant interaction in reading fluency that we observed between the FF and FB groups between Day 2 and 3 of reading.

Then again, the face-grapheme recap test correlates more strongly with word condition (especially non-words) than with reading fluency. This indicates that participants' ability to accurately recognize faces may not have as great of an impact on their reading fluency as it would on their word reading. Perhaps reading relies more on context than does single-word decoding; therefore, how well a participant knows the face-graphemes will not be of much importance during story reading. Thus, the recognition of the face-graphemes themselves may not offer an explanation for the interaction effect observed in the current study.

Finally, the current study does not answer whether individuals with dyslexia and alexia are able to learn the FB orthography or whether the FB orthography is easier for them to learn than a phoneme-based orthography. Similar face-grapheme tests, word tests, and reading tests should be conducted among this population as were conducted among the population of typical readers. Comparing these results, as well as neuroimaging scans of typical readers versus disordered readers, may indicate to us whether the face orthographies allow for improved reading. If they do, we might be able to determine whether the reading-impaired individuals are reading by accessing the VWFA or by recruiting other brain areas for decoding.

In summary, the findings from this study suggest that, in light of prior research, our present findings do not necessarily lend support to our second hypothesis that reading English at the syllable level is easier than reading English at the phoneme level. The validity of our hypothesis may be contingent upon: face-grapheme knowledge, the qualitative characteristics of the words being decoded, as well as the decoding strategies being elicited by the orthography.

APPENDIX A

SAMPLE FACE STIMULI

TAH

TEE

TOH

TYE

TUH

STAH

STEE

STOH

STYE

STUH

APPENDIX B

SAMPLE STORIES

Sample Stories from *Now I'm Reading!* Series

Level 1 Example.

Fat Cat: A cat. A tan cat. A tan fat cat. A tan fat cat ran. A tan fat cat ran fast. A tan fat cat is last. A tan fat cat is sad. Cats Slap! A tan fat cat has pals. A tan fat cat is glad.

Level 2 Example.

Ape Date: The ape. The gray ape. The gray ape makes a cake. The gray ape places the cake to bake on a tray. The gray ape is waiting for the cake to bake. Yay! The cake came off the flames. The gray ape is laying the cake on a plate. The gray ape is waiting for his date. The gray ape ate the cake. The date came too late.

Level 3 Example.

Car Sparks: Mark gets in the car for a ride. The car starts. Mark drives to the park. The car drives by a barn on a farm. The car drives by a barking dog in a yard. The car drives far and it is getting dark. Mark sees a spark. Mark stops the car. Mark checks all the parts on the car. No spark! But now it is too dark for the park. Mark is sad that it is too dark for the park. Then Mark sees lots of sparks. Mark looks at the car. No sparks! Mark looks up. Mark sees the sparks. The sparks are the stars!

Level 4 Example.

What a sight: The sky was bright. The light woke Dwight. He wished it was night. Dwight tried to fight with all his might. But he could not fight the light. Dwight went out into the night. The sky is just right for flying a kite. “I want to fly my kite,” sighed Dwight. Dwight started to fly his kite high. Up and up the kite took flight. The kite took flight in the bright sky light. Dwight held on tight. The kite kept flying high. Dwight held on with all his might. Then the light got too bright and Dwight lost his kite. “This is not right,” sighed Dwight. “I was holding on with all my might.” Dwight looked up at the light for his kite. What a sight!

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