Cognition 147 (2016) 127–132

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Short Communication

Knowing Chinese character grammar

James Myers

Graduate Institute of Linguistics, National Chung Cheng University, 168 University Road, Min-Hsiung, Chia-Yi 62102, Taiwan

ARTICLE INFO

Article history:
Received 29 June 2015
Revised 9 November 2015
Accepted 20 November 2015

Keywords:
Grammar
Orthography
Acceptability
Phonology
Reduplication
Chinese

ABSTRACT

Chinese character structure has often been described as representing a kind of grammar, but the notion of character grammar has hardly been explored. Patterns in character element reduplication are particularly grammar-like, displaying discrete combinatoriality, binarity, phonology-like final prominence, and potentially the need for symbolic rules (X → XX). To test knowledge of these patterns, Chinese readers were asked to judge the acceptability of fake characters varying both in grammaticality (obeying or violating reduplication constraints) and in lexicality (of the reduplicative configurations). While lexical knowledge was important (lexicality improved acceptability and grammatical configurations were accepted more quickly when also lexical), grammatical knowledge was important as well, with grammaticality improving acceptability equally for lexical and nonlexical configurations. Acceptability was also higher for more frequent reduplicative elements, suggesting that the reduplicative configurations were decomposed. Chinese characters present an as-yet untapped resource for exploring fundamental questions about the nature of the human capacity for grammar.

1. Introduction

There is a vast experimental literature exploring grammatical knowledge (Cohn, Fougeron, & Huffman, 2011; Kawahara, 2011; Myers, 2009; Phillips & Wagers, 2007). Chinese characters also show systematic patterns, and researchers have often applied the term grammar to them as well (Kordek, 2013; Ladd, 2014; Sproat, 2000; Wang, 1983). Yet much more is known about the processing challenges that characters pose to learners (Chan & Nunes, 1998), readers (Honorof & Feldman, 2006), and writers (Chen & Cherng, 2013) than about the knowledge of character grammar per se.

The core of Chinese character grammar is discrete combinatoriality: characters are usually decomposable into smaller elements, which are often decomposable in turn. Most characters (85%, as estimated by Perfetti & Tan, 1999) are decomposed, at the first step, into a semantic component (associated with the meaning of the whole character) and a phonetic component (associated with the character's pronunciation). A typical example (from Ladd, 2014, p. 129) is 鐳 *léi* 'radium', decomposed into the semantic component 金 *jīn* 'gold, metal' and phonetic component 雷 *léi* 'thunder', where the latter, in turn, is composed of 雨 *yǔ* 'rain' and 田 *tián* 'field', which themselves share stroke complexes with 兩 *liǎng* 'two' and 十 *shí* 'ten', respectively. Ladd (2014) compares this hierarchical structure to the duality of patterning of Hockett (1960), with the deeper levels reminiscent of the phonology of spoken or signed languages.

Chinese readers are sensitive to the combinability of character components (Hsu, Tsai, Lee, & Tzeng, 2009), their typical positions (Taft, Zhu, & Peng, 1999), consistency in the pronunciation of the phonetic components (Lee, Huang, Kuo, Tsai, & Tzeng, 2010), and the overall arrangement of character elements (Yeh & Li, 2002). Writers, who need more detailed character representations than readers, are also influenced by the elements within phonetic components (Chen & Cherng, 2013). The processing challenges posed by orthography are partly universal; English reading is also influenced by stochastic orthographic patterns (Bailey & Hahn, 2001; Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004), and the brain's visual word form area is activated both by Chinese characters (Liu et al., 2008) and by alphabetic orthographies (Dehaene & Cohen, 2011).

In other words, the structure of information shapes how that information is processed. But orthographic structure is itself a product of the mind, and the phonology-like aspects of character structure go beyond mere combinatoriality. For example, the semantic component is typically reduced (shrinking or even losing strokes) when it is on the left or the top, but rarely when it is on the right or bottom (Myers, 1996). This pattern may relate to the order

E-mail address: Lngmyers@ccu.edu.tw
URL: http://www.ccunix.ccu.edu.tw/~lngmyers/

http://dx.doi.org/10.1016/j.cognition.2015.11.012
0010-0277/

in which strokes are normally written, from left to right and top to bottom, putting prominence on the stroke-final position, just as phrase-final syllables tend to be longer in speech (Beckman & Edwards, 1990) and in signed languages (Sandler, 1993). However, semantic components are closed-class (belying the common term *radical*, they are more analogous to affixes than roots), so it is difficult to test whether Chinese readers have active knowledge of these patterns.

This paper tests another phonology-like pattern, involving the configuration of reduplicated constituents (Kordek, 2013). Many characters contain horizontal configurations of two copies of the same element, like 朋 *péng* 'friend' (cf. 月 *yuè* 'moon, month'). Other reduplicative configurations are vertical, like 炎 *yán* 'inflammation' (cf. 火 *huǒ* 'fire'), while still others consist of three identical elements arranged in a upward-pointing triangle, like 森 *sēn* 'forest' (cf. 木 *mù* 'wood'). (A rare fourth type of reduplicative configuration, not studied here, forms a two-by-two square, as in 叕 *zhuó* 'join together'; cf. 又 *yòu* 'also'). Character element reduplication is partly iconic: a forest (森) contains more trees (木) than do woods (林 *lín*). Yet iconicity is not a reliable cue to whole-character meaning: 朋 and 月 are totally unrelated, 哥 *gē* 'older brother' relates to 可 *kě* 'may' only in pronunciation, and iconicity is irrelevant when it appears in phonetic components. Iconicity is also found in spoken and signed reduplication (Aronoff, Meir, & Sandler, 2005; Hurch, 2005), but these patterns nevertheless also conform to phonological constraints (Brentari, 1998; McCarthy & Prince, 1994).

Reduplicative configurations in Chinese characters obey formal constraints as well: triangular configurations cannot point downward (two elements over one), and horizontal and vertical configurations cannot contain three elements (the sole exception being 㗊 *líng* 'raindrops', an archaic character that now only appears in 靈 *líng* 'spirit'). No such restrictions apply to mere strokes (e.g., 州 *zhōu* 'prefecture', 三 *sān* 'three') or to combinations of distinct components (e.g., the three 火 *huǒ* 'fire' in 熒 *yíng* 'glimmering' do not form an illicit downward pointing triangle because the two 火 at the top form a constituent with 冖 *mì* 'cover', also seen in 營 *yíng* 'camp'). These patterns are not merely formal, but reminiscent of familiar phonological constraints. In particular, reduplicative configurations obey binarity, just as stress feet are much more likely to be disyllabic than trisyllabic (Gordon, 2002). The upward-pointing triangles obey binarity both horizontally and vertically, while also making the configuration "bottom-heavy", consistent with the stroke-final prominence noted earlier.

Before speculating on how to explain such patterns, we must first establish that they are part of the active knowledge of Chinese readers. We thus ran an acceptability judgment experiment (Bailey & Hahn, 2001; Topolinski & Strack, 2009) using speeded binary (yes/no) responses (Weskott & Fanselow, 2011), testing fake characters that crossed grammaticality (e.g., upward-pointing vs. downward-pointing triangular configurations) with lexicality of the reduplicative configuration (i.e., whether the grammatical version of this configuration appears within real characters), while also taking into account character element frequency and visual complexity.

2. Method

2.1. Participants

The participants were 20 university students in southern Taiwan. All were native speakers of Mandarin Chinese with normal or corrected-to-normal vision. Participants were paid for their participation and provided written consent (among other things, to share their response data online).

2.2. Materials and design

Forty-eight sets of four fake characters each were created by editing traditional characters in Microsoft MingLiU font. All characters contained reduplicated elements in a horizontal, vertical, or triangular configuration (16 sets each). The four characters in each set contained a semantic component in its standard position, with the reduplicative configuration forming the remainder and crossing grammaticality and lexicality. In grammatical configurations, reduplication obeyed the constraints discussed above. Each grammatical configuration was paired with an ungrammatical one formed of the same element, but where horizontal and vertical configurations contained three repetitions and triangular configurations formed a downward pointing triangle. Grammatical configurations were called lexical if they also appear in real characters; matching ungrammatical characters were created as just described. In nonlexical configurations, the reduplicated element is never reduplicated in real characters. Sample materials are shown in Table 1 ('NA' indicates that reduplication of the given element, e.g., 支 *zhī* 'branch', is not lexically attested).

A three-way ANOVA on the log number of strokes showed effects of configuration shape ($F(2,180) = 7.70$, $p < .001$), lexicality ($F(1,180) = 4.15$, $p < .05$), and grammaticality ($F(1,180) = 15.63$, $p < .001$), with an interaction between grammaticality and shape ($F(2,180) = 3.85$, $p < .05$). These potential confounds with visual complexity are unavoidable because lexical reduplication, particularly vertical reduplication, favors simpler elements, and ungrammatical horizontal and vertical (but not triangular) configurations necessarily contain more strokes. Thus we included the log number of strokes as a covariate in the analyses described below.

We also calculated the type frequencies of the reduplicated base elements (e.g., 木). Character components were extracted with the help of a Wikimedia resource (Chinese Characters Decomposition, 2015) that recursively decomposes 21,170 traditional and simplified characters while also providing information about reduplicative configuration shape. Type frequencies were based on just the 6962 traditional characters in the Academia Sinica Balanced Corpus of Modern Chinese (Huang, Chen, Chen, & Chang, 1997).

An additional 120 fillers were created by editing other real characters (see Table 2). The fillers, all composed of real semantic and phonetic components in their standard positions but in novel combinations, were designed to vary gradiently in acceptability: 40 had no further modification (best), 40 added or removed strokes (worse), and 40 reflected an asymmetrical element vertically or horizontally (worst).

Test items were divided into four lists of 48 items each in a Latin square design, so that all four participant groups saw all test item types (defined by configuration shape, grammaticality and lexicality) but never from the same matched set. All participants saw all 120 filler items.

2.3. Procedure

The experiment was run with PsychoPy v. 1.82 (Peirce, 2007, 2009). Participants were told they would see a series of characters that were not real Chinese characters. They were asked to decide if they were like or not like Chinese characters by pressing, respectively, a key on the right or left side of a computer keyboard. Trials consisted of a 500 ms display of a fixation cross at the center of the screen, followed by 500 ms of a blank screen, and finally a fake character that remained at the center of the screen for 3000 ms or until the participant pressed one of the response keys, after which the next trial began. Characters were displayed in black on a white background, subtending approximately 4.5° vertically and horizontally from a viewing distance of 50 cm. Prior to the

Table 1
Sample test items.

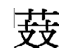
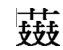
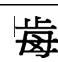
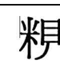
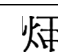
	Lexical grammatical	Lexical ungrammatical	Nonlexical grammatical	Nonlexical ungrammatical
Horizontal				
Reduplication	林 *lín* ‘woods’		NA	
Element	木 *mù* ‘wood’		支 *zhī* ‘branch’	
Vertical				
Reduplication	多 *duō* ‘more’		NA	
Element	夕 *xī* ‘evening’		夫 *fū* ‘husband’	
Triangular				
Reduplication	晶 *jīng* ‘crystal’		NA	
Element	日 *rì* ‘sun, day’		欠 *qiàn* ‘owe’	

Table 2
Sample filler items.

	Novel combination	Added stroke	Removed stroke	Reflected element
Fake filler				
Real models	院 *yuàn* ‘court’ 域 *yù* ‘domain’	歲 *suì* ‘years’ 母 *mǔ* ‘mother’	粉 *fěn* ‘powder’ 現 *xiàn* ‘now’	炸 *zhà* ‘fry’ 姓 *xìng* ‘surname’

main experiment, participants were given 10 trials of fake characters as practice; these were designed the same way as the fillers, but were not used in the main experiment. In the main experiment each participant saw 168 items (48 test items and 120 fillers) in random order. Each experimental session lasted approximately 10 min.

3. Results

Seventeen trials (including two test trials) were dropped for lack of a response within the time limit, leaving 958 experimental data points (3343 including fillers). Response choices and log reaction times were analyzed with mixed-effects logistic regression and mixed-effects linear regression respectively (Bates, Mächler, Bolker, & Walker, 2015), with grammaticality and lexicality in effect coding and configuration shape in dummy coding with horizontal shape as base. Likelihood ratio tests showed that models with random participant and item intercepts but no random slopes provided sufficient fit (cf. Barr, Levy, Scheepers, & Tily, 2013). Wald tests were used to compute significance (treating *t* as *z* for the linear regressions). Effect sizes are indicated by standardized coefficients (β).

The overall acceptance rate was .53, with virtually identical rates for fillers (.52) and test items (.54) ($p > .5$) (compare the overall acceptance rate of .11 for nonce Mandarin syllables in Myers, 2015, and the weighted mean acceptance score of .42 on a zero-to-one scale for nonce English words in Bailey & Hahn, 2001). An analysis of response choices crossing lexicality (of the reduplicative configurations), grammaticality, configuration shape, and log type frequency of the test items' reduplicated elements, with the log number of strokes as additive covariate, showed that acceptability was improved both by lexicality ($\beta = 0.65$, $SE = 0.13$, $z = 4.98$, $p < .001$) and by grammaticality ($\beta = 0.75$, $SE = 0.14$, $z = 5.467$, $p < .001$), but these variables did not interact ($p > .5$); see Fig. 1 (figures do not include error bars due to lack of agreement over their calculation in mixed-effects models, but data distributions are visually suggested by the scatterplots in Figs. 2 and 4). Element frequency also significantly improved acceptability

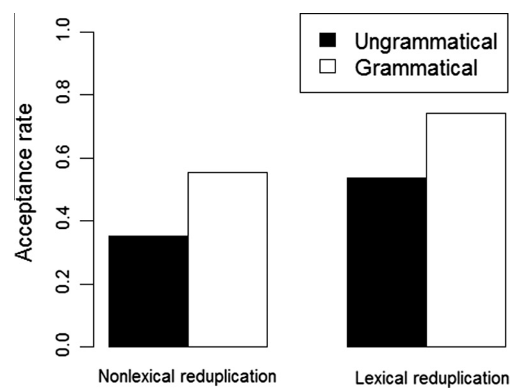


Fig. 1. Acceptance rates for fake characters containing lexical/nonlexical and grammatical/ungrammatical reduplicative configurations.

($\beta = 0.31$, $SE = 0.15$, $z = 2.09$, $p < .05$) and interacted marginally with lexicality ($\beta = -0.28$, $SE = 0.15$, $z = -1.89$, $p = .059$) but not with grammaticality ($p > .1$); as shown in Fig. 2, element frequency had a greater effect on acceptability with nonlexical than with lexical reduplicative configurations. This was particularly true for triangular (vs. horizontal) configurations, with a significant three-way interaction among element frequency, lexicality, and shape ($\beta = -0.51$, $SE = 0.18$, $z = -2.82$, $p < .01$). Shape otherwise showed no interactions (*ps* > .1). Strokes had no effect ($p > .9$).

Log reaction times for acceptances were analyzed in terms of the same model structure. Both lexicality ($\beta = -0.04$, $SE = 0.02$, $z = -2.13$, $p < .05$) and grammaticality ($\beta = -0.04$, $SE = 0.02$, $z = -1.96$, $p < .05$) significantly sped up acceptances, and the two variables interacted ($\beta = -0.05$, $SE = 0.02$, $z = -2.79$, $p < .01$); as shown in Fig. 3, grammatical items were accepted more quickly than ungrammatical ones if lexical configurations were involved, but the reverse was true for nonlexical configurations. While there was no overall effect of element frequency ($p > .8$), it interacted with both lexicality ($\beta = -0.04$, $SE = 0.02$, $z = -2.09$, $p < .05$) and grammaticality ($\beta = 0.04$, $SE = 0.02$, $z = 2.01$, $p < .05$); as shown in

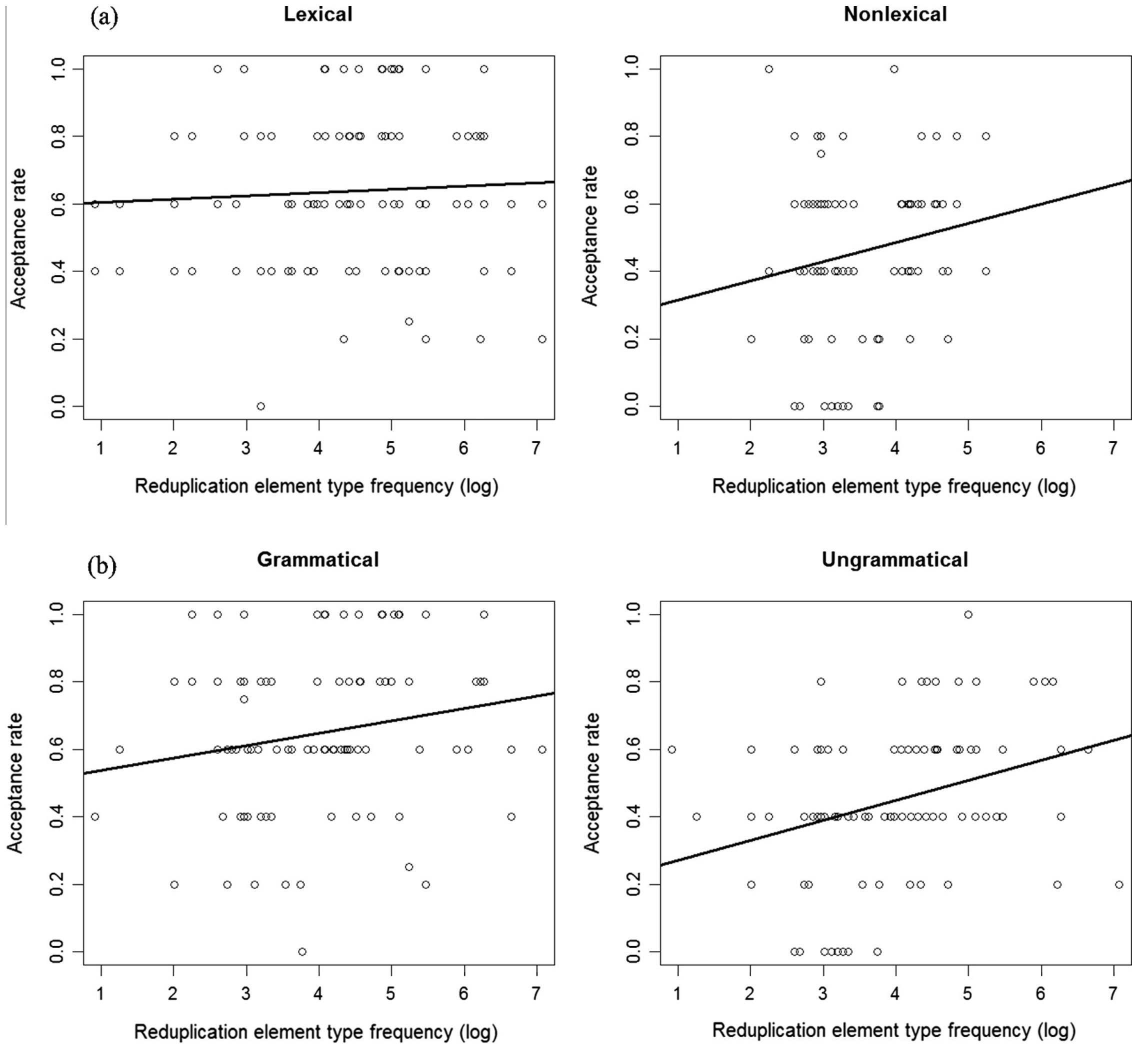


Fig. 2. The interactions of (a) lexicality and (b) grammaticality with element frequency in acceptability rates. Data points are test items, with linear trend lines fit to them.

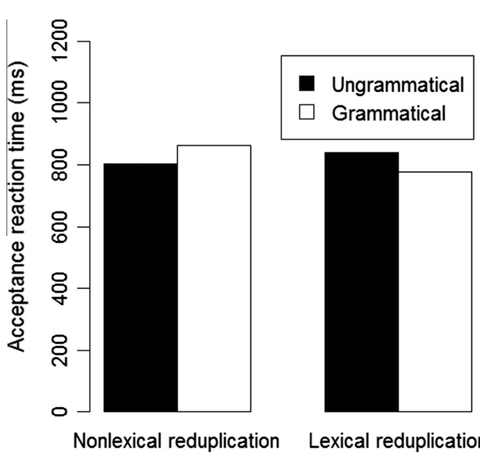


Fig. 3. Reaction times for accepting fake characters containing lexical/nonlexical and grammatical/ungrammatical reduplicative configurations.

Fig. 4, element frequency slowed acceptances only for nonlexical and ungrammatical configurations. A four-way interaction among shape, lexicality, grammaticality, and element frequency suggested that vertical configurations interacted with the other three factors more strongly than horizontal ones ($\beta = -0.07$, $SE = 0.02$, $z = -2.84$, $p < .01$); shape otherwise showed no interactions ($ps > .1$). Strokes had a marginally facilitative effect ($\beta = -0.03$, $SE = 0.02$, $z = -1.76$, $p < .08$).

4. Discussion

Grammaticality improved acceptability for both lexical and nonlexical reduplicative configurations regardless of shape, indeed to the same degree regardless of lexical status. Nevertheless, the reaction times revealed that acceptability judgments were filtered through a processing system better at judging lexicality than grammaticality: lexical grammatical configurations were accepted more quickly than ungrammatical ones, but the reverse was true for nonlexical configurations. Independently, element type frequency improved acceptability and slowed responses, suggesting that readers decompose reduplicative configurations, particularly nonlexical ones.

The grammaticality and lexicality findings replicate an earlier experiment (Myers, 2012) that used somewhat different materials (only 168 of its 240 test items were included among the 192 in the current experiment). This earlier experiment showed no effect of element type frequency, however, perhaps because its materials were chosen without the help of the Chinese Characters Decomposition (2015) database, making this variable hard to calculate accurately for many items.

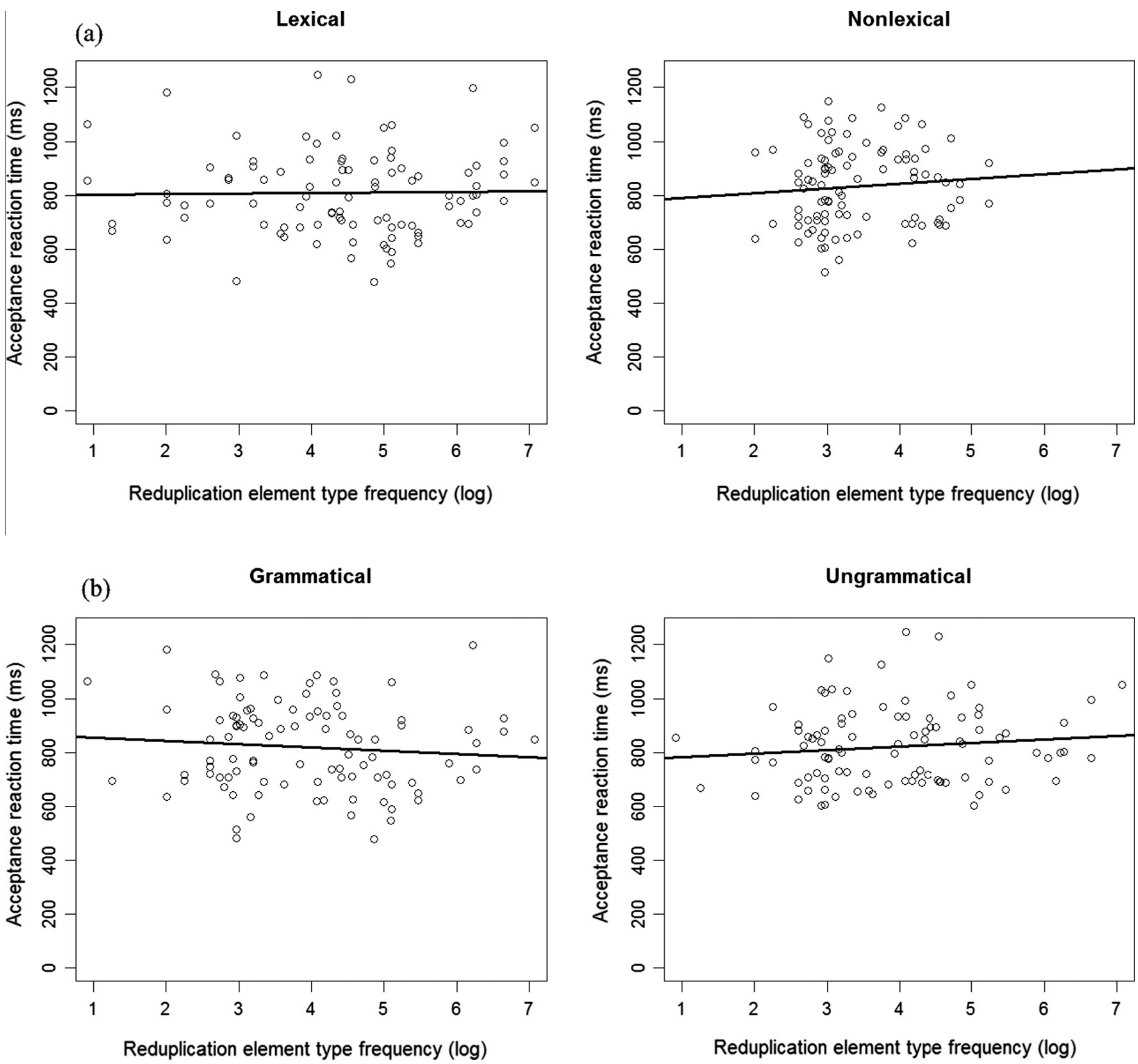


Fig. 4. The interactions of (a) lexicality and (b) grammaticality with element frequency in acceptance reaction time. Data points are test items, with linear trend lines fit to them.

Many follow-up experiments immediately suggest themselves: extending these findings to simplified characters (cf. Liu & Hsiao, 2012; Peng, Minett, & Wang, 2010), using other tasks (e.g., lexical decision or production), or testing other neglected character patterns (surveyed in Myers, 1996; Wang, 1983). Theoretical work is needed too; while processing models for reading, speech, and signing already accommodate the influence of lexical statistics (Caselli & Cohen-Goldberg, 2014; Chen & Mirman, 2012; Lee, 2011), capturing the spatial aspects of character reduplication will also require incorporating insights from visual processing. It has also been argued that reduplication in speech and sign provides evidence for symbolic representations (Berent, Dupuis, & Brentari, 2014; Pinker & Prince, 1988), suggesting that 林 may be encoded not as 木 + 木 but via the abstract rule X → XX.

Cognitive scientists should ultimately aim their sights even higher, since the unique natural experiment of Chinese orthography has the potential to shed light on the human capacity for grammar more generally. Should similarities between character grammar and "language proper" (discrete combinatoriality, affix-like semantic components, reduplication showing binarity and final prominence) be dismissed as coincidences, or do they arise from the former sharing cognitive or neural hardware with the latter (as may or not be the case with music and language; Wallin, Merker, & Brown, 2001), or are they emergent properties of complex systems (Abler, 1989; Piattelli-Palmarini & Uriagereka, 2008)? Addressing such grand questions will require, among other things, more subtle probing of the visual word form area, formal frameworks for comparing actual and unattested Chinese characters (perhaps building on Li & Zhou, 2007; Sproat, 2000), and visual artificial grammar tasks testing the learnability of different character-like systems (Chang & Knowlton, 2004; Ehrich & Meuter, 2009; Stobbe, Westphal-Fitch, Aust, & Fitch, 2012).

Acknowledgments

This study was supported by Grants from Taiwan's National Science Council (now Ministry of Science and Technology) NSC 101-2410-H-194-115-MY3 and MOST 103-2410-H-194-119-MY3. I thank Chang Yu-chu, Chen Pei-shan, Chen Tsung-Ying, Ciou Yan-jhe, Hong Guo-Ming, Hsu Zi-Ping, and Liu Mei-chun for their help in creating the fake characters, and the audiences of the 7th Conference of the European Association of Chinese Linguistics and the 34th Annual Conference of the Cognitive Science Society, William Abler, Chang Yu-Chu, Chen Tsung-Ying, Mike Hammond, Liu Mei-chun, the *Cognition* associate editor, and three anonymous reviewers for comments (the usual caveats apply).

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2015.11.012.

References

Abler, W. L. (1989). On the particulate principle of self-diversifying systems. *Journal of Social and Biological Structures, 12*(1), 1–13.

Aronoff, M., Meir, I., & Sandler, W. (2005). The paradox of sign language morphology. *Language, 81*(2), 301–344.

Bailey, T. M., & Hahn, U. (2001). Determinants of wordlikeness: Phonotactics or lexical neighborhoods? *Journal of Memory and Language, 44*(4), 568–591.

Balota, D. A., Cortese, M. J., Sergent-Marshall, S. D., Spieler, D. H., & Yap, M. (2004). Visual word recognition of single-syllable words. *Journal of Experimental Psychology: General, 133*(2), 283–316.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*(3), 255–278.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1). http://dx.doi.org/10.18637/jss.v067.i01.

Beckman, M. E., & Edwards, J. (1990). Lengthening and shortening and the nature of prosodic constituency. In J. Kingston & M. E. Beckman (Eds.), *Papers in laboratory phonology I: Between the grammar and the physics of speech* (pp. 152–178). Cambridge, UK: Cambridge University Press.

Berent, I., Dupuis, A., & Brentari, D. (2014). Phonological reduplication in sign language: Rules rule. *Frontiers in Psychology, 5*, 560.

Brentari, D. (1998). *A prosodic model of sign language phonology*. Cambridge, MA: MIT Press.

Caselli, N. K., & Cohen-Goldberg, A. M. (2014). Lexical access in sign language: A computational model. *Frontiers in Psychology, 5*, 428.

Chan, L., & Nunes, T. (1998). Children's understanding of the formal and functional characteristics of written Chinese. *Applied Psycholinguistics, 19*(01), 115–131.

Chang, G. Y., & Knowlton, B. J. (2004). Visual feature learning in artificial grammar classification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(3), 714–722.

Chen, J.-Y., & Cherng, R.-J. (2013). The proximate unit in Chinese handwritten character production. *Frontiers in Psychology, 4*, 517. http://dx.doi.org/10.3389/fpsyg.2013.00517.

Chen, Q., & Mirman, D. (2012). Competition and cooperation among similar representations: Toward a unified account of facilitative and inhibitory effects of lexical neighbors. *Psychological Review, 119*(2), 417–430.

Chinese Characters Decomposition (2015). In Wikimedia Commons. Retrieved June 9, 2015, from <http://commons.wikimedia.org/wiki/Commons:Chinese_characters_decomposition>.

Cohn, A. C., Fougeron, C., & Huffman, M. K. (Eds.). (2011). *The Oxford handbook of laboratory phonology*. Oxford: Oxford University Press.

Dehaene, S., & Cohen, L. (2011). The unique role of the visual word form area in reading. *Trends in Cognitive Sciences, 15*(6), 254–262.

Ehrich, J. F., & Meuter, R. F. I. (2009). Acquiring an artificial logographic orthography: The beneficial effects of a logographic L1 background and bilinguality. *Journal of Cross-Cultural Psychology, 40*, 711–745.

Gordon, M. (2002). A factorial typology of quantity-insensitive stress. *Natural Language & Linguistic Theory, 20*(3), 491–552.

Hockett, C. (1960). The origin of speech. *Scientific American, 203*, 88–111.

Honorof, D. N., & Feldman, L. (2006). The Chinese character in psycholinguistic research: Form, structure, and the reader. In P. Li, L. H. Tan, E. Bates, & O. J. L. Tzeng (Eds.), *The handbook of East Asian psycholinguistics: Chinese* (Vol. 1, pp. 195–208). Cambridge, UK: Cambridge University Press.

Hsu, C. H., Tsai, J. L., Lee, C. Y., & Tzeng, O. J. L. (2009). Orthographic combinability and phonological consistency effects in reading Chinese phonograms: An event-related potential study. *Brain and Language, 108*(1), 56–66.

Huang, C.-R., Chen, K.-J., Chen, F.-Y., & Chang, L.-L. (1997). Segmentation standard for Chinese natural language processing. *Computational Linguistics and Chinese Language Processing, 2*(2), 47–62.

Hurch, B. (Ed.). (2005). *Studies on reduplication*. Berlin: Walter de Gruyter.

Kawahara, S. (2011). Experimental approaches in theoretical phonology. In M. van Oostendorp, C. Ewen, E. Hume, & K. Rice (Eds.), *The Blackwell companion to phonology* (pp. 2283–2303). Oxford, UK: Wiley-Blackwell.

Kordek, N. (2013). *On some quantitative aspects of the componential structure of Chinese characters*. Wydawnictwo Rys.

Ladd, D. R. (2014). *Simultaneous structure in phonology*. Oxford, UK: Oxford University Press.

Lee, C. Y., Huang, H. W., Kuo, W. J., Tsai, J. L., & Tzeng, J. L. O. (2010). Cognitive and neural basis of the consistency and lexicality effects in reading Chinese. *Journal of Neurolinguistics, 23*(1), 10–27.

Lee, C.-Y. (2011). The statistical learning perspective on Chinese reading. In P. McCardle, J.-R. Lee, O. Tzeng, & B. Miller (Eds.), *Dyslexia across languages: Orthography and the brain-gene-behavior link* (pp. 44–61). Baltimore: Brookes Publishing.

Li, J., & Zhou, J. (2007). Chinese character structure analysis based on complex networks. *Physica A: Statistical Mechanics and its Applications, 380*, 629–638.

Liu, T., & Hsiao, J. H.-W. (2012). The perception of simplified and traditional Chinese characters in the eye of simplified and traditional Chinese readers. In N. Miyake, D. Peebles, & R. P. Cooper (Eds.), *Proceedings of the 34th annual conference of the cognitive science society* (pp. 2067–2072). Austin, TX: Cognitive Science Society.

Liu, C., Zhang, W. T., Tang, Y. Y., Mai, X. Q., Chen, H. C., Tardif, T., et al. (2008). The visual word form area: Evidence from an fMRI study of implicit processing of Chinese characters. *Neuroimage, 40*(3), 1350–1361.

McCarthy, J. J., & Prince, A. (1994). Prosodic morphology. In J. Goldsmith (Ed.), *The handbook of phonological theory* (pp. 318–366). Oxford: Basil Blackwell.

Myers, J. (1996, June). *Prosodic structure in Chinese characters*. Poster presented at the Fifth International Conference on Chinese Linguistics, National Tsing Hua University, Taiwan.

Myers, J. (2009). Syntactic judgment experiments. *Language & Linguistics Compass, 3*(1), 406–423.

Myers, J. (2012, August). *Levels of analysis in the generalization of Chinese character regularities*. Talk presented at CogSci 2012: The 34th Annual Conference of the Cognitive Science Society, Workshop on Grammatical Approaches to Written and Graphical Communication, Sapporo, Japan.

Myers, J. (2015). Markedness and lexical typicality in Mandarin acceptability judgments. *Language & Linguistics, 16*(6), 791–818.

Peirce, J. W. (2007). PsychoPy: Psychophysics software in Python. *Journal of Neuroscience Methods, 162*(1–2), 8–13.

Peirce, J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics, 2*, 10. http://dx.doi.org/10.3389/neuro.11.010.2008.

Peng, G., Minett, J. W., & Wang, W. S. Y. (2010). Cultural background influences the liminal perception of Chinese characters: An ERP study. *Journal of Neurolinguistics, 23*(4), 416–426.

Perfetti, C. A., & Tan, L. H. (1999). The constituency model of Chinese word identification. In A. Inhoff, J. Wang, & H. C. Chen (Eds.), *Reading Chinese scripts: A cognitive analysis* (pp. 115–134). Mahweh, NJ: Erlbaum.

Phillips, C., & Wagers, M. (2007). Relating structure and time in linguistics and psycholinguistics. In M. G. Gaskell (Ed.), *The Oxford handbook of psycholinguistics* (pp. 739–756). Oxford: Oxford University Press.

Piattelli-Palmarini, M., & Uriagereka, J. (2008). Still a bridge too far? Biolinguistic questions for grounding language on brains. *Physics of Life Reviews, 5*(4), 207–224.

Pinker, S., & Prince, A. (1988). On language and connectionism: Analysis of a parallel distributed processing model of language acquisition. *Cognition, 28*(1), 73–193.

Sandler, W. (1993). A sonority cycle in American Sign Language. *Phonology, 10*(02), 243–279.

Sproat, R. (2000). *A computational theory of writing systems*. Cambridge, UK: Cambridge University Press.

Stobbe, N., Westphal-Fitch, G., Aust, U., & Fitch, W. T. (2012). Visual artificial grammar learning: Comparative research on humans, kea (*Nestor notabilis*) and pigeons (*Columba livia*). *Philosophical Transactions of the Royal Society B: Biological Sciences, 367*(1598), 1995–2006.

Taft, M., Zhu, X., & Peng, D. (1999). Positional specificity of radicals in Chinese character recognition. *Journal of Memory and Language, 40*(4), 498–519.

Topolinski, S., & Strack, F. (2009). The architecture of intuition: Fluency and affect determine intuitive judgments of semantic and visual coherence and judgments of grammaticality in artificial grammar learning. *Journal of Experimental Psychology: General, 138*(1), 39–63.

Wallin, N. L., Merker, B., & Brown, S. (2001). *The origins of music*. Cambridge, MA: MIT Press.

Wang, J. C. (1983). *Toward a generative grammar of Chinese character structure and stroke order*. University of Wisconsin-Madison, Ph.D. dissertation.

Weskott, T., & Fanselow, G. (2011). On the informativity of different measures of linguistic acceptability. *Language, 87*(2), 249–273.

Yeh, S. L., & Li, J. L. (2002). Role of structure and component in judgments of visual similarity of Chinese characters. *Journal of Experimental Psychology: Human Perception and Performance, 28*(4), 933–947.