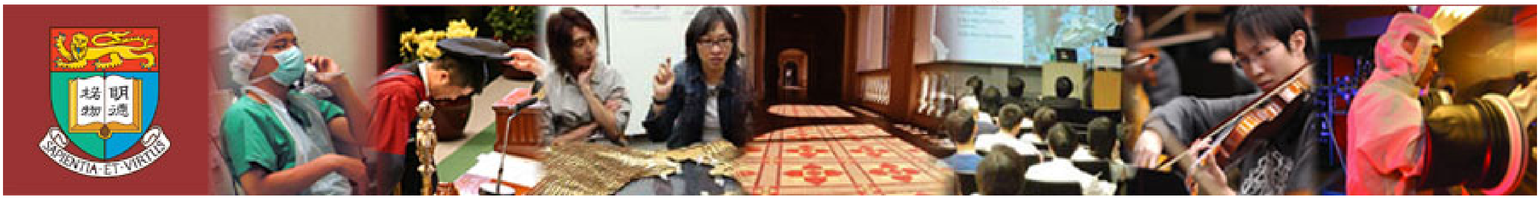

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| Author(s) | Ip, Ka-man, Jasmine; 葉嘉敏 |
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Running head: BIDIRECTIONAL SCRIPT-SOUND INCONSISTENCY IN CHINESE

# Feedforward and feedback consistency in Chinese – Database analysis and behavioural study on writing Chinese

Ip Ka Man, Jasmine

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## Abstract

Old perspective of one-way spelling-to-sound (feedforward) inconsistency was challenged and sound-to-spelling (feedback) inconsistency was highlighted in word recognition recently in alphabetic scripts. However, corresponding data on logographic script is lacking. The current study presented statistical data of a newly established data corpus – Hong Kong Corpus of Feedforward and Feedback Consistency (HKCFFC). The data corpus analysis came up with three major findings: 1). Chinese is more feedforward inconsistent than English and French while all three languages are highly feedback inconsistent. 2). Large proportion of feedforward consistent characters in HKCFFC was found feedback inconsistent 3). Strong correlation was shown between type and token consistency computed. Furthermore, feedback inconsistency computed from type and token consistency values was examined in a writing-to-dictation task on 30 university students. Significant feedback consistency effect was found in error percent rate. It evidenced that frequency-weighted token consistency better represents feedback inconsistency than type consistency.

Feedforward and feedback consistency in Chinese –

Database analysis and behavioural study on writing Chinese

Spelling-to-sound inconsistency attracted much interest for extensive investigations on its effect in word recognition and reading in both alphabetic and logographic scripts over the past decades (Fang, Horng, & Tzeng, 1986; Jared, 1997; Lee, Tsai, Su, Tzeng, & Hung, 2005). Sound-to-spelling inconsistency had long been neglected until the works by Stone, Vanhoy, and Orden (1997) and Ziegler, Stone and Jacobs (1996, 1997), putting forth the significance of sound-to-spelling inconsistency in visual word recognition. According to Jared (1997), in alphabetic scripts, spelling body refers to the series of letters (medial vowels and final consonants) following the initial consonant(s). Ziegler, et al. (1996, 1997) defined a word as feedforward inconsistent when its spelling body (body) could be mapped into more than one pronunciation, e.g. body _int is read as /aɪnt/ in "pint" but /ɪnt/ in "hint". Similarly, a word is feedback inconsistent if its phonologic body maps with more than one spelling body. For example, phonologic body /-ip/ could be spelled as _eep in "deep" but _eap in "heap".

*Why does feedback inconsistency come into focus?*

Stone, et al. (1997) challenged the old perspective which focuses on one-way spelling-to-sound consistency in visual word recognition solely. They highlighted the role of feedback consistency (sound-to-script mapping) in word recognition using a feedback model for visual word perception. Remarkably, their claim was supported by demonstrating robust feedback consistency effect in the visual lexical decision task. The authors stressed the necessity of controlling both feedforward and feedback inconsistency (bidirectional inconsistency) in psycholinguistic experiments on word perception.

This new perspective of bidirectional inconsistency in the mapping of orthography and phonology and the significance of feedback inconsistency were further supported by Ziegler, et al. (1996, 1997). Ziegler and their colleagues pointed out that it is not uncommon to find a phonologic body with multiple spellings in French and English, in which the prevalence of feedback inconsistent words probably makes spelling difficult. Regarding this phenomenon, the authors hypothesized that failure in controlling feedback inconsistency could lead to insignificant consistency effects in previous studies. Hence, the adult corpora in French and English were analyzed by computing type and token consistency values for feedforward and feedback inconsistency. Type consistency was based on the friend count while token consistency was based on the summed frequency count of friends for each monosyllabic word. Accordingly, they defined friends as words sharing the same spelling body with similar pronunciation, e.g. body _int in "hint" and "mint" are both pronounced as /-ɪnt/.

Zeigler et al. (1996, 1997) reported that 77.4% (French) and 72.1% (English) of all feedforward consistent monosyllabic words were indeed feedback inconsistent in their analyses. Furthermore, both feedforward and feedback inconsistent words were more frequently occurring than the consistent ones. In simpler words, it is likely to pick a feedforward consistent word which is sound-to-spelling inconsistent if feedback consistent is not controlled. The authors, hence, emphasized the importance in controlling feedback inconsistency on visual word recognition tasks in further studies.

Feedback inconsistency seems to play a significant role in visual word recognition until a recent study reported by Zeigler, Ferrand, and Petrova (2008). Contrast to the findings from Stone, et al. (1997), Zeigler and their colleagues reported robust feedback consistency effect in auditory lexical decision task only but not in visual modality in both English and French. Although their findings contradicted the notion of Stone, et al. (1997), leaving a question on the role of feedback inconsistency in word recognition via visual modality, it provides an excellent ground for further studies on other language like Chinese which also characterized by a high degree of homophony (feedback inconsistency)..

*Why Chinese is a perfect language for studying feedback inconsistency?*

Chinese is a logographic writing system in which orthography and phonology correspondence is often described as being arbitrary (Lee, et al., 2005). A character is a unit which corresponds to a syllable which can be represented by onset, rime and tone in Chinese. According to the Hong Kong Corpus of Primary School Chinese (HKCPSC) (Leung & Lee, 2002), there are a total of 3842 Chinese characters in primary school textbook, and they correspond to 1355 syllables. In other words, in average, three characters share the same pronunciation. If tones are not regarded as a distinctive feature in script-sound mapping, leaving only 554 syllables to map onto the 3842 characters. Consequently, in average, seven characters are homophones sharing a single pronunciation. Homophony could lead to ambiguity in spoken Chinese in primary grades. Not surprisingly, homophony is probably more pervasive in adult. Specifically, Chinese orthography is bound to be feedback inconsistent, which explains why memorizing and writing Chinese orthography in a writing-to-dictation task could be difficult. The extensive homophony of Chinese has made it an excellent language for studying the unresolved mystery in alphabetic counterparts – Is there feedback consistency effect in visual word recognition? Behavioural studies on the effect of feedback inconsistency in Chinese are warranted. To investigate the effect of feedback inconsistency, data on bidirectional inconsistency is indispensable. Currently, there is no data available for traditional Chinese. Therefore, the first step of the current study is to establish a data corpus on bidirectional inconsistency in Chinese (see P.8)

*Script-sound mapping unit in Chinese*

Although Chinese is a logographic orthography, similar to alphabetic scripts with grapheme-to-phoneme correspondence (GPC) rules for letter-sound mapping (Venezky, 1970), the script-sound mapping unit smaller than character does exist in Chinese. Characters comprising at least two radicals - phonetic radical hinting the sound of the character and semantic radical implying its meaning, e.g. 晴/cing4/ ‘sunny’ consists of phonetic radical 青/cing1/ ‘green’ and semantic radical 日/jat3/ ‘sun’ are ideophonetic compound, which is known to be the major character type in Chinese. It accounts for 74% of all characters according to the HKCPSC (Leung & Lee, 2002) on traditional Chinese. Throughout this paper, the phonetic transcription of each syllable is based on the Linguistic Society of Hong Kong (LSHK) (Tang, 2002).

Tzeng (1981) identified the script-sound mapping regularities as orthography-to-phonology correspondence (OPC) rule in ideophonetic compounds. According to Chen, Shu, and Anderson (2003), regularity was defined in terms of the contribution of a constituent phonetic radical to the pronunciation of the corresponding ideophonetic compound. Phonetic radical 青/cing1/ helps predict the pronunciation of 清/cing1/ ‘clear’. However, OPC rule is not applicable to predict the pronunciations of all ideophonetic compounds due to the existence of semi-regular characters and irregular characters, of which their pronunciations are different from their own phonetic radical in onset, rime or tone. With phonetic radical 青/cing1/, semi-regular characters could be tone-different 請/cing2/ ‘invite’, onset-different 精/zing1/ ‘elite’, or rime-different 猜/caai1/ ‘guess’ while 倩/sin3/ ‘beauty’ is irregular (different onset, rime, tone). Importantly, a phonetic radical in an ideophonetic compound serves as a script-sound mapping unit for studying script-sound relationship in Chinese.

*The specific feature of consistency in Chinese versus alphabetic scripts*

Regularity rule is only applicable to about 40% of Chinese characters for script-sound correspondence. Learning regularity rule solely is inadequate to predict the sound of the remaining characters (Zhu, 1987). Specifically, it is not uncommon to find characters demonstrating a clear double dissociation between regularity and consistency in Chinese orthography. Tzeng, et al. (1995) defined characters sharing the same phonetic radical as neighbours in the same phonetic family and phonetic consistency as the degree of congruence in the pronunciation of the characters in a phonetic family. In Chinese, there are irregular but consistent characters e.g. 溉/koi3/ 'irrigate' and 慨/koi3/ 'generous' (phonetic radical: 既 /gei3/); regular but inconsistent characters e.g. 清/cing1/ 'clear' and 倩/sin3/ 'beauty' (phonetic radical: 青/cing1/). Clearly, regularity and consistency are separable in script-sound mapping in Chinese. With reference to Ziegler, et al. (1996, 1997), feedforward inconsistency only accounts for 12.4% of French words and 30.7% of English words. It indicates that regular but inconsistent and irregular but inconsistent words account for relatively small proportion in alphabetic scripts. Obviously, consistency is a specifically different feature in Chinese orthography, when compared with alphabetic counterparts.

Similar to the alphabetic counterparts (Jared, 1997; Weeks, Castles, & Davies, 2006), feedforward consistency effect was successfully simulated in behavioral studies and computational model in Chinese (Fang, et al., 1986; Lee, et al., 2005; Yang, McCandliss, Shu, & Zevin, 2009). Lee, et al. (2005) concluded that consistency is a better index for studying script-sound mapping in Chinese than regularity. It further highlights the significance of studying consistency and its relationship with character recognition in Chinese.

*The present study*

Since Lee, et al. (2005) demonstrated significant feedforward consistency effect on character naming in adults, it directed our interest to investigate the developmental changes in consistency and its effect on learning to read and write Chinese. That's why our new database was established from a children corpus - HKCPSC (Leung & Lee, 2002). Our study would serves as a basis for future studies on bidirectional inconsistency in school-age population.

In order to make cross-linguistic comparison with alphabetic scripts - French and English, the present study computed type and token consistency, the number and summed frequency of friend and enemies for each character, with reference to the work of Ziegler, et al. (1996, 1997). Since stimulus characters selection is based on consistency value calculated, the current study aimed at determining either type or token consistency computed could better represent sound-to-script consistency in Chinese.

Since Chinese is tonal language, the role of tones in script-sound mapping has not been explored in previous studies, which leaves a question on the necessity of considering tonal discrepancy in the calculation of consistency value. Therefore, this issue was addressed by computing bidirectional consistency under both conditions of considering (tones considered) and ignoring tonal discrepancy (tones ignored) for further comparison and discussion.

Followed by the data corpus establishment, three major research questions were asked.

1). What are the similarities and differences of feedforward and feedback inconsistency in Chinese comparing with alphabetic scripts - French and English (Ziegler et al., 1996, 1997)?

2). Which consistency value computed - type or token could better describe feedback inconsistency in Chinese characters?

3). How do feedforward and feedback inconsistency change across grades and what are their implications on learning Chinese?

## Database establishment

*Corpus*

All ideophonetic compounds were extracted from the Hong Kong Corpus of Primary School Chinese (HKCPSC) (Leung & Lee, 2002) for analysis and establishment of the new data corpus – Hong Kong Corpus of Feedforward and Feedback Consistency (HKCFFC).

*Script-sound mapping unit*

Since ideophonetic compounds account for 74% of all characters, they were used as the script-sound mapping unit for bidirectional consistency. In each script-sound mapping unit, each character (orthographic form) corresponds to one syllable (phonologic body). As 95 characters (2%) carry more than one pronunciations, for instance, 長 can be pronounced as 長/coeng4/ ‘long’ and 長/zoeng2/ ‘elder’, they were separated into two records 長 1 and 長 2 as two script-sound mapping units before the computation of consistency. The tones of syllables were deleted for the computation of consistency under tones ignored condition. After the modification, there are currently 3842 records of characters stored in the new data corpus.

*Feedforward consistency*

A character is regarded as feedforward consistent if its phonetic family in which all neighbours share the identical pronunciation with respect to onset, rime and tone. Those neighbours sharing the same onset, rime and tone are friends while neighbours which differ in onset, rime or tones are enemies to each other (note that characters with tonal difference is counted as friends in “tone ignored” condition). Thus, 猴/hau4/ ‘monkey’ and 喉/hau4/ ‘larynx’ are friends but 油/jau4/ ‘oil’ and 抽/cau1/ ‘draw’ are enemies to each other. Type consistency was computed from the ratio of the friend count of each character in the phonetic family to its family size. Since Jared (1997) and Lee, et al. (2005) found that the relative summed frequency of friends and enemies affected the magnitude of feedforward consistency effect, token consistency was computed as the ratio of the summed frequency of friends to the summed frequency of neighbours in the phonetic family. Feedforward consistent and inconsistent characters and consistency calculation were illustrated in Table 1.

*Feedback consistency*

Similarly, both type and token consistency were computed for feedback consistency as

Table 1

*Examples and Calculation of Feedforward Type and Token Consistency*

| | | Tones considered | | Tones ignored | |
|---|---|---|---|---|---|
| Example 1 (feedforward consistent) | | 猴/hau4/ ‘monkey’ | | 猴/hau/ ‘monkey’ | |
| Family neighbours | | 侯/hau4/ ‘marquis’, 喉/hau4/ ‘larynx’ | | 侯/hau/ ‘marquis’, 喉/hau/ ‘larynx’ | |
| Type = | No. of friends in family / family size | 3 / 3 | = 1 | 3 / 3 | = 1 |
| Token = | total summed frequency of friends / total summed frequency of family | (63+38+6) / (63+38+6) | = 1 | (63+38+6) / (63+38+6) | = 1 |
| Example 2 (feedforward inconsistent) | | 嬉/hei1/ ‘play’ | | 嬉/hei/ ‘play’ | |
| Family neighbours | | 嘻/hei1/ ‘laugh’, 喜/hei2/ ‘like’ | | 嘻/hei/ ‘laugh’ 喜/hei/ ‘like’ | |
| Type = | No. of friends in family / family size | 2 / 3 | = 0.67 | 3 / 3 | = 1 |
| Token = | total summed frequency of friends / total summed frequency of family | (19+32) / (19+32+320) | = 0.14 | (19+32) / (19+32+320) | = 0.14 |

shown in Table 2. Homophones sharing the same phonetic radical are regarded as friends while those do not are enemies, e.g. for syllable /cim1/, 纖/cim1/ ‘slim’, 籤/cim1/ ‘lots’ (phonetic: 韱/cim1/) are friends but are enemies to/cim1/, 簽 ‘sign’ (phonetic radical: 僉 /cim1/). Type consistency was computed as the ratio of the number of friends for each character to the total number of homophones. Similar to feedforward consistency, token consistency was computed as the ratio of the summed frequency of friends to the total summed frequency of all homophones for each character. Homophones with larger number or summed frequency of friends than enemies are more feedback consistent.

Table 2

*Examples and Calculation of Feedback Type and Token Consistency*

| | Tones considered | Tones ignored |
|---|---|---|
| Example 1 (feedback consistent) | 潑/put3/ ‘splash’ | 潑/put/ ‘splash’ |
| Homophones | None | None |
| Type = $\frac{\text{number of friends in homophones}}{\text{total number of homophones}}$ | $\frac{1}{1} = 1$ | $\frac{1}{1} = 1$ |
| Token = $\frac{\text{summed frequency of friends}}{\text{summed frequency of homophones}}$ | $\frac{31}{31} = 1$ | $\frac{31}{31} = 1$ |
| Example 2 (feedback inconsistent) | 簽/cim1/ ‘sign’ (pr: 僉) | 簽/cim1/ ‘sign’ (pr: 僉) |
| Homophones | 纖 ‘slim’, 籤 ‘lots’ (pr: 韱) | 纖 ‘slim’, 籤 ‘lots’ (pr: 韱) 潛 ‘dive’ (pr: 朁) |
| Type = $\frac{\text{number of friends in homophones}}{\text{total number of homophones}}$ | $\frac{1}{3} = 0.33$ | $\frac{1}{4} = 0.25$ |
| Token = $\frac{\text{summed frequency of friends}}{\text{summed frequency of homophones}}$ | $\frac{77}{(77+60+14)} = 0.51$ | $\frac{77}{(77+60+14+53)} = 0.38$ |

*Note*: pr refers to phonetic radical

*New data corpus establishment*

The data corpus (HKCFFC) on feedforward and feedback consistency is presented as two files in of FileMarker Pro 11 database format. For feedforward consistency, each record is coded with its basic information - the character, its syllable in LSHK format, its phonetic radical and its frequency count in each grade extracted from HKCPSC (Leung & Lee, 2002). The values of friend count, enemy count, the summed frequency of friends, type and token consistency for each character were computed. Each of the above mentioned values were stored in a new separate field within each record. In addition, each record displays all its neighbours and their frequency values via the mutually shared field of phonetic radical. For

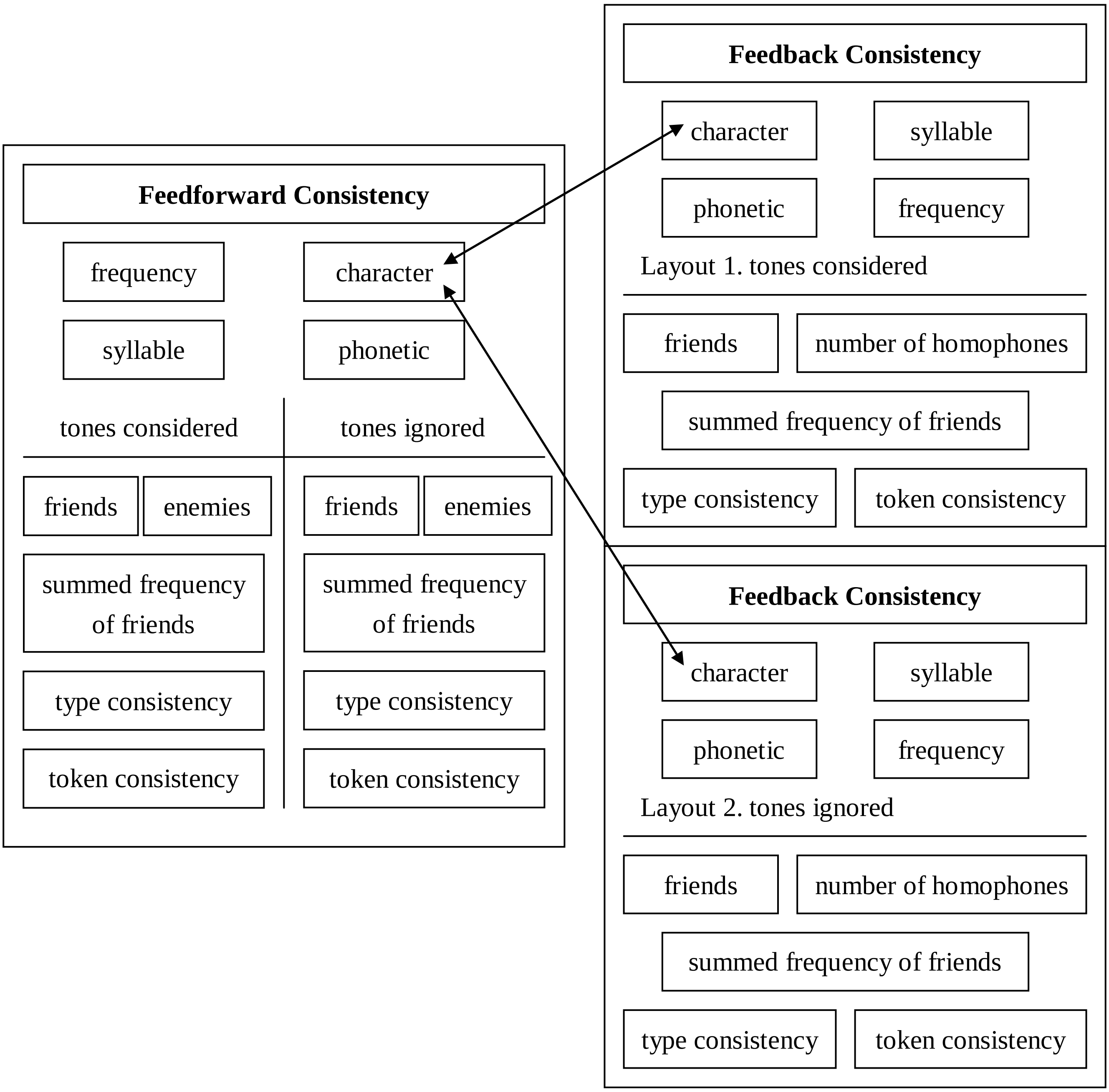


*Figure 1.* The architerature of data corpora on feedforward and feedback consistency

*Note:* “⟷” represents the relational linkage established between the data corpora.

feedback consistency, each record is coded with the basic information, the homophone count, friend count, the summed frequency of friends computed, type and token consistency, each in a new separated field. Within each record, it displays all the corresponding homophones and their frequency values via the mutually shared field of syllable. All corresponding values computed under the condition of ignoring tonal discrepancy were stored in another layout in the same data corpus. The comprehensive data present in each record allows users to search all related records by specifying the values in the corresponding fields. Another feature worth highlighting is the relational linkage built up between the feedforward and feedback consistency database via the mutually shared fields of character. This linkage allows displaying all the values in the fields of the matched record from another database. Thus, the bidirectional consistency data could be displayed within each record. The architerature of data corpora on feedforward and feedback consistency was illustrated in Figure 1.

*Data analysis*

In order to make cross-linguistic comparison between Chinese and alphabetic scripts, the number and percentage of feedforward and feedback inconsistent characters across six primary grades were calculated. Pearson product-moment correlation coefficient was computed to demonstrate the correlation between type and token consistency.

## Results

*Feedforward and feedback consistency in Chinese corpus* (HKCFFC)

For the sake of cross-linguistic comparison with relevant data in alphabetic scripts - English and French (Ziegler et al., 1996, 1997), the cut-off value for inconsistency was 1.

Regarding feedforward and feedback inconsistency in Chinese, interestingly, the established database showed that type and token consistency presents highly comparable figures. Among the 3842 Chinese characters, when tonal difference was considered (tones considered), feedforward inconsistent characters account for 73.1% (type), 72.5% (token) while 77.7% (type), 77.4% (token) are feedback inconsistent. In contrast, when tonal discrepancy was ignored (tones ignored), there is considerably larger proportion of feedback inconsistent characters than feedforward characters. Again, type and token consistency

Table 3

*Proportion of Characters in Bidirectional (in)Consistency using Type Consistency*

| | Tones considered | | | | | Tones ignored | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Feedforward | | | | | Feedforward | | | | |
| | Consistent | | Inconsistent | | Σ | Consistent | | Inconsistent | | Σ |
| Feedback | *n* | % | *n* | % | % | *n* | % | *n* | % | % |
| Consistent | 198 | 5.2% | 659 | 17.2% | 22.3% | 42 | 1.1% | 140 | 3.6% | 4.7% |
| Inconsistent | 835 | 21.7% | 2150 | 56.0% | 77.7% | 1318 | 34.3% | 2342 | 61.0% | 95.3% |
| Σ | | 26.9% | | 73.1% | | | 35.4% | | 64.6% | |

Table 4

*Proportion of Characters in Bidirectional (in)Consistency using Token Consistency*

| | Tones considered | | | | | Tones ignored | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Feedforward | | | | | Feedforward | | | | |
| | Consistent | | Inconsistent | | Σ | Consistent | | Inconsistent | | Σ |
| Feedback | *n* | % | *n* | % | % | *n* | % | *n* | % | % |
| Consistent | 202 | 5.3% | 665 | 17.3% | 22.6% | 51 | 1.3% | 144 | 3.7% | 5.1% |
| Inconsistent | 853 | 22.2% | 2122 | 55.2% | 77.4% | 1338 | 34.8% | 2309 | 60.1% | 94.9% |
| Σ | | 27.5% | | 72.5% | | | 36.2% | | 63.8% | |

*Note:* **Σ**: total percentage of characters; *n*: number of characters in the subset

showed comparable figures, with 95.3% (type) and 94.9% (token) feedback inconsistent and 64.6% (type) and 63.8% (token) feedforward inconsistent characters. Table 3 and 4 presented the number and percentage of both consistent and inconsistent characters.

Ziegler et al. (1996, 1997) found large proportion of feedforward consistent words in English (72%) and French (77%) are indeed feedback inconsistent. Accordingly, in Chinese, larger percentage of characters with contradictory feedforward and feedback consistency values was found, especially when tones were ignored. It is noteworthy that, whenever tones were considered or ignored, type and token consistency showed high agreement in the figures. Among all feedforward consistent characters, 80.8% (type, tones considered), 80.9% (token, tones considered), 96.9% (type, tones ignored) and 96.3% (token, tones ignored) of them are indeed feedback inconsistent.

*Correlation between type and token consistency*

Pearson product-moment correlation coefficient showed a strong significant correlation between type and token consistency. For feedforward consistency, $r = 0.75$, $p < .001$ (tones considered), $r = 0.79$, $p < .001$ (tones ignored). For feedback consistency, $r = 0.78$, $p < .001$ (tones considered), $r = 0.75$, $p < .001$ (tones ignored).

*Consistency levels in feedback consistency*

Instead of dichotomous division, Ziegler, et al. (1996, 1997) suggested that the continuum of inconsistency was better represented by the metrics of type and token consistency. In order to differentiate the degree of inconsistency among inconsistent characters (value <1), consistency values were subdivided into ten inconsistency levels (e.g. 0-0.9; 0.1-0.19; 0.2-0.29). It is worth highlighting the difference between type and token consistency in showing the distribution of characters in subdivided consistency levels. Type consistency showed that characters distributed into three major feedback consistency levels - high (value = 1), medium (value = 0.41-0.99) and low consistency (value ≦ 0.4) in Figure 2. On the contrary, frequency-weighted token consistency manifested a different pattern in Figure 3, with characters concentrating in two extreme ends of consistency continuum - high consistency (value = 1) and extremely low consistency (value <0.1).

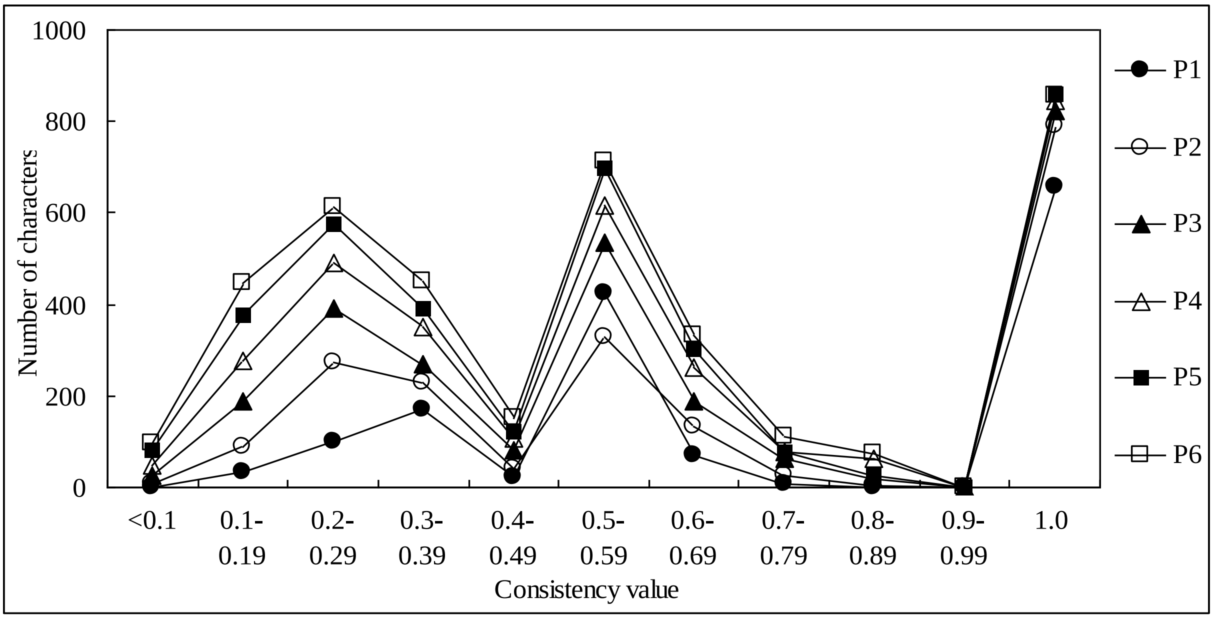


*Figure 2.* Distribution of characters in subdivided feedback consistency levels - type, tones considered.

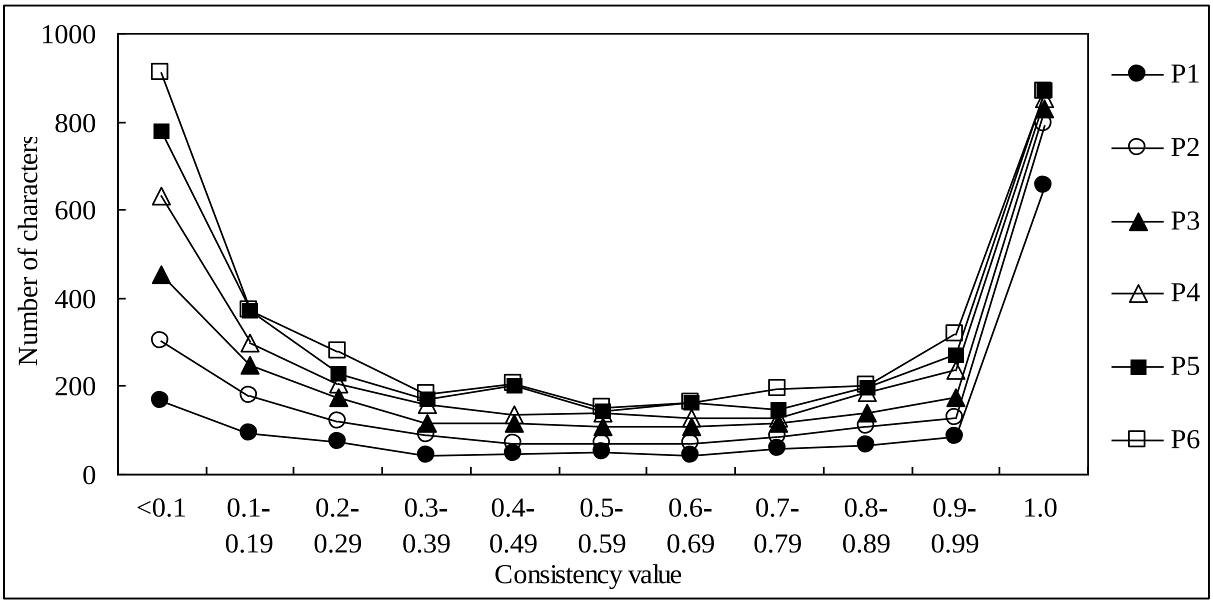


*Figure 3.* Distribution of characters in subdivided feedback consistency levels - token, tones considered.

## Discussion

*Agreement between type and token consistency*

The type and token consistency presented basically similar figures in the percentage of feedforward and feedback inconsistency either when tones were considered or ignored. Quite a bit of overlapping of inconsistent characters (value <1) is expected based on either type or token consistency. Their high agreement was further supported by the strong significant correlation coefficient.

*Disagreement between type and token consistency*

The distribution of feedback inconsistent characters in finer consistency levels was different for type and token consistency (Figure 2 and 3). Type and token consistency showed discrepancy in quantifying the degree of feedback inconsistency. Since consistency values of characters directly affect the selection of stimuli for further study of feedback inconsistency on word recognition, it is necessary to figure out if type or token consistency determines the consistency effect. As Jared (1997) and Lee, et al. (2005) showed that the relative summed frequency of friends and enemies affected the magnitude of feedforward consistency effect, it was predicted that feedback token consistency would also be more likely to predict the performance in a writing task. Participants would likely to respond slower and have lower accuracy rate in characters with low feedback token consistency. It was hypothesized that feedback consistency effect is affected by the frequency of exposure to the target character and its relative summed frequency of friends and enemies.

## Method

*Participants*

The participants were 15 males and 15 female from Year I to Year IV students in the University of Hong Kong. All of them were volunteers and native speakers of Cantonese with normal visual and hearing abilities.

*Stimuli*

A total of 26 traditional monosyllabic Chinese characters were selected from the new corpus – HKCFFC to form four groups of stimuli based on feedback type and token consistency (tones considered). Group 1: 6 characters with high type and token consistency (≧0.8). Group 2: 6 characters with low type and token consistency (≦0.4). Group 3: 7 characters with high type consistency (≧0.8) but low token consistency (≦0.4). Group 4: 7 characters with low type consistency (≦0.4) but high token consistency (≧0.8). Variables such as feedforward type and token consistency, strokes, number of homophones, frequency of occurrence were matched between Group 1 and 2, Group 3 and 4. Each stimulus formed a disyllabic word. The statistics of stimuli were shown in Table 5. In order to control for the duration of each stimulus presented, each stimulus was recorded as audio files by a MP3 player (Samsung YP-U4A4) and edited into a two-second sound track by Audacity software.

*Procedures*

All subjects completed the 20-minute writing-to-dictation task in a sound-booth room at Prince Philip Dental Hospital. The stimuli were presented through a Samsung notebook (Model N130) and an attached loudspeaker in a randomized fashion. The participants were informed that only their hands and the writing process were recorded by the Sony digital camera (Model DCR-SR47E). Participants were instructed to rest their hands on a mark, 7.5 cm from the blank papers given for their writing response. After a stimulus was presented each participant was asked to write the target character on the blank papers immediately the target character. The sound track was paused manually by the investigator after each stimulus was presented until the participants finished writing signaled by flipping to the next blank page. Participants were asked to mark a cross on the paper if they did not know the target

Table 5

*Means (and standard deviations) of Experimental Stimuli of Group 1 to Group 4*

| | Group 1 | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) |
| Feedback type consistency | 1.0 (0.2) | 0.3 (0) | 0.4 (0.2) | 0.7 (0.1) |
| Feedback token consistency | 1.0 (0.1) | 0.1 (0) | 0.8 (0.1) | 0.2 (0) |
| Feedforward type consistency | 0.9 (0.1) | 1.0 (0.1) | 0.8 (0) | 1.0 (0.1) |
| Feedforward token consistency | 0.9 (0.1) | 1.0 (0.1) | 1.0 (0.1) | 1.0 (0.1) |
| Strokes | 14.5 (2.9) | 14.0 (1.5) | 12 (1.9) | 11.9 (2.7) |
| Number of homophones | 4.7 (1.5) | 4.7 (1.5) | 5.6 (0.8) | 4.6 (1.5) |
| Frequency count | 26.0 (24.3) | 25.8 (25.8) | 42.1 (43.3) | 45.6 (44.5) |

character. Each participant was given five practice trials before the experimental trails started.

*Measures*

The correct percentage in each group of character was calculated for each participant. Response time was measured as the time lag right after the stimuli presented until the participant just started writing on the paper. The time lag for each stimulus was measured in terms of the number of frames edited from the video captured using the video-editing software Corel VideoStudio ProX3. Each frame represents 0.04 second in a video.

## Results

Table 6 summarized the mean error percentage and response latencies from Group 1 to Group 4. The four groups of characters formed four levels of independent variables for analysis. The mean error rate was analyzed in four groups of stimulus by paired sample *t*-tests. As the average correct percentage across four groups was only 80.5%, statistical analysis was not run for the response latencies.

Table 6

*Mean Percent Error Rate and Response Latencies of Group 1 to Group 4*

| | Group 1 | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|
| Mean percent error rate | 16.1 | 35 | 7.6 | 19 |
| Mean response latencies (number of frames) | 64.5 | 77.4 | 45.5 | 48.8 |

The participants made significantly more errors in characters of low consistency (Group2) than characters of high consistency (Group1), $t$ (29) = 4.49, $p < .001$. Participants made significantly more errors in Group 4: characters with low token consistency but high type consistency than Group 3: characters with high token consistency but low type consistency $t$ (29) = 4.12, $p < .001$. The results indicated that character of lower consistency was more difficult than character of high consistency and that token consistency seems to be able to explain effect of consistency on writing better.

*Data analysis on the development of feedfoward and feedback inconsistency across grades*

Regarding token consistency was shown to determine feedback inconsistency in the above study and feedforward consistency effect was also shown to be affected by token consistency in Lee, et al. (2005), the developmental changes on feedback and feedforward inconsistency were analyzed with reference to the token consistency of characters.

*Developmental trend of feedback consistency across grades*

As predicted, larger proportion of feedback inconsistent characters than consistent ones was present in each grade. When tonal difference was considered, feedback inconsistent characters increased from 52.8% in grade one and continuously to 77.4% in grade six. Remarkably, a much significant proportion of feedback inconsistent characters (85%) was present in grade one and followed by slight increment in each grade to 94.9% by grade six. Table 7 showed the number and percentage of feedback inconsistent characters in each grade.

Table 7

*Developmental Changes of Feedback Inconsistency across Grades (Token)*

| | P1 | | P2 | | P3 | | P4 | | P5 | | P6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| Tones considered | 729 | 52.8% | 1224 | 60.7% | 1751 | 67.9% | 2247 | 72.5% | 2673 | 75.4% | 2973 | 77.4% |
| Tones ignored | 1174 | 85% | 1827 | 90.6% | 2393 | 92.8% | 2913 | 94% | 3355 | 94.6% | 3647 | 94.9% |

*Note: n* refers to the number of feedback inconsistent characters with consistency value <1.

*Developmental changes of feedback inconsistency levels across grades*

If we further looked into the developmental change within each subdivided feedback consistency levels (high, medium and low), the most remarkable change across grade was noticed in characters of low consistency level (≦0.4), especially when tonal discrepancy was ignored. In Figure 4, characters of low consistency level were characterized by the steepest increase of number across grades, comparing with the more gradual increase across grades for characters of high and medium consistency levels. Similarly, this pattern of change appeared with more remarkable discrepancy among three consistency levels in tone ignored condition. Referring to Figure 5, the change in number of characters of high and medium consistency level was relatively insignificant and reached plateaus starting from grade two.

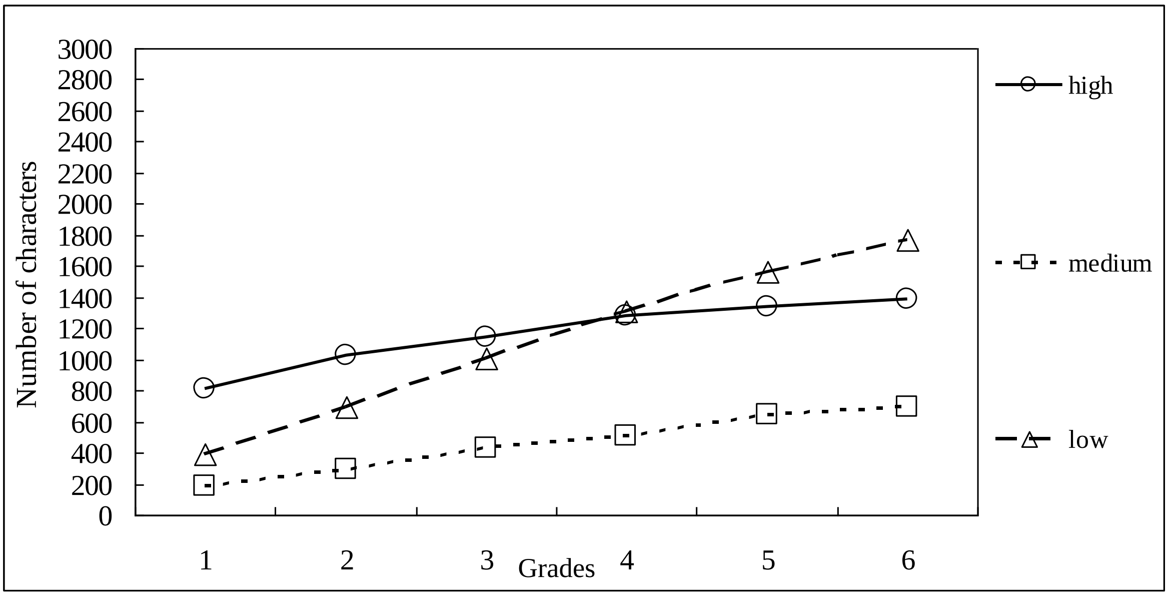


*Figure 4.* Changes in the number of characters within three consistency levels across grades - token, tones considered.

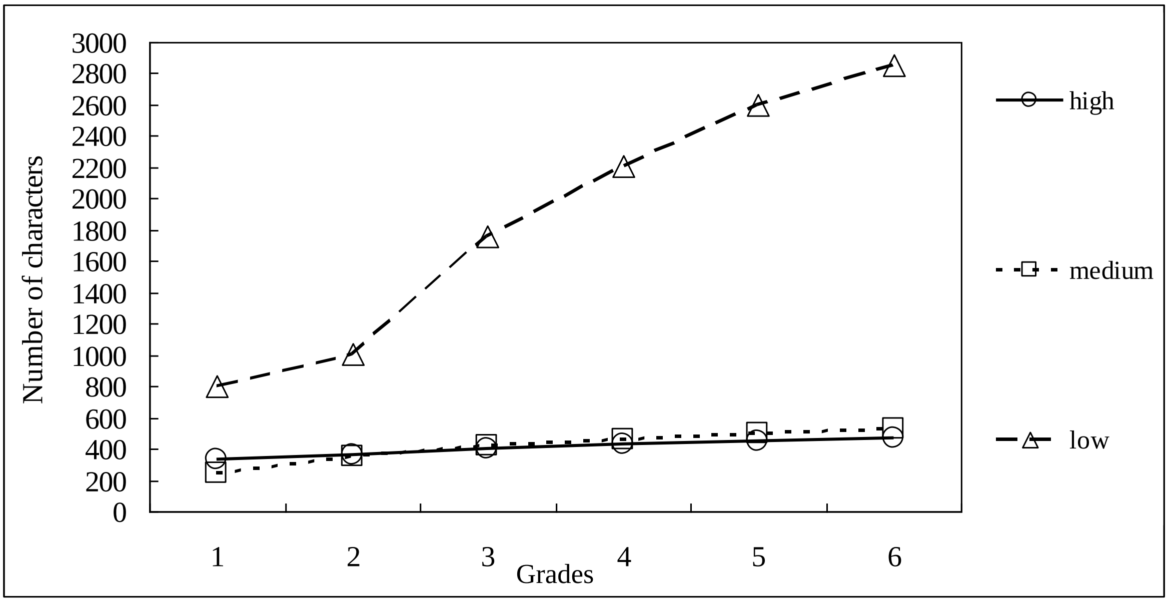


*Figure 5.* Changes in the number of characters within three consistency levels across grades - token, tones ignored.

*Note:* High (value≧0.8), medium (value 0.41-0.79), low (≦0.8).

*Developmental trend of feedforward consistency across grades*

Similar to feedback inconsistency, both the number and percentage of feedforward inconsistent characters increased across primary grades. Feedforward inconsistent characters

Table 8

*Developmental Changes of Feedforward Inconsistency across Grades (Token)*

| | P1 | | P2 | | P3 | | P4 | | P5 | | P6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| Tones considered | 725 | 61.3% | 1223 | 70.3% | 1718 | 76.4% | 2133 | 78.1% | 2528 | 80.4% | 2787 | 72.5% |
| Tones ignored | 617 | 52.2% | 1049 | 60.3% | 1494 | 66.4% | 1901 | 69.6% | 2243 | 71.3% | 2453 | 63.9% |

*Note: n* refers to the number of feedback inconsistent characters with consistency value <1.

increased from 61.3% since grade one and peaked at 80.4% in grade five, and then declined to 72.5% in grade six. Similarly, the increasing trend of feedforward inconsistency was shown when tonal difference was ignored, except smaller proportion of feedforward inconsistent characters, with about 10% less, was found in each grade. Table 8 presented the number and percentage of feedforward inconsistent characters across grades in detail.

## General discussion

*Feedback consistency effect in writing Chinese*

In current study, significant consistency effect was found in mean percent errors between Group 1 and Group 2 characters. This result appears to support the hypothesis that the processing of feedback less consistent characters was more difficult than consistent ones as demonstrated in the writing-to-dictation task. As characters in Group 2 had low feedback type and token consistency, they were characterized by both smaller number and summed frequency of friends than enemies, compared with Group 1. The difference could be attributed to the greater competition between the target character and enemies activated by the presented syllable. If the number and summed frequency of friends were smaller than that of enemies, the target character suffered and the participants were more likely to make errors.

*Token consistency is more representative in sound-script mapping*

In Group 3 and Group 4, with characters of contradictory type and token consistency values, the performance on characters with high token consistency but low type consistency value (Group 4) was better than on characters with low token consistency but high type consistency values (Group 3). The result appears to follow the prediction based on the effect of relative summed frequency of friends and enemies on the phonology-to-orthography conversion (token consistency). High type consistency indicates larger friends count while low token frequency indicates smaller summed frequency of friends for a character among the homophones. Since Group 4 was characterized by high type consistency but low token consistency, enemies with large summed frequency probably outweighed the superiority of having large number of friends during the retrieval process. Hence, the target character suffered from having greater competition from enemies, reducing the chance of retrieving its correct orthography. It agrees with Jared (1997) and Lee, et al. (2005), who found robust consistency effect in word naming when the summed frequency of enemies was higher than that of friends. Therefore, the evidence appears to support the conclusion that the frequency-weighted token consistency is better to represent sound-script mapping in Chinese.

*Cross-linguistic comparison on bidirectional inconsistency*

Comparing with corresponding data on bidirectional inconsistency of spelling and sound in alphabetic scripts (Ziegler et al., 1996, 1997), Chinese is characterized by a much larger percentage of feedforward inconsistent characters (72.8%) than English (30.7%) and French (12.4%). Regarding 72.5% of Chinese characters carry more than one pronunciation in its phonetic family, without the GPC rules for coding script-sound relationship, reading Chinese characters is always more difficult than alphabetic scripts.

When feedback inconsistency (value <1) was found to be prevalent in alphabetic scripts - English (72.1%) and French (79.1%) (Ziegler, et. al, 1996, 1997), feedback inconsistency in Chinese could be interpreted in two perspectives. If tone is considered as an essential distinctive feature for sound-script mapping in Chinese, with 77.4% of characters as feedback inconsistent, Chinese is just slightly more inconsistent than English but very close to French. It showed that feedback inconsistency of Chinese, a logographic script is comparable with alphabetic scripts like French and English. Although homophony is known to be prevalent in Chinese, the phonology-to-orthography conversion appears not particularly difficult as predicted, even without the sound-script correspondence rules. In contrast, if tonal discrepancy is ignored in sound-script mapping, the prevalence of feedback inconsistency becomes extremely high (94.9% of all characters) in Chinese. Then, feedback inconsistency could be a possible index to show the difference between Chinese, a logographic script with deep orthography, and alphabetic scripts like French and English. Writing, which requires recalling orthography from its syllable, could be more difficult than reading aloud in Chinese.

*Feedback inconsistency in word perception*

In Chinese, 80.8% (tones considered) and 96.9% (tones ignored) of all feedforward consistent characters are indeed feedback inconsistent, comparing with 72.1% in English and 77.4% in French (Ziegler, et al., 1996, 1997). Therefore, the chance of finding a feedforward consistent but feedback inconsistent character is relatively higher in Chinese. Ziegler, et al. claimed that ignoring feedback inconsistency could lead to insignificant consistency effect. Yet, the findings on feedback consistency effect in visual lexical decision tasks from Stone, et al. (1997) and Ziegler, et al. (2008) were contradictory. Given that Chinese is characterized by characters with contradictory feedforward and feedback consistency, the existence of feedback consistency effect in visual word recognition is worth verifying in Chinese. The results could probably resolve the question regarding feedback consistency effect on visual word recognition in alphabetic counterparts.

*The implications of feedforward inconsistency on learning to read Chinese*

Noted that feedforward inconsistent characters accounted for above 50% of all characters in grade one, with increasing proportion to above 70% in grade six, memorizing the sound of characters could be difficult for school-age children. Yet, if tonal discrepancy is ignored, with about 10% less feedforward inconsistent characters in each grade, feedforward inconsistency in Chinese is lessened. Anderson, et al. (2002) showed that children of higher reading ability could take advantage of partial phonological information (onset, rime and tone) in phonetic radicals to predict pronunciation of tone-different or onset different characters. If tonal difference is ignored in a phonetic family, neighbours with same onset and rime but different tones become friends instead of enemies to each other. Thus, tonal difference among neighbours might not always discourage character reading. It may depend on reader’s ability in decoding and utilize the phonological information in family neighbours to aid pronunciation retrieval.

*The implications of feedback inconsistency on learning to write Chinese*

Similar to feedforward inconsistency, feedback inconsistency is also prevalent in Chinese. Yet, feedback inconsistency is more prevalent if tonal difference is not necessarily involved in sound-script mapping, with feedback inconsistent characters increases from 85% in grade one to 94.9% in grade six. Opposite to feedforward inconsistency, phonology-to-orthography conversion would suffer from considerably larger homophony if tones are ignored. In this way, tones played an important role in memorizing the orthography from limited syllables in Chinese. In addition, the steep increase in the number of characters with low consistency level ($\leqq 0.4$) indicated feedback inconsistency is aggravated by having more characters of low consistency level in higher grades. It might explain why writing-to-dictation could be more challenging than reading aloud throughout the school years.

*Further studies*

Concerning feedforward and feedback consistency was found to be continuously changing as one moves up the primary grades, it is believed that the role of consistency in reading and writing Chinese possibly changes from school-age children to educated adults. Thus, further studies on school-age population are warranted to investigate the development of the influence of consistencies on writing and reading. Importantly, the role of feedback inconsistency is warranted to be testified in word naming task in Chinese in order to resolve the debates on its effect on lexical perception tasks.

*Conclusion*

In the present study, descriptive statistical data of feedforward and feedback consistency in the new data corpus (HKCFFC) illustrated how consistency could be a possible index to compare Chinese with alphabetic scripts. Also, developmental trend in bidirectional inconsistency highlighted the importance of feedforward and feedback inconsistency in reading and writing Chinese. Lastly, the result of current study supported that frequency- weighted token consistency is more representative in sound-script mapping. This newly developed data corpus is able to generate valuable implications on reading and writing development and it serves a good source of statistical basis for further investigations.

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