THE EFFECT OF NON-ADJACENT LETTER COMBINATIONS IN LETTER IDENTIFICATION

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Abstract

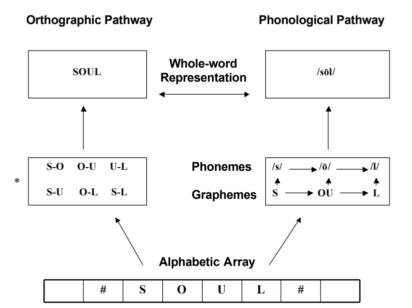
According to some recent word recognition models, words are coded as sets of two-letter combinations (i.e., bigrams) formed by both adjacent and non-adjacent letters. In this study, we explored the effect that non-adjacent letter bigrams have on letter identification. Using a forced-choice letter identification task, twenty-eight participants were asked to identify the third letter in five-letter strings. Participants performed better when the bigram frequency of adjacent letters was high compared to low. Also, the bigram frequency of non-adjacent letters modulated participants' performance in two ways: it increased accuracy when the bigram frequency of adjacent letters was high, but it decreased accuracy when the bigram frequency of adjacent letters was low.

Introduction

➢ Early models of word recognition posited that letter position is unambiguously coded during early stages of orthographic processing (e.g., SOUL = S1, O2, U3, L4; Rumelhart & McClelland, 1981).

➢ However, recent behavioral data have challenged these models. For example, masked priming effects have been observed for transposed letters (e.g., relovution-REVOLUTION; e.g., Perea & Lupker, 2004), subset primes (e.g., prct-APRICOT; Grainger et al., 2006), and superset primes (e.g., apgricfot-APRICOT; e.g., Van Assche et al., 2006; Welvaert et al., 2008). These results suggest that primes activate targets as long as all the target letters are present in the primes in the same order, even if not in the absolute position.

➢ Some recent models (e.g., Grainger, 2008; Whitney, 2001) have tried to account for these results by proposing that letter position is not precisely coded during early stages of word recognition (e.g., SOUL= S1-2, O1-2-3, U=2-3-4, L=2,3,4). According to these models, words are coded as ordered two-letter combinations, or *bigrams*, of both adjacent and non-adjacent letters. For example, the word SOUL would be coded by the bigrams (SO, OU, UL, SU, OL, SL).



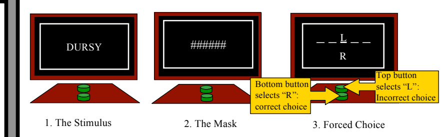
(Adapted from Grainger & Holcomb, 2009)

• Ordered pairs of contiguous and non-contiguous letters (also named "open-bigrams" by Grainger and colleagues; Grainger & Holcomb, 2009).

Purpose of the Present Study

➢ The purpose of this study was to investigate whether adjacent and non-adjacent letter combinations indeed play a role during early stages of reading (other models of word recognition do not include a sublexical stage of processing, e.g., Davis & Bowers, 2006).

➢ Whereas the existence of such bigram units has been posited at the cognitive level, their role has rarely been explored, although it has essentially been hypothesized to be facilitatory (e.g., Dehaene et al., 2005). In this study, we orthogonally manipulated bigram frequency for both adjacent and non-adjacent letter combinations. Whereas previous studies have privileged masked priming paradigms, we employed a letter identification task, also known as the Reicher-Wheeler paradigm (Reicher, 1969; Wheeler, 1970).



Examples of stimuli

Low ALBF-Low NALBF (LL)	Low ALBF-High NALBF (LH)	High ALBF-Low NALBF (HL)	High ALBF-High NALFB (HH)
JBRWO	DBRWY	JURSO	DURSY

ALBF= Adjacent Letter Bigram Frequency (e.g., JB, RW, WO, JU, RS, SO, DU, SY)
NALBF= Non-adjacent Letter Bigram Frequency (e.g., JR, RO, DR, RY)

Predictions

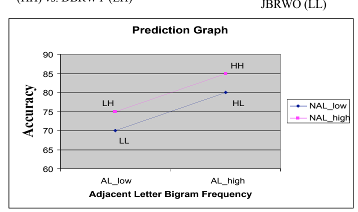
The following predictions were based on previous research on letter identification (i.e., word and pseudoword superiority effects; e.g., McClelland, 1976; Grainger et al., 2003):

Adjacent Letters

Participants would perform better when the bigram frequency of adjacent letters is high rather than low
- E.g., JURSO (HL) vs. JBRWO (LL) and DURSY (HH) vs. DBRWY (LH)

Non-adjacent Letters

Participants would perform better when the bigram frequency of non-adjacent letters is high rather than low
- E.g., DURSY (HH) vs. JURSO (HL) and DBRWY (LH) vs. JBRWO (LL)



Methods

Participants. Twenty-eight native English speakers (19 females; mean age 21.3 yrs., range 18-25 yrs.) participated. No participants had a history of neurological disorders or were taking neurological medications. All participants were compensated with $8.00 for their participation

Stimuli. Four lists of five-letter stimuli were created. Written frequency and other orthographic measures were calculated using the N-Watch software (Davis, 2005), based on the Celex database. Bigram frequency was defined as the average bigram frequency across the entire letter string, both position and length-sensitive. Bigram frequencies for letters combinations 1-3 and 3-5 were based on frequencies for letter combinations 1-2 and 4-5, respectively.

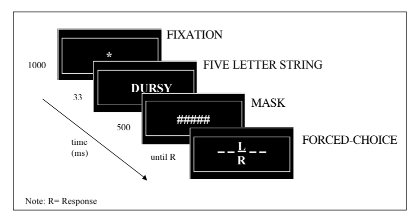
		Adjacent letter bigram frequency	Non-adjacent letter bigram frequency	Neighborhood Density
LL	Low ALBF & Low NALBF	0.44 (0.54)	1.31 (1.17)	0.00
LH	Low ALBF & High NALBF	0.58 (0.65)	31.53 (22.64)	0.00
HL	High ALBF & Low NALBF	24.3 (11.54)	1.28 (1.18)	0.58 (0.93)
HH	High ALBF & High NALBF	27.1 (12.2)	31.53 (22.64)	0.75 (0.9)

ALBF= Adjacent Letter Bigram Frequency; NALBF= Non-adjacent Letter Bigram Frequency
Standard deviations are shown in parentheses.

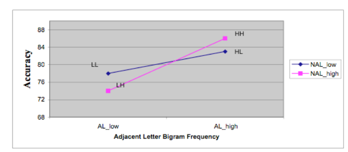
LL and LH stimuli did not differ in terms of ALBF (p=0.3) or neighborhood density, similarly to HL and HH stimuli (all p's>0.3).

Alternate letters (letters to be presented in the forced-choice task with the target letter) were selected so that the stimulus that they would form in the HH condition (high ALBF and high NALBF) would match the target stimulus in terms of adjacent letter BF (mean=26.57, SD=13.0), non-adjacent letter BF (30.45, SD=18.36), and ND (0.95, SD=1.2; all p's>0.4). Alternate letters were also matched for frequency in third position (p=0.87).

Procedure. Participants were positioned 100 cm away from a computer monitor and asked to identify the third letter. Accuracy was stressed. Each participant saw 160 trials , whose order of presentation was counterbalanced across participants.



Results



➢ Result 1: Participants performed with greater accuracy when the frequency of adjacent letters was high compared to low (p <.0001), similar to previous findings.

➢Result 2: The bigram frequency of non-adjacent letters did not affect participants' performance (p=.17) but interacted with bigram frequency of adjacent letters:
- ➢ When bigram frequency of adjacent letters was high, participants were more accurate when bigram frequency of non-adjacent letters was high (HH; e.g., DURSY) compared to low (HL; e.g., JURSO; p=.05).
- ➢ Furthermore, when bigram frequency of adjacent letters was low, participants were more accurate when bigram frequency of non-adjacent letters was low (LL; e.g., JBRWO) compared to high (LH; e.g., DBRWY; p=.01).

Discussion & Conclusions

➢ Greater accuracy was observed when the bigram frequency of adjacent letters was high (i.e., HL and HH conditions; e.g., JURSO and DURSY, respectively) compared to low (i.e., LL and LH conditions; e.g., JBRWO and DBRWY, respectively) in letter identification. This successful replication is consistent with previous research findings (e.g., pseudoword superiority effect; McClelland, 1976; Grainger et al., 2003; Grossi et al., 2009).

➢ The interaction between bigram frequencies of non-adjacent and adjacent letters showed that combinations of non-adjacent letters affected participants' performance both positively and negatively depending on the orthographic (and phonological) regularity of the letter string.

➢These results suggest that there are clear qualitative differences in processing between random strings of letters and strings that follow orthographic (and phonological) regularities. Furthermore, these results suggest that sublexical entities (bigrams, in this case) affect early stages of reading.

➢ Future research will be aimed at understanding how non-adjacent letter bigram frequency both facilitates and inhibits performance.

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