Visual Word Processing in Native and Non-native Speakers of English

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Abstract

A considerable body of evidence can be found supporting the view that Chinese readers do not rely on phonological processing to read Chinese characters to the same extent as native speakers of English when reading text based on an alphabetic writing system. The reason for this is thought to be due to the difference of orthographic structure within script types. Research findings by Perfetti and Zhang (1991) conflict with this view and support an orthography-independent principle of reading, indicating phonological reading processes are universal to the reading of all written forms of language. Recently, evidence which does not support the findings of Perfetti and Zhang has been reported by a series of researchers. In a comparative study, Feng, Miller, Shu and Zhang (2001) suggest that Chinese script readers access the lexicon using a direct visual route in order to process Chinese characters in contrast to readers of English who rely on a phonological route. There remains the question of whether these two different cognitive strategies used by native Chinese and English speakers respectively when processing their own writing systems, are script dependent or transfer with the reader across different scripts. This paper reports on an extension of a previous study by Jared, McRae and Seidenberg (1990) which supported a single phonological route to the lexicon. The indicator used was spelling-sound consistency effect in native readers of English. According to The Universal Phonological Principle (Perfetti and Zhang 1991) a consistency effect should be found for fluent readers of both script types when reading English. This present study used three groups of participants, native English, non-English European and Chinese. A difference was found between the pattern of response times in a naming task indicating the processing of consistent words by the Chinese group of students differed from the native English and European groups of students. A consistency effect was found for the European and English groups. A Consistency effect was not found for the Chinese group. Therefore spelling-sound correspondences affected performances differently when reading English for native alphabetic and Chinese script readers. The results are interpreted within current models of naming and frequency but call into question the Universal Phonological Principle reported by Perfetti and Zhang (1991).

Introduction

The focus of the present research is to determine whether native Chinese people who are fluent readers of Chinese script, process visually presented English differently from native and other non-native readers of English. Most European languages use graphemic symbols made up of phonemes. In Chinese, a symbol system has developed which directly encodes meaning. This is called the logographic principle. Much research has attempted to find evidence for either universal principles applied to the reading processes utilized by all readers of written language or orthographic-specific processes. Perfetti and Tan (1998) suggest that phonology is crucial in word recognition across orthographies. However Chen and Shu (2001) dispute this view having consistently failed to replicate the study of Perfetti and Tan (1998). In agreement with Zhou and Marslen-Wilson (2001), Chen and Shu suggest that semantic rather than phonological activation plays the more crucial role in Chinese word recognition. The conclusion from the majority of published research indicates that in the case of Chinese, meaning can be accessed by orthography directly.

The main research question that has been investigated is whether spelling-sound knowledge consists of a set of rules with a list of exceptions or whether there is a single route which is mediated by phonological processes. According to the dual-route model (Coltheart 1978) regular words can be pronounced using the rules stored in the memory. Coltheart called these rules grapheme-phoneme correspondence. (GPC). However, exception words such as *have* (not pronounced to rhyme with *cave*) have to be recognised using a direct visual access route to the lexicon. This causes a slight delay due to the conflict between the phonological route which would use the GPC rules and the visual route which produces the sound directly by means of mapping the letters to the stored representation of (in this case) the meaning to own immediate possession of (*have* – '*hAve'* would be a non-word). Further evidence for this model comes from brain injured patients who have difficulty naming words. Jared, McRae and Seidenberg (1990) challenged the concept of GPC which they called the assembly route. The assembly route refers to the process of sub vocalization of the phonemes individually and then putting them together in order to gain access to the lexicon. To challenge GPC, they compared two factors: these were frequency and consistency.

The dual route model was based on findings that orthographically unique words such as *tzsar* show no disadvantage in naming latencies. Jared et al (1990) reinterpreted these findings in terms of a consistency effect (Glushko 1978). All consistent words (friends) are constructed of word-bodies that are identical both visually and by pronunciation, such as '*ade*'. Inconsistent words have alternative spelling-sound rules (enemies), such as '*ead*' sounded differently in *'bead*' and *'bread'*). The consistency effect can be measured by the magnitude of the difference in response times (Rts) between words that have the same number of friends but have either zero or more enemies. The consistency effect can account for the disadvantaged naming latencies and can be explained in terms of competing pronunciations. Jared et al (1990) demonstrated that the ease of pronunciation is mediated by the degree of consistency of a word's pronunciation with other similarly spelled words. Consistency effects arise from processing all types of words via the phonological route. Connectionist modelling also supports this approach to word recognition. Paterson and Coltheart (1987) adapted the dual route model to reinterpret the consistency effect within their dual route model, by suggesting the GPC route was at syllabic level rather than phonemic. No research to date has been located which investigates the consistency effect with readers of English who are experienced non-alphabetic script readers. This is potentially because a great deal of research in this field has been conducted on native English speakers in research institutions. However, with more Chinese people gaining employment in Europe, cross-cultural research into reading techniques has implications for teaching Chinese children in European schools.

In a comparative psycholinguistic experiment, Feng, Miller, Shu and Zhang (2001) compared how readers of Chinese take advantage of phonological and orthographic features in Chinese with how English readers take advantage of .phonological and orthographic features in English. Feng et al found evidence for early phonological processing in English, but in line with Wong and Chen(1999), they found no evidence of early phonological processing in the matched Chinese character reading condition. The indication is that there are important differences in processing these two different forms of written language. These findings would suggest that the choice of reading process is dependent on different orthographies. The question still remains as to whether these processing differences transfer across scripts or whether they are script dependent. The difficulty for alphabetic readers to process Chinese characters has been acknowledged and addressed by the development of Pinyin. This is a Romanization system that uses letters from the Roman alphabet (ABCD…) to recreate sounds of Mandarin Chinese. Pinyin was approved by the People's Republic of China in 1979 in order to encourage foreigners to learn Chinese. Conversely, it is logical that experienced logographic script readers might develop a preference for using a direct recognition route for reading English. This principle of choice of lexical access for English reading has been proposed by Coltheart (1978). However Jared (1999) found that readers do not have strategic control over phonological processing.

The whole-word system of reading is commonly introduced to early readers of both written language systems. The analogy to processing of Chinese Characters is the ability of alphabetic script readers to interpret numbers when not in phonemic form ie 1966. Children taught alphabetic writing systems progress on to learning new words using phonics. (eg *ker-a-ter = cat*). Chinese children continue to learn written English by rote memory and there is little emphasis on the connection between speech and reading.

In order to look for the possibility of different cultural preferences for processing written English words, a sensitive measure was required. It was necessary to both control and manipulate the effect of word frequency within the phonological process, in order to determine any different phonological dependency. Jared, McRae and Seidenberg (1990) suggested that native readers of English cannot bypass the phonological route when reading. To test this, they controlled the frequency of identically pronounced word-bodies (friends) whilst manipulating the frequency of competing word-body pronunciation (enemies). The consistency effect was found to be the greater between consistent and inconsistent words in a naming task when the inconsistent words had a high number of enemies. Jared et al used native speakers of English.

It would be logical to expect that users of other European languages (based on the Roman alphabetic system) would produce similar results to the participants of Jared et al as the consistency effect is phonologically based. The response times would be expected to be slower than those from a native English group, but a similar pattern of responses would be also be expected. This would mean that the consistency effect might be more robust due to the greater difference measured. Jared et al had said the consistency effect was very sensitive and difficult to isolate.

If Chinese people process written languages based on the alphabetic system differently from native users of it, then the results found by Jared et al (1990) for native English readers, should be different for Chinese readers of English. The consistency effect found by Jared et al was associated with a single phonological process, so any lack of difference found between high-frequency enemy inconsistent and matched consistent words would provide evidence for different cognitive strategies used for reading, because processing through a direct visual route would not return a consistency effect. The reasoning for this is that phonologically, the competing pronunciation in the high enemy group should slow down the response time even though the frequency of friend had been controlled for. If a direct access to the lexicon was employed, then the competing pronunciations would not effect response time according to Coltheart et al (1978). Jared et al used the control of frequency of enemies in order to reinterpret Coltheart's results. Therefore if the Chinese use a direct route, according to Coltheart, frequency of enemies should return quicker responses because without the competing pronunciation problem, the more frequent exposure to the same letter combinations should facilitate response times.

A lack of difference in response times between matched consistent and inconsistent high-frequency enemy word types would indicate a difference in processing between native English and Chinese readers of English. This might also suggest that cognitive processing when reading written language systems may be culturally dependent rather than universal or script dependent. If the response time difference between high frequency enemy inconsistent and matched consistent words was similar between groups, then this would indicate a shift from direct processing to phonological processing by the

Chinese group. The majority of research into Chinese character reading and phonological processing has indicated that a direct route is used by fluent native readers and so a native Chinese group of readers of English would have to switch cognitive processing strategies in order to replicate the findings of Jared et al.

In order to control for whether any difference found in response times between consistent and inconsistent words which could be accounted for by exposure to written language alone, a second group of non-native English, alphabetic script users would be required to control for experience. The Chinese and European groups would need to be matched in terms of English language proficiency, so that any difference found would be likely to be due to differences in script rather than English language proficiency. A significant difference found in the consistency effect between the two non-native readers of English could indicate the possibility that learning style rather than script type determines different processing of words when read aloud. The European group would be expected to return a similar pattern of results not only to the control group of native English readers, but to those recorded by Jared et al (1990).

Hypotheses

Native English speakers will take longer to name inconsistent words than consistent words and therefore produce a significant consistency effect as shown by Jared et al (1990)

The European readers for whom English is a second language will take significantly longer to name highly inconsistent words than matched consistent words to pattern similarly with the native English speakers.

The Chinese readers will not take longer to name highly inconsistent words than matched consistent words indicating a difference in response times between the Chinese readers and the English and European readers.

The Experiment

The experiment compared the naming latencies of two categories of words each with two levels. The first category was consistency, which compared words that by definition have no enemies against inconsistent words that do. These were labelled consistent and inconsistent respectively. These were matched in terms of the number and frequency of friends, that means all words that have similar spelling-sound correspondence. These were also matched in terms of summed frequency of word-body. A word-body, is the part of the word without its prefix as in '*ade'* as in *spade, wade, etc.* According to Brown (1987), under these conditions the naming latencies for consistent and inconsistent words should show no significant difference if it is the frequency of friends and not consistency that matters. If, however, consistency effects occur, then the consistent words should show an advantage in terms of naming latencies because according to this hypothesis, it is the number of enemies (those competing) which affects the naming latency. So in addition to consistency, another factor of frequency of enemies was manipulated. The two groups of inconsistent words differed in terms of mean summed frequency of enemies. This was accomplished by counting the number of enemies in each group and totaling their frequencies (Kucera and Francis 1967). According to Jared et al (1990) if this figure is low then the naming latency may only be disadvantaged by high frequency inconsistent neighbours. For instance, although '*own'* and '*aste'* are both inconsistent, '*gown'* would have a much higher frequency of enemies in the form of the pronunciation '*grown'* than '*haste*' suffers from '*caste'*. Therefore this confounding variable in past experiment may have masked the real consistency effect. The consistency effect has also proved to be elusive when comparing exception words (those who have many enemies and no friends) and unique words (those who have neither friends nor enemies). Brown (1987) argued that these two types of words (exception and unique) were matched in terms of friends by both sharing none at all and failed to find a consistency effect. According to Jared et al (1990) it is the strength of the enemies of inconsistent words in terms of frequency of inconsistent neighbours that influenced the size of the consistency effect, and so frequency of friends was controlled whilst frequency of enemies was manipulated.

The effect should be larger for words with high frequency enemies. It is easily explained in terms of a tug of war model. If all words, (both consistent and inconsistent) are matched, in terms of number of friends on their side of the rope, there will be a greater consistency effect (or naming latency difference) for those inconsistent words, who have a greater frequency of enemy neighbours.(also pulling on their end of the rope) Therefore the difference between not only consistent and inconsistent words will be measured, but the difference between categories of words within frequency levels of enemies. However if recognition is facilitated by the frequency of exposure to word endings in terms of orthography, the 'tug of war' model of consistency should not be found in the high frequency enemy neighbour condition, because these neighbours visually are friends and not enemies. (See Appendix B) This could be described as the 'towing' model. A consistency effect for native alphabetical script readers would be expected due to competition from opposing pronunciation choices and a further effect of frequency of enemy neighbours on naming latency for inconsistent words. Therefore a consistency effect is expected in the non-Chinese groups whilst a frequency effect regardless of consistency is expected for the Chinese group.

Method

Participants

The participants were 48 University of Hertfordshire undergraduates aged between 19-25 and were paid for their participation. 8 male and 8 female were native speakers of English (mean age 22.5), 8 male and 8 female participants were native Chinese and skilled Chinese character readers(mean age 24.3), The third group were 8 male and 8 female students from France,(2) Italy,(6) Holland,(3)Denmark(2) and Spain(3) for whom English was a foreign language with their native text based on an alphabetic script (mean age 24.2). The three groups of participants were equated in terms of their educational experience and age range. Standardised test scores were collected from all participants and the means for use of English, reading and writing for each group statistically analysed and means compared using an analysis of variance. The mean scores of assessment results are listed in Table 2. No main effect of group or interactions were found between group and test score means. Therefore all participants in the Chinese and European group were equated in terms of test assessments supplied by the University of Hertfordshire. The test used was a standard test for all students who are foreign to England who wish to pursue further education in an English qualification.

Stimuli

Eighty low frequency monosyllabic words were used (See Appendix A) Spelling patterns were not repeated in order to avoid priming effects by repetition. The stimuli were matched in terms of initial phoneme, word frequency, length and complexity in terms of orthography. All these factors were equated in order to isolate spelling-sound consistency, so that any difference could be attributed to this factor. The neighbourhood of each word was determined by choosing uninflected monosyllabic words listed in Kucera and Francis (1967). Half the words had consistent word-bodies (without any opposing pronunciations) and half had other opposing word-body pronunciations. Of these two main categories, the frequencies for each inconsistent word-body were divided into low-frequency enemy (summed frequency less than 110) and high-frequency enemy (summed frequency of enemies greater than 260). The mean summed frequency of enemies was 39 and 1300 respectively. These words were matched for length, initial letter, number of existing words containing exact pronunciations and orthographic error score. (See Table 1).

Procedure

The participants read through the standardised procedure and signed a consent form. Each participant was allocated a number to maintain anonymity. The stimuli were displayed in lower case letters on a laptop computer using © *SuperLab* software, licensed to the researcher. Words were presented one at a time and remained on the screen until the participant began to speak into the in-built microphone set at threshold level of 30 and connected to a voice-activated relay interfaced with the computer. The real-time computer clock measured the response latencies in milliseconds. A practice set of 10 word-trials was presented to ensure the correct volume level. 80 low frequency monosyllabic words were presented in random order at intervals of 1500ms. The entire procedure was tape recorded in order to record mispronunciations and microphone failure.

TABLE 1

CHARACTERISTICS OF THE STIMULI IN JARED ET AL EXPERIMENT

	INC HF enemies	CON	INC LF enemies	CON
Number of words	20	20	20	20
length in letters	4.3	4.3	4.8	4.6
K&F frequency	5.5	5.5	5.5	5.5
Number of friends	8.2	8.4	8.5	8.7
Summed freq friends	976.7	913.8	287.0	288.9
Number of enemies	4.9	0	1.5	0
Summed freq of enemies	1300.3	0	39.3	0
Ortho error score	6.99	7.60	9.48	9.66
Bigram frequency	2137.8	2101.4	1344.0	1471.7

TABLE 2

MEAN SCORES OF GROUP IN THE USE OF ENGLISH, READING AND WRITING

Group Type	Use of English M	Use of English SD	Reading M	Reading SD	Writing M	Writing SD	F = .045 p=.834
Chinese n = 16	13.88	1.9	12.42	2.0	10.75	1.7	Age M = 24.3
European (not native English speakers) n=16	13.59	2.0	12.23	1.6	11.56	1.7	Age M = 24.2

Results

The dependent variable was speed of response. An error analysis was performed in order to investigate the accuracy and therefore the reliability of the data. The data used was that which had been carefully controlled by Jared et al (1990) in order to isolate the consistency effect. . This was the evidence given for a single phonological processing route, however as the words were very simple, a high degree of accuracy was also vital in order for the data to be of any practical use in terms of reliability.

Descriptive statistical tests were used in order to investigate the distribution of the three groups. The experimental hypotheses were investigated using Paired Sample T Tests in order to find a significant difference. Further analysis was undertaken using a mixed design Analysis of Variance. The two within factors were word type and frequency and each factor had two levels. The word type levels were consistent and inconsistent and the two levels of frequency were high and low frequency of enemies. The consistent words were matched for summed frequency of friends with the inconsistent words. There was also a between subject factor of group with three levels, Chinese, English and European. (See Table 2 in the design section).

<u>Analysis of error data for mispronunciation</u>

The error rate with respect to mispronunciation was very low

Data from 0.05% of the trials was excluded from the analysis due to microphone failure. The error data was converted to 1 or 0 to represent either a correct or incorrect response respectively. Any failure of the microphone was left as a blank score. All cells were summed across the variables in order to produce a score out of a possible 20 for each category of word. The categories were high-frequency enemy inconsistent, matched consistent, low-frequency enemy, inconsistent and matched consistent. The means score of errors for each word category was also calculated. An analysis of variance was performed on the error data. (See Table 3)

A main effect of group was significant F(2,45)=1428789.0 p<0.000 The main effect of consistency was found to be significant F(1,45)=6.076 p<0.018 . The main effect of frequency was not significant. The Interactions between group and consistency, group and frequency, consistency and frequency and consistency, frequency and group all failed to reach significance. These data suggest errors were significantly affected by consistency but not frequency. Over all, the accuracy rate for all three groups was high. This analysis indicated the data was reliable for further analysis purposes.

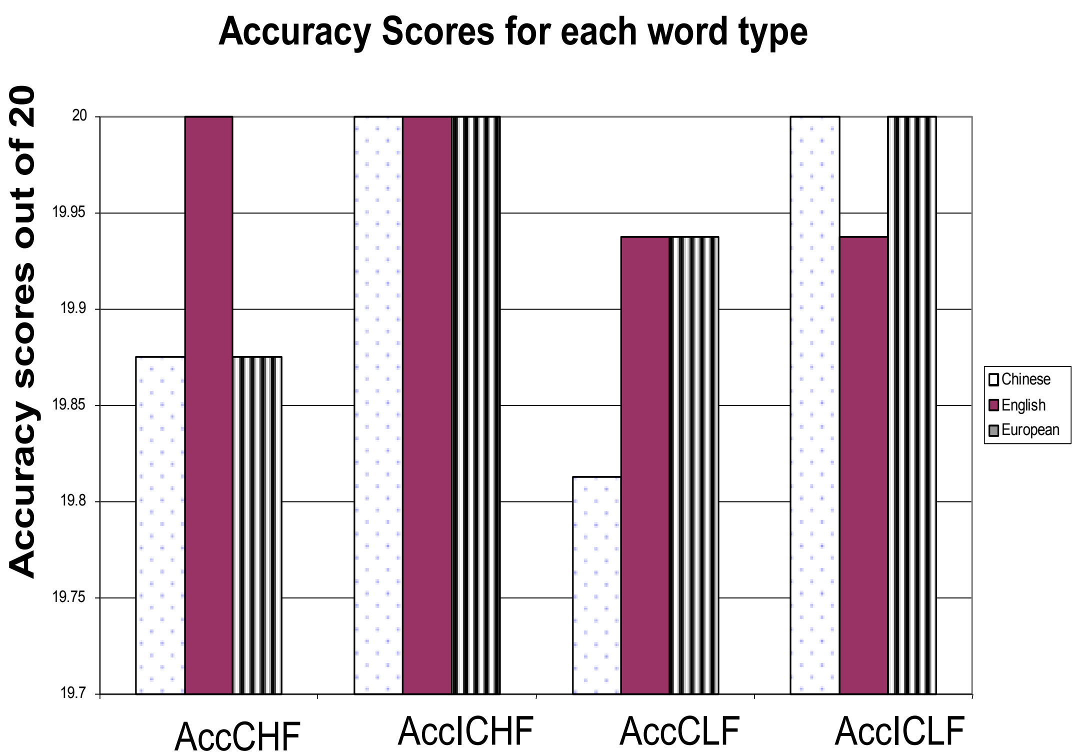

FIG 1 Accuracy of responses by Group and Word Type

TABLE 3

MEAN ACCURACY FOR EACH GROUP BY WORD TYPE

Group	Mean Accuracy Score for High frequency Consistent words	Mean accuracy Score for High frequency Inconsistent words	Mean Accuracy Score for Low frequency Consistent words	Mean Accuracy Score for Low frequency Inconsistent words
Chinese n=16	19.88(SD 0.34)	20	19.81(SD0.54)	20
English n=16	20	20	19.93(SD0.25)	19.94(SD 0.25)
European n=16	19.87 (SD 0.34)	20	19.94 (SD 0.25)	20

Response Time Data

The response scores were plotted for a selection of items for each group. The distributions were not normal throughout. All data was square-root transformed in order to ensure a normal distribution of Rts for each item. The reason for the transformation was to ensure that any scores more than 2.5 standard deviations from the normal did not distort the mean score for the group.

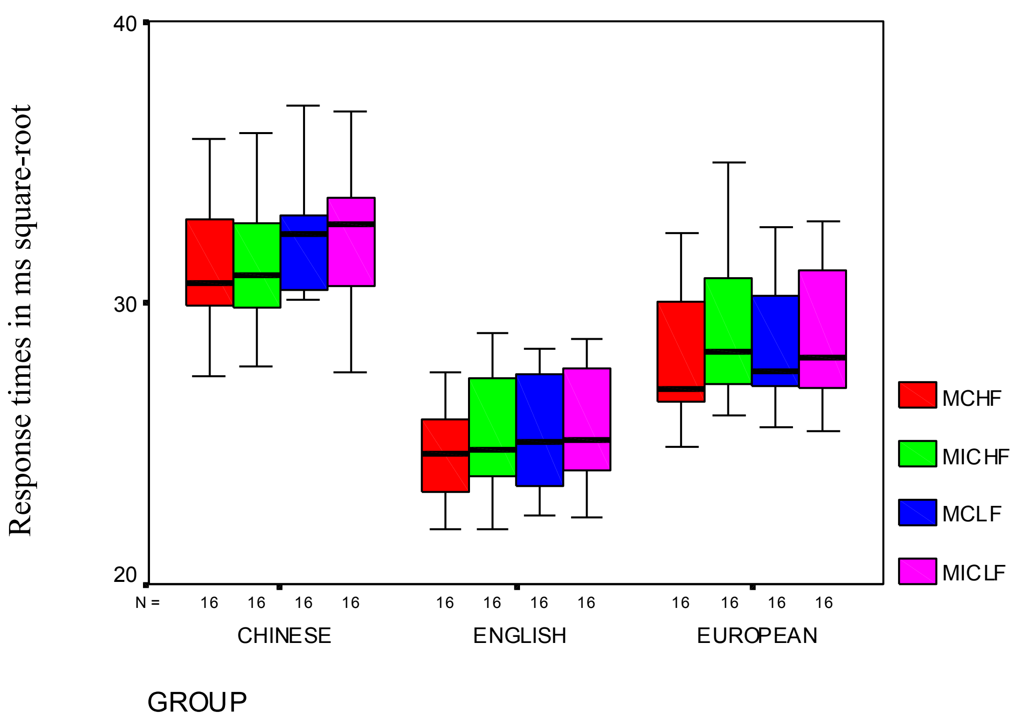

FIG 2 Boxplot of data to check for cases to eliminate

It was decided to leave all cases in the analysis as there were no serious outliers. (See Figure 1) It was immediately apparent that the spread of scores in the Chinese group were greater than the matched European group

The consistent and inconsistent response times were collapsed across frequency and Figure 4 shows that there was very little difference in response times between consistent and inconsistent words in the Chinese group. The two other groups showed a similar pattern with a greater difference for the European group.

TABLE 4

MEANS OF RESPONSE TIME AND STANDARD DEVIATION FOR EACH WORD TYPE BY GROUP

Group	High Frequency Consistent words	High Frequency Inconsistent words	Low Frequency Consistent words	Low Frequency Inconsistent words
Chinese	31.14 (SD 2.18)	31.47 (SD 2.32)	32.58(SD 2.31)	32.34 (SD 2.21)
English	24.67(SD1.61)	25.27(SD2.03)	25.36(SD1.99)	25.55(SD1.94)
European	27.90(SD 2.34)	29.05(SD2.52)	28.46(SD 2.25)	28.89(SD 2.36)

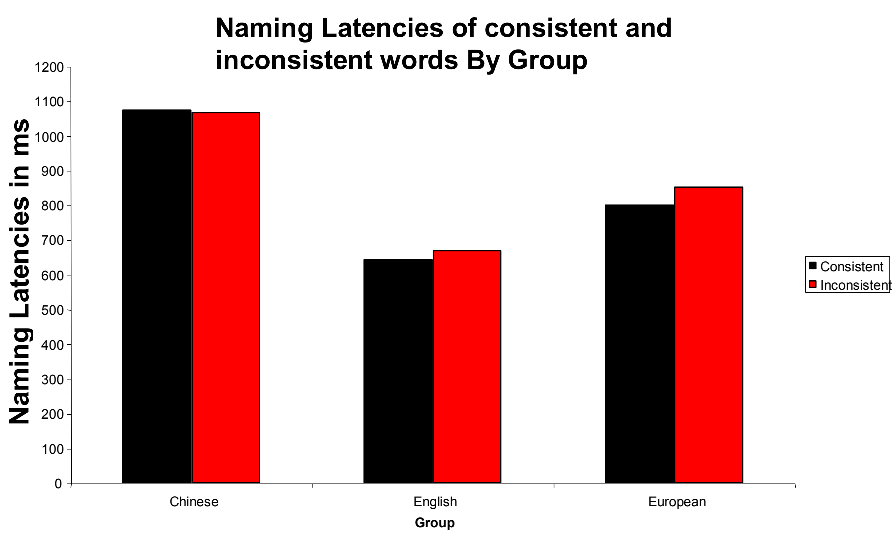

FIG 3 Bar chart showing the mean Rts for consistent and inconsistent words by group

Figure 3 illustrates the reduced effect size when frequency of enemies were not separated. Jared et al (1990) said that the failure to account for frequency of enemies could explain the failure to find a consistency effect. In other words there was a confounding variable of frequency of enemy. Figure 3 supports the hypotheses that there was a difference in cognitive processing as evidenced by consistency effect for the Chinese group. The next step was to test this difference for significance.

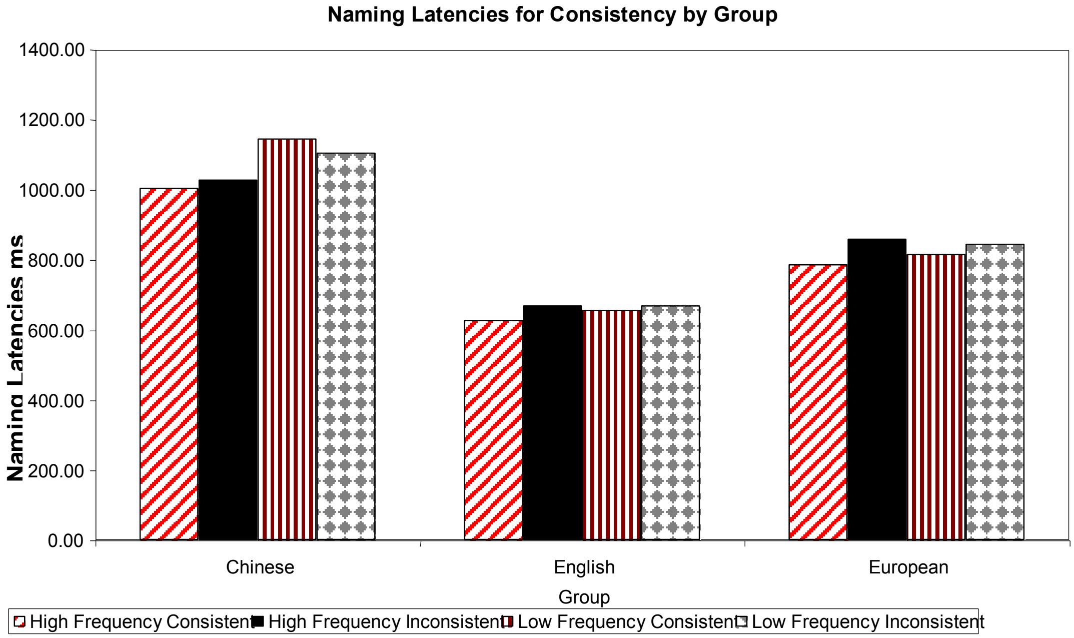

FIG 4 Bar Chart showing mean Rts for consistent and inconsistent words by frequency of enemies and group.

A different pattern emerged (See Figure 4) when different frequency of enemy was used as a factor level. The main difference between groups could be seen between the mean Rt for the inconsistent word type with high-frequency enemies in relation to the matched consistent words.

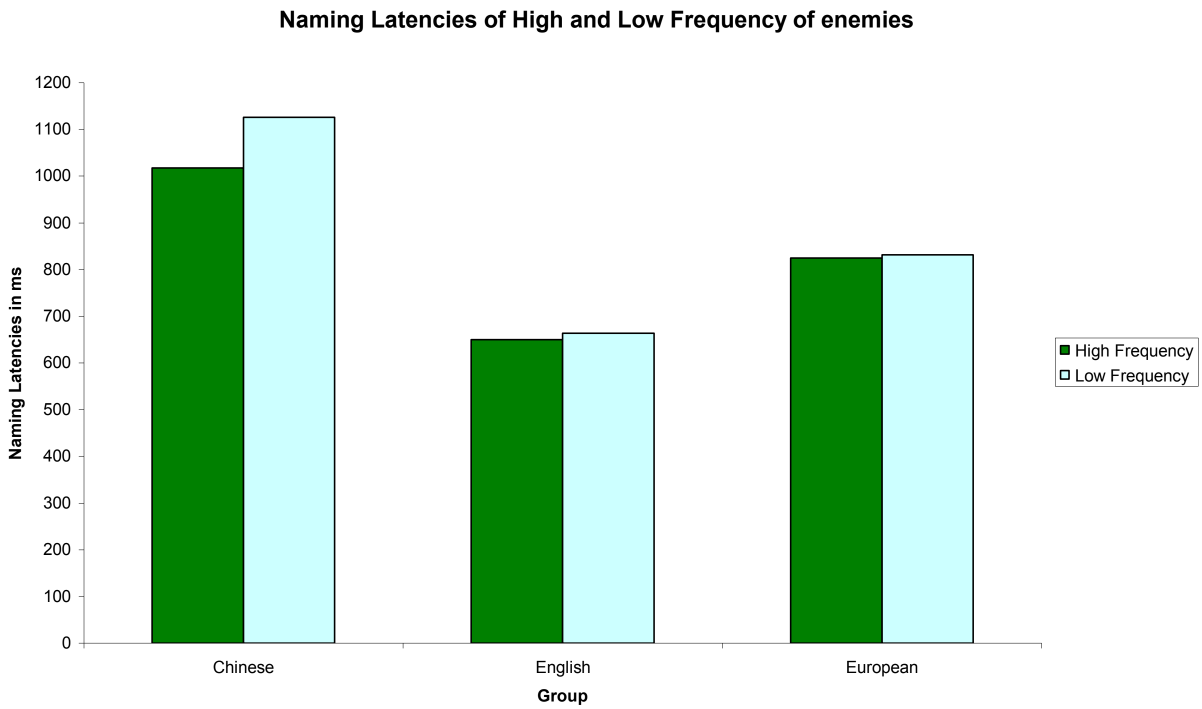

FIG 5 Mean Rts were collapsed across word type into frequency of enemies by group

Figure 5 shows the results when frequency was collapsed across consistency. In other words all response times for high frequency words were plotted together and all response times for low frequency words were plotted together regardless of consistency. This time a different pattern emerged. Frequency difference was greater in the Chinese group but for the European group there was very little difference, but the difference was slightly less than for the English group.

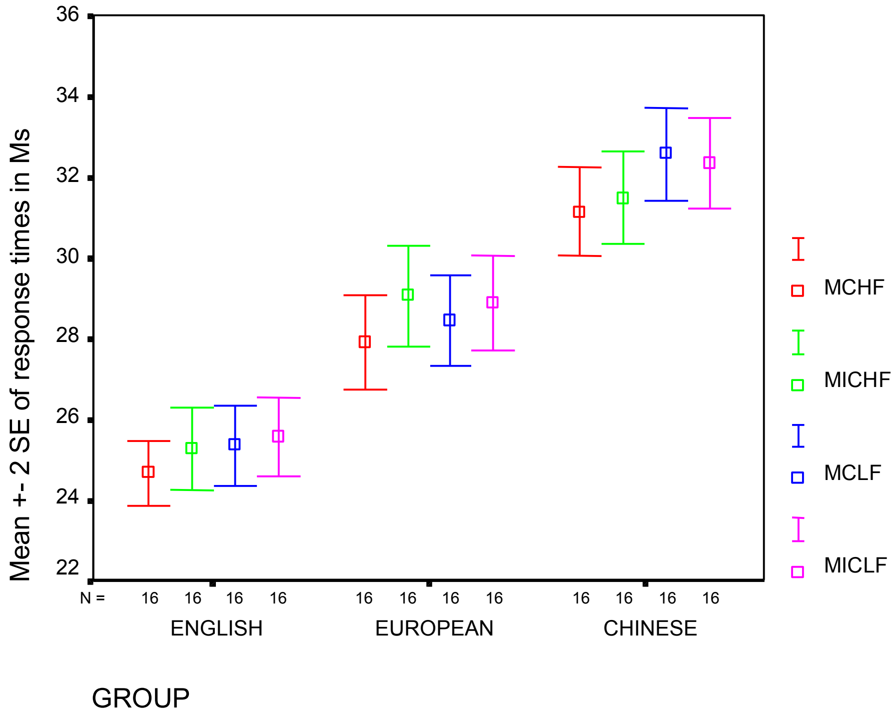

FIG 6 Error bars for the Mean Rts for the 4 categories of words. Consistent matched frequency (MCHF) Inconsistent high frequency enemy (MICHF). Consistent matched frequency (MCLF) and Inconsistent low frequency enemies (MICLF)

The Chinese group showed a greater difference between frequencies of enemies regardless of consistency. The difference was less for the other two groups. (See Figures 5 and 6) This difference was investigated further by using Paired Sample T Tests.

To test the 3 hypotheses, Paired Sample T Tests were conducted for all groups. (See Table 5) A Paired Sample T Test was conducted for all groups to investigate total consistency against total inconsistency. To control for Type 1 error over the two comparisons for each of the 3 groups separately, in order to investigate significant difference, the alpha level was set at .01 (05/5). The variables were collapsed across frequency levels. The results indicated consistent words for the English group (M=25.01,SD1.79) took significantly less time for response than the inconsistent words (M=25.41,SD=1.96), t=(15)-3.878 p =0.001. The standard effect size index d was .97, a high value. The mean difference was –0.3978. The results indicate that the consistent words for the European group (M=28.89,SD=2.30) took significantly less time for response than the inconsistent words (M=28.97,SD=2.40), t =(15)-5.789 p= 0.0001. The standard effect size index d was .1.46, a high value. The mean difference was –-0.7850. The English and European groups patterned together by having significant differences between consistent and inconsistent with combined frequency levels, in contrast to the Chinese group. The Chinese group, consistent words (M=31.86, SD=2.18) and inconsistent words (M=31.91, SD =2.18), for which there was no significant difference between the two word types.

TABLE 5

THE RESULTS OF THE PAIRED SAMPLE T TESTS USED TO ANALYSE THE FIRST HYPOTHESIS

Group	Consistent Mean	Inconsistent Mean	t	Mean difference	p
English n=16	25.01 (SD1.75)	25.41 (SD1.96)	(15) –3.878	-0.3978	0.001
European n=16	28.89 (SD2.30)	28.97 (SD2.40)	(15) –5.789	-0.7850	0.0001
Chinese N=16	31.86 (SD2.18)	31.91 (SD2.18)	(15)-.294	-5.43	0.773

The English group took significantly longer to name the inconsistent words than the consistent words t=-3.878 p = 0.001. See table 7 column C.

TABLE 6

THE RESULTS OF THE PAIRED SAMPLE T TESTS USED TO ANALYSE THE SECOND AND THIRD HYPOTHESES

Group	Matched Consistent Mean	Inconsistent High freq enemy Mean	t	Mean difference	p
English n=16	24.67 (SD1.61)	25.27 (SD2.03)	(15) –3.246	–0.6025	0.005
European n=16	27.91 (SD=2.34)	29.05 (SD=2.52)	(15)-5.273	-1.1443	0.0001
Chinese n=16	31.14 (SD2.18)	31.48 (SD2.31)	(15) –1.56	-.346	0.141

The European group took significantly longer to name high summed frequency inconsistent words than matched consistent words. t =5.273 p =0.0001

The Chinese group did not take significantly longer to name high summed frequency inconsistent words than matched consistent words. (See Table 7 column A)

The results indicated that the matched high summed frequency consistent words for the English group (M=24.67,SD1.61) took significantly less time for response than the summed high frequency inconsistent words (M=25.27,SD=2.03), t =(15)-3.246 p = 0.005. The standard effect size index d was .81, a high value. The mean difference was –0.6025. The results indicated that high summed frequency consistent words for the European group (M=27.9065,SD=2.3445) took significantly less time for response than the summed high frequency inconsistent words (M=29.0507,SD=2.5227), t =(15)-5.273 p =0.0001 The standard effect size index d was .1.32, a high value. The mean difference was –1.1443 t = *-5.273* p = 0.0001 indicated that the English and European groups patterned together by having significant differences between consistent and inconsistent words at both frequency levels, in contrast to the Chinese group. The Chinese group, consistent words (M=31.1403,SD=2.1761), inconsistent words (M=31.4864,SD =2.31), for which their was no significant difference between the two groups. (See table 5)

Further analysis

To control for Type 1 error over two further comparisons a new alpha level was set to .005 (.01/2).

The Paired Sample T Test was conducted to evaluate whether low summed frequency enemies differed in response times to matched consistent words. (See Table 7 column B) Jared et al (1990) had not found a significant difference between these two groups of words for native English speakers. The results indicated that the matched low summed frequency consistent words for the English group (M=25.36,SD=1.99) took less time but not significant, for response than the summed low frequency inconsistent words (M=25.56,SD=1.94), t =(15)-2.771 p = 0.014. The standard effect size index d was .69, a moderately high value. The mean difference was –0.1942. This result replicated those obtained by the original study by Jared et al. The results indicated that the matched low summed frequency consistent words for the European group (M=28.46,SD=2.25) took significantly less time for response than the summed low frequency inconsistent words (M=28.88,SD=2.37), t =(15)-3.702 p = 0.002. The standard effect size index d was .92, a high value. The mean difference was –-0.4265. The English and European groups patterned together by having significant differences between consistent and inconsistent words at both frequency levels, in contrast to the Chinese group. The Chinese group, low summed frequency consistent words (M=32.58, SD =2.1761), inconsistent words (M=332.34,SD =2.21), indicated there was no significant difference between the two groups of word type at either frequency level.

A Paired Sample T Test was conducted for all groups to investigate high summed frequency against low summed frequency collapsed across consistency. (See Figure 5 and Table 7 column D) The variables were collapsed across consistency levels. The results indicated high summed frequency words for the English group (M=25.97,SD1.80) took significantly more time for response than the low summed frequency words (M=25.41,SD=1.96), t =(15)-4.489 p = 0.0001. The standard effect size index d was 1.12, a high value. The mean difference was –0.4832. The results indicated that the high summed frequency words for the European group (M=28.48,SD=2.39)did not take significantly more time for response than the inconsistent words (M=28.67,SD=2.29). In contrast to the Chinese group. The Chinese group, mean for high summed frequency words (M=31.31,SD=2.20), low summed frequency words (M=32.46,SD=2.15), t =(15)-6.474 p = 0.0001. The standard effect size index d was 1.62, a high value. The mean difference was –1.1474. Table 7 shows all the Paired T Tests together in order to quickly see the patterns of results.

A final Paired Sample T Test was performed to look at significance of the difference between the differences already found between the consistency effect in the high enemy and low enemy conditions. Looking at Figure 3 there appeared to be a different pattern emerging between the size of consistency effect between the Chinese group and the alphabetic script users. (English and European groups). Table 7 column E has used data which subtracted the difference between response times used in column A and the difference between response times used in column B. There was a significant difference between the response times for the high summed frequency inconsistent matched consistent words and the difference between response times for the low summed frequency inconsistent words and the matched consistent words for the alphabetic based writing system. The difference between high summed frequency word types for the English group(M=.6025,SD=.7424) and the difference between the summed low frequency word types (M-.1942,SD=.2803) t =3.883 p = 0.001 reached significance. . The standard effect size index d was .97, a high value. The mean difference was 0.7967. The difference between high summed frequency word types for the European group (M=-1.1443,SD=.8680.) and the difference between the summed low frequency word types (M=-.4265,SD=.4608) reached significance, t =5.799 p = 0.0001. The standard effect size index d was .1.45, a high value. The mean difference was 1.5708. This difference failed to reach significance for the Chinese group, the mean for the high summed frequency words (M=.3461, SD=.8901), and the mean for the low summed frequency words (M=.2378,SD=1.39).

TABLE 7

RESPONSE TIMES FOR MEAN SCORES COLLAPSED OVER WORD TYPE AND OVER FREQUENCY

Group	*A)t* value for Mean **High frequency** Consistent Inconsistent F	*B)t* value for Mean **low frequency** Consistent Inconsistent	*C)t* value for Total **Consistent** Total **Inconsistent**	*D)t* value for Total **High frequency** Total **low frequency**	*E)t* value Difference between the difference between word types in high and low frequency groups
1)Chinese	*Not Significant*	*Not significant*	*Not significant*	t = *-6.474* p *=0.0001*	*Not significant*
2)English	t = *-3.246* *p =0.005*	*Not significant*	t = -3.878 p *=0.001*	t*=-4.489* p *0.0001*	t*=3.883* p *=0.001*
3)European	t = *-5.273* p = *0.0001*	t *=-3.702* p = *0.002*	t = *-5.789* p = *0.0001*	*Not significant*	t *=5.799* p *=0.0001*

To investigate the data further and in line with the original study of Jared, McRae and Seidenberg (1990), and to evaluate the effects of consistency and frequency and group, a mixed Analysis of Variance was performed. . The variable was speed of response. The two within factors were word type and frequency and each factor had two levels. The word type levels were consistent and inconsistent and the two levels of frequency were high and low frequency of enemies. The consistent words were matched for summed frequency of friends with the inconsistent words. There was also a between subject factor of group with three levels, Chinese, English and European.

The assumption of homogenerity of variance was checked. The Levene Test was not significant. The observed power for the main effect of group was high (1). The observed power for the effect of consistency was also high (.998). The observed power for consistency and group was .high (.881). The observed power for frequency was high (1).

The observed power for frequency and group was high (.991). The observed power for consistency and frequency was high (.874).
The two within factors were word type and frequency and each factor had two levels. The word type levels were consistent and inconsistent and the two levels of frequency were high and low frequency of enemies. The consistent words were matched for summed frequency of friends with the inconsistent words. There was also a between subject factor of group with three levels, Chinese, English and European. A significant main effect was found for group $\underline{F}(2,45)=8676.40$, $\underline{p}<0.0001$, partial $\eta^2 = .995$. A significant main effect for consistency was found, $\underline{F}$ $(2,45)=.24.330$, $\underline{p}<0.0001$, partial $\eta^2 = .351$ The main effect for frequency was significant $\underline{F}(1,45)=54.180$, $\underline{p}<0.0001$, partial $\eta^2 = .546$ A significant interaction between consistency and group was found $\underline{F}(2,45) = 6.373$, $\underline{p}<.004$, partial $\eta^2 = .221$ There was a significant interaction between frequency and group $\underline{F}(2,45) = 11.648$, $\underline{p}<0.0001$, partial $\eta^2 = .341$. The interaction of consistency and frequency was found significant, $\underline{F}$ $(2,45) =10.086$, $\underline{p}<$ 003, partial $\eta^2 = .183$. The interaction between consistency, frequency and group failed to reach significance. The observed power was .998 for consistency and 1.0 for frequency.

The results replicated those of Jared, McRae and Seidenberg showing that the cohort together took longer to name inconsistent words ($\underline{M}$=28.76) than consistent ($\underline{M}$=28.35). They also took longer to name low frequency enemy words ($\underline{M}$=28.86). than high frequency enemy words ($\underline{M}$=28.26). However these main effects were for comparison purposes only as the interactions were expected because the Paired T Tests had indicated significant differences which supported the experimental hypotheses. It had been suggested in the introduction that if the Chinese group were not relying on the phonological route to read written English, then the difference between the high enemy inconsistent scores and the matched consistent should be significantly smaller. The results supported this view.

These results are discussed in terms of the original study by Jared, McRae and Seidenberg (1990) and the implications for universal phonological processing in word naming.

Discussion

The experimental hypotheses were supported by the results. These data indicate that there was a consistency effect which was significant for both the alphabetic script readers but not for the Chinese readers. It is necessary to consider why a consistency effect was not found. To date there is a convincing argument for universal phonological processing requirements for word recognition using all script types. Jared et al (1990) needed tight controls in order to isolate an effect that has proved to be hard to find in practice. The work by Perfetti and colleagues has not been replicated and gradually the argument has moved away from obligatory phonological processes that mediate access to the lexicon to an argument about the stage at which phonological processes are activated. Intuitively, phonological processes must be activated in order to read words aloud. Reading is a skill which is taught and it has been established that children and others who develop into fluent readers are encouraged to read aloud at the beginning of their training, for assessment purposes. This discussion will consider the evidence for and against early phonological activation for alphabetic script readers and logographic script readers followed by the arguments put forward by advocates and opponents of a dual route model for lexical access.

These data contradict the view put forward by Brown (1987) that frequency of spelling-sound correspondence influenced response times for word naming and not consistency, because frequency and number of friends were controlled. The clever design of the experiment managed to separate the issue of frequency from consistency. In other words the number of words which rhyme and (importantly) are identical in terms of the construction of the word-body letter combination, influenced the priming effect of words stored together. The effects of homophones (words which sound the same but are visually different) is known to slow down naming response times. The reason for this has been argued that competing meanings have slowed down the process of reading text. Pseudohomophones (non-words but sound the same as a real word) have been shown to slow down response times in naming tasks due to the conflict between sounding plausible but visually non-existent. All these complex anomalies were removed in order to measure whether strength of enemy spelling-sound combination caused any adverse effect on naming latency. This was investigated by further grouping the words into two levels of enemy frequency. Both these levels had two competing rhyming combinations but identical word-bodies, the issue of strength of opposition (how many and often they occurred) was able to be measured.

The consistency effect is associated with a single phonologically mediated route to the internal lexicon. This effect was found for all the European language speakers and so the effect does exist. (See Figure 3) It could be argued that this effect only exists under very specific circumstances. This was the rationale for choosing the Jared et al study to extend the design for different cultural groups. Jared et al (1990) suggested that the consistency effect found was phonological in nature and not orthographic. This was because all orthographic factors such as bigram frequency (Solso and Juel 1980), orthographic error score (Seidenberg and McClelland 1989), number of letters and initial letter were controlled for. Jared et al suggested that the consistency effect might be greater for less skilled readers. This was found to be the case for the European readers in this study. (See Table 7 column C) The consistency effect was greater and shown by the larger mean difference between all consistent and inconsistent words. The frequency of enemy level was an important issue for the Europeans because unlike the English group the low frequency of competing pronunciations adversely affected response times to a significantly higher degree. Figure 6 and Table 7 column B) Jared et al had said that low frequency of enemies would not prejudice response times for fluent readers because their 'army' was not strong enough to impact on the large pool of identical pronunciations. However, for people for whom English is a second language, many of these words would be less familiar for both consistent and inconsistent words, and so familiarity would itself be an issue. Connectionist modelling would support the view that the frequency of activation would impact on response times. That was the reason for choosing an experimental design where the four word categories could be collapsed across two dimensions with 50% of the words having no competing enemies at all, but were matched in terms of frequency at two levels. The native English data from the current study followed the same response time patterns at the original study by Jared et al.

Table 4 shows that for the English group, both word types in the high-frequency enemy divide took less time than the low-frequency enemy. The pattern of responses was slightly different for the European group where both the consistent groups of words showed lower response times than the inconsistent. This would suggest that competing pronunciations slowed down the response times more than for the native English speakers.

Taking into account the longer reaction times for the Chinese group,(Figure 4 and Table 4) the effect should be greater still according to Jared et al. It i possible that the longer reaction times recorded (for all word types) were not because of lack of skill per se, but because of a lack of phonological processing skill or perhaps a different processing style altogether. The results produced showed a different pattern when word types were collapsed across frequency. (See Figure 5) The difference between high and low frequency enemy conditions including the matched consistent words presented a different pattern between alphabetic script readers and logographic. Figure 6 shows that both the high frequency error bars for the Chinese group are closer together and with a greater separation in terms of frequency from the low-frequency enemy inconsistent works and their matched consistent. Seidenberg (1985b) suggested that the consistency effect was greater for less skilled readers because they treat all words as low frequency words. If this were the case for the Chinese group, then it would be hard to explain the difference in scores between the higher frequency words and the lower frequency words. If they were not skilled readers the scores should not show the high frequent/low frequent divide. Both the European group and the Chinese group were assessed and matched in terms of reading ability, (Table 2) so clearly there is another explanation.

Jared et al concluded that models of word recognition need to include processes which take account the knowledge of other similarly pronounced words as suggested by Glushko (1979). This model would argue against GPC Coltheart (1978) because all words used in this experiment would be regarded as 'rule-governed' and not' irregular' as defined by previous models of written word processing. Therefore because the consistency effect for both alphabetic script readers affected performance, the dual route mechanism which supported a direct route cannot be applied in order to interpret these data. However can it in part, explain the difference found for the Chinese group. If the Chinese group were not using a single phonological path in order to gain access to the lexicon then high frequency of visually similar items would facilitate response whether there were competing pronunciations or not. This discussion will return to this aspect.

The consistency effect was not found for the Chinese group in this experiment, which due to the tight controls designed by Jared et al, calls into question any argument for universal phonological processing. Perfetti and colleagues (Perfetti and Tan 1998; Perfetti and Zhang 1991, 1995) have used a selection of techniques to show evidence for mandatory phonological activation in reading Chinese characters. The focus of their research has been to study the time-course of semantic and phonological processing activation. This issue is important because it indicates whether phonology plays a vital role in access to the lexical semantics. Perfetti and colleagues have claimed that phonological activation is universal across different orthographies which means that it plays a fundamental role in word recognition. Dual route theories (Coltheart 1978) assume that access to meaning can go one of two ways: Either direct conversion from orthography, or through phonological mediation in which orthographic activation passes through phonological representation and then finally on to semantic representation. In contrast, the connectionist view suggests that semantic and phonological activation are as a result of the interactive processes with phonology playing the primary role. The difficulty for the connectionist single route is how to account for the research findings of researchers such as Zhou and Marslen-Wilson (2000) who suggest that semantic activation in reading Chinese is not due simply to mediation through phonological activation.

The Chinese data suggests that conflicts within phonological activation as measured through consistent and inconsistent words showed no significant difference. These findings would be consistent with the findings of recent researchers (Chen and Shu, 2001; Feng, Miller, Shu and Zhang 2001; Chen and Wong,1999; Zhou and Marslen-Wilson,1999;Taft and Zhu,1999) that Chinese readers process written words differently from alphabetic script readers. The current research indicates that this is not only the case for the reading of logographic script but reading techniques carry across script types with the reader. This is hardly surprising as English is taught in Chinese through the use of recognition skills and participants of the current experiment explained that spoken English plays a secondary role to written English. This is in stark contrast to how Europeans learn English. The Europeans also have the advantage of greater exposure to English and American TV programmes and popular music.

Feng, Miller, Shu and Zhang (2001) have already produced convincing evidence that Chinese readers of their own characters do not have the option of a phonological lookup route to the lexicon available to them. They explained that Seidenberg and McClelland (1989) found that their parallel distributed processing models differentiated between orthographically similar words that had phonological dissimilarity. The Chinese data collected in the current experiment suggests that phonological pronunciation dissimilarity does not impact on naming latencies to the same extent as it does for the alphabetic script readers. (See Figure 4 and Table 7). This difference was explored further by contrasting the difference of the differences between the consistent and inconsistent words. Jared et al had said that low-frequency enemies do not impact so greatly on response times because of the lack of opposition to the friend controlled version of the pronunciation. For both the English and European groups the weight of the opposition impacted far more and so the difference between consistent and inconsistent high-enemy response times (Table 7 column A minus Column B = Column E) was significantly greater than the difference between the low-frequency enemy inconsistent words and their matched consistent words. This difference (See Table 7 column E) was not significant for the Chinese group as there were no significant differences between any measure which compared consistent with inconsistent.

The implication of this study is that it is possible to extract meaning from alphabetic scripts using different cognitive processes. If this is the case then there is an educational implication for the teaching of reading to children who have poor phonological memory. Chinese children learn to read Chinese characters by using their fingers to trace the outline of the character. This is reminiscent of Baddeley's theory which states that which is visualized is a constructive action which generates visuo-spatial images (Baddeley 1989). Ho, Law and Mang (2000) report that Chinese dyslexics show inferior performance in tests of visual performance (Fostig Developmental Test of Visual Perception) but unlike English children with dyslexia they do not have difficulty with digit span tests. (The Auditory Association Test of the Illinois Test of Psycholinguistic Abilities). Both groups of dyslexic children have difficulty learning new words through listening. Phonological memory is related to the development of phonological recoding. Mandarin Chinese has no derivational morphology (Marslen-Wilson 2001) which means that the compounding is the only productive means of word formation. This is terms morphosyllabic, which means each character is both a syllable and a morpheme. So perhaps the way Chinese children learn to read could inform alternative teaching methods for those who have difficulty learning by conventional means. Firstly it is necessary to review the differences between the two script type which causes the different teaching methods.

Marslen-Wilson also pointed out that there are two types of homophone in Chinese: Those which sound similar but look different with different meanings and those that look similar but have different meanings. It is necessary therefore for young Chinese readers to learn the written form of their language in terms of being a detective by searching the logograph for visual clues to meaning rather than pronunciation. In the Chinese language 12,000 phonetic compounds represent over 1100 phonetic radicals (the part of the written system that indicates pronunciation) and only 34% are identical to the output sound required. The other problem is that these radicals can be concealed in any part of the character, so through searching would be necessary in order to equate to the alphabetic phonetic system. Therefore naming of Chinese characters cannot be achieved non-lexically. To make a comparison with English, a non-character will result in silence rather like a real character would for any non reader of Chinese. This contrasts to the ability of alphabetic script readers who can make informed guesses about how to read languages which are entirely alien, but with the aid of guidelines can become accomplished readers of any language without having to know the meaning of what they read.

The dissociation between the ability to name and understand lends support to the GPC route to the lexicon (Coltheart 1978). Therefore patients who have an impaired semantic system who show no regularity effect and cannot read non words, supports the existent of the direct visual route. Weekes and Chen (1999) found that Chinese patients with semantic impairment made Larc (legitimate alternative reading component) errors. They suggested this was due to the inability to inhibit competing visually similar logographs. The logograph (geil 1) has five similar characters with five competing meanings, and without the semantic pathway in tact, homophonic errors occur. The difference is that these errors are visually 'homophonic'. Further evidence for a direct visual access to the lexicon was presented by Po, Law and Or (2001) who used neurologically damaged patients to demonstrate that the reading system can bypass the semantic system which must use a direct visual route because a non-lexical conversion system is not possible in Chinese.

In conclusion it seems that there may be two routes to the lexicon as suggested by Coltheart, but as suggested by Jared (1997) these are not optional for the reader. The balance of evidence seems in favour of phonological activation mediating access to the lexicon for readers of alphabetic script. However the picture is less clear for skilled readers of Chinese script. On balance evidence from neurological impairment, error disruption paradigm, backward masking procedures, phonological and semantic judgements and primed naming have indicated that phonological information in the lexicon is not activated earlier than semantic information, when Chinese participants read Chinese characters. Combined with the evidence which supports a direct route to word naming which can bypass the semantic system, it seems that phonology does not play a major role in the reading of Chinese characters.

The results from this experiment support the view that cognitive processing for basic word naming varies according to the reader rather than elicited through the properties of the script. These findings indicate that it is possible to read English words with a reliance on alternative cognitive skills. This possibility suggests that some teaching methods used in China could inform an alternative method for teaching reading of English. This could be beneficial for those whom failure to learn to read would be inevitable due to poor phonological memory and awareness. For social inclusion, the ability to communicate in written form has never been as necessary as it is in the twenty first century.

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