Evidence of Visual Statistical Learning in the Reading of Unspaced Chinese Sentences

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Abstract

Chinese texts are renowned for the lack of physical spaces between words in a sentence. Reading these sentences requires a stage of word segmentation, the mechanism of which may involve visual statistical learning. In three experiments employing the RSVP task along with the Saffran et al. (1997) paradigm, we provided evidence that foreign learners of Chinese could capture the statistical information embedded in a string of characters and use that information to tell apart a "word" from a "nonword". The statistical learning effect (.57) was comparable to that observed previously in an auditory task using the same stimuli. The results of the experiments also suggested that significant visual statistical learning required a conscious level of processing that directed the participants' attention at the characters as well as an unconscious level, at which the distributional information across the characters can be continuously computed and accumulated.

Keywords: Visual statistical learning; reading; Chinese; word spacing

Introduction

It is well known that Chinese sentences consist of strings of characters with no explicit spaces between words. How the readers of Chinese segment and identify words in a sentence remains a mystery. Past psycholinguistic research on this issue has not addressed it directly, but, instead, turned the question around and investigated the psychological reality of a word in Chinese (Cheng, 1981; Hue, 1989; Hoosain, 1992; J.-Y. Chen, 1998; Peng & Chen, 2004) or asked whether inserting word spaces or other physical cues could facilitate reading (Liu, Yeh, Wang, & Chang, 1974; Yang, 1998; Bai, Yan, Liversedge, Zang, & Rayner, 2008; Bai, Liang, Blythe, Zang, Yan, & Liversedge, 2013; Li, Rayner, & Cave, 2009; Shen et al., 2018). Research in computational linguistics has investigated the statistical meaning of a word and proposed a few algorithms for automatic word segmentation by machines (Huang, Chen, Chen, & Chang, 1997; Tang, Geva, Xu, & Trotman, 2009; Shu, Wang, Shen, & Qu, 2017). Few studies have examined whether Chinese readers represent words statistically and whether they use the statistical and distributional information to segment and identify words while reading. The lack of such studies may be due to the fact that the questions have been (mis)construed in the context of skilled reading while it is really learning that the questions are about. That is, the question to ask is whether beginning readers of Chinese can learn to capture the statistical and distributional information in a string of characters and use that information to find the words therein.

There is now ample evidence to suggest that the answer to the above question is positive. Saffran, Aslin, and Newport's seminal work (1996) demonstrated the potential of 8-month-old infants in capturing the transitional probabilities (TPs) between syllables in a continuous flow of speech-like sounds and used them to distinguish syllable strings with high TPs ("words") from those with low TPs ("nonwords"). Subsequent research replicated this statistical learning effect in infants and adults with a natural language (Saffran, Newport, Aslin, Tunick, & Barrueco, 1997; Hay, Pelucchi, Graf Estes, & Saffran, 2011; Kittleson, Aguilar, Tokerud, Plante, & Asbøjrnsen, 2010). Additional research shows that statistical learning extends to visual, tactile, and kinesthetic modalities as well as nonlinguistic stimuli, pointing to its domain-general nature (Fiser & Aslin, 2002; Conway & Christiansen, 2005; Baldwin, Anderson, Saffran, & Meyer, 2008; Aslin, Saffran, & Newport, 1999; Frost, Armstrong, Siegelman, & Christiansen, 2015). Moreover, it is a type of implicit learning, requiring little attention (Baker, Olson, & Behrmann, 2004; Toro, Sinnett, & Soto-Faraco, 2005; Perruchet & Pacton, 2006; Kim, Seitz, Feenstra, & Shams, 2009; Kittleson et al., 2010; Hamrick & Rebuschat, 2012). For recent reviews, see Armstrong, Frost, and Christiansen (2017) and Cunillera and Guilera (2018).

Although statistical learning has been examined in the visual modality, existing research has all used visual nonlinguistic stimuli. Visual linguistic stimuli such as the script of a language have not been investigated. The Chinese script, with its characters and no-word-spacing sentences, offers a perfect testing ground for such an investigation. Our laboratory has made a few attempts to investigate whether statistical regularity between characters could be captured by foreign beginning learners of Chinese (see Chen & Wang, 2019). We briefly summarize our findings below.

Our initial attempt repeated Saffran, Newport, Aslin, Tunick, and Barrueco's (1997) experiment but manipulated the transitional probabilities between six Chinese syllables (gu3, ke4, xi4, qu1, pi2, xian1). Six "words" (gu3ke4, xi4ke4, gu3qu1, pi2qu1, ke4xian1, xian1pi2) were defined where the TPs between characters ranged from .46 to 1. These "words" were judged to be not real words whether read forwards or backwards. Each was repeated 300 times and randomly concatenated to form a continuous string of 3600 syllables. The TPs between syllables across "words" ranged from 0 to .29. The syllable string was artificially pronounced by a speech synthesizer developed by the Industrial Technology Research Institute (ITRI) of Taiwan, R.O.C. The syllable string was played back to 20 foreign learners of Chinese while they performed a paper coloring task. In the subsequent two-alternative-forced-choice (2AFC) task, they could distinguish “words” from “nonwords” with a mean accuracy of .57 (s.e. = .08), which was significantly greater than .5 (p < .05). The accuracy was similar to that observed by Saffran et al. (1997), which was .58. The result demonstrated a successful replication of Saffran et al. (1997) using Chinese syllables. It served as a methodological check of the adequacy of our experimental procedure.

Our next attempt was to turn the above experiment into the visual mode, presenting the syllable string as a character string. The six characters were 古, 文, 唐, 詩, 仙, 人. The six words were 古文, 唐詩, 仙人, 古詩, 詩仙, 人文. The string of 3600 characters were divided into 36 consecutive blocks with 100 characters in each block presented in one single screen. In a screen, the 100 characters was presented one at a time at a rate of .5 second per character, from left to right and from top to bottom. Sporadically (0~.03), the presentation rate doubled for two consecutive characters and the participants were required to press a button to indicate that they had noticed the change. In the subsequent 2AFC task, they could barely distinguish words from nonwords with a mean accuracy of .53 (s.e. = .08), which was not significantly greater than the .5 chance expectation. Although the result could be shown to be significant if the accuracy rate for each participant was analyzed first and the p values pooled meta-analytically, the mean accuracy of .53 was obviously lower than the .57 accuracy in the previous auditory experiment.

To boost the statistical learning effect in reading Chinese, the subsequent attempts (1) doubled the exposure and (2) reduced the complexity of characters. The mean accuracy rates for these attempts were .52, and .52, respectively, and not significant. When pooled across the three attempts, the effect was significant. These experiments suggested that statistical learning probably contributed to word segmentation during reading of Chinese texts but the effect was small.

To understand how readers of Chinese learn to segment words in a Chinese sentence, we needed to find a task as similar to normal reading as possible and to demonstrate a statistical learning effect with a significant size that was comparable to the one we observed in our auditory experiment. A good candidate was the Rapid Serial Visual Presentation (RSVP) of characters, which had been used in past investigations of visual word recognition (Potter, 1983; Yen & Chien, 2011; Öquist & Goldstein, 2002; Cao, Yang, & Yan, 2017). The sequential nature of the task was also an essential feature for computing transitional probabilities across adjacent items. In order to ensure that the participants kept their eyes on viewing the fast flashing characters shown in the RSVP task, three different kinds of cover task was attempted. In Experiment 1, the participants needed to press a button whenever they detected an English letter. In Experiment 2, the participants were not required to respond to English letters. Experiment 3 contained no English letters. The participants were simply told to pay attention to the flashing characters because they would be asked to write down the characters at the end of the experiment.

Experiment 1

Method

Participants Experiment 1 recruited 15 foreign beginning learners of Chinese (4 males, 11 females; 18-49 years of age (M = 24.2, SD = 7.57). Hours of learning Chinese ranged from 30 to 180 (M = 98.1, SD = 70.1). Their mother languages included Polish, Kazakh, Russian, French, English, German, and Spanish. They were all at the beginners’ level of learning Chinese, as inferred from the fact that they were all learning from the first book of various Chinese language textbooks (A Course in Contemporary Chinese, Mastering Chinese, Practical Audio-Visual Chinese).

Materials The learning materials were six experimenter defined “words” (三上, 久也, 女上, 三也, 大女, 也大) made from 6 Chinese characters. None of these “words” can be found in real usage. Each “word” was repeated 300 times and concatenated into a pseudorandom sequence of “words” (the same word did not appear in a row), or a stream of 3600 characters. The transitional probabilities (TPs) of adjacent characters between “words” ranged from 0 to .29, while the TPs of adjacent characters within “words” were from .46 to 1. The stream of 3600 characters were divided into nine sets of equal size. Each set of 400 characters were mixed with 20 English letters (randomly chosen for each set). The English letters were randomly inserted into the 400 Chinese characters, with the restrictions that they did not appear at the beginning or end of the stream and that they appeared between “words” and not within a “word”. The test materials consisted of “words” and “nonwords”. The “nonwords” were character reversal of the “words”. Each “word” was paired with each “nonword” to make up 36 pairs and served as test items in a two-alternative-forced-choice (2AFC) test.

Procedure Before the experimental task was given, the participants were shown the 6 characters, told the pronunciation of each, and checked to ensure they could tell apart the six characters. For the experiment task, the nine stimulus sets were administered in nine separate sessions, with a break in between. A session started with a fixation cross displayed at the center of the screen. Pressing the spacebar removed the cross and brought in the stimulus stream. The stream of Chinese characters and English letters were shown one at a time at the center of the screen. Each character or letter appeared for 350 ms, followed by a 150-ms blank screen. The participants were asked to view each character and to press ‘1’ on the numeric keypad whenever and as soon as an English letter appeared. The next character came on regardless of whether they responded in time. At the end of the learning phase, the participants were given a surprise 2AFC test, in which they were shown the 36 “word”-“nonword” pairs, one pair at a time randomly chosen and with one member above the other, the order of which was random. The participants had to indicate which member in a pair was the one they had seen in the stimulus stream during learning. Following the 2AFC test, a memory test was given, in which the participants were shown the 6 characters and asked to write down the pinyins and the meanings.

Results and Discussion

The mean accuracy from the 15 participants was .53 (SD= .09, Max = .64, Min = .39), which was not significantly greater than the .5 guessing rate: t(14) = 1.29, one-tailed p = .1090, Cohen's d = .47. Nine out of the 15 participants scored above .5. The mean signal detection d' was .11, (SD = .33, Max = .52, Min = -.40). Table 1 presents the proportion of responses cross-tabulated according to the type of stimulus and the type of responses.

Table 1: Crosstabulation of the proportion of the participants' responses in Experiment 1.

		Stimulus	
		"word"	"nonword"
Participants' response	seen ("word")	0.54	0.48
	not seen ("nonword")	0.46	0.52

The result of the memory test showed a mean score of 5.8 (*SD*= .77, *Max* = 6, *Min* = 3) for pinyin and 4.93 (*SD*= .96, *Max* = 6, *Min* = 2) for meaning.

No significant statistical learning was observed in Experiment 1 despite that the participants had been familiarized with the characters and that the RSVP task should have been ideal for computing transitional probabilities. Having to initiate a manual response might disrupt the statistical computation. Simply anticipating the appearance of an English letter might also distract the participants' attention away from the statistical computation. Experiment 2 removed the manual responses and Experiment 3 removed the distracting English letters.

Experiment 2

Method

Participants Experiment 2 recruited another 15 foreign beginning learners of Chinese (9 males, 6 females; 18-46 years of age (M = 22.5, SD = 7.1). Hours of learning Chinese ranged from 75 to 225 (M = 166.7, SD = 54). Their mother languages included French, English, German, Spanish, Tagalog, Portuguese, and Indonesian. They were all at the beginners' level of learning Chinese, as inferred from the fact that they were all learning from the first book of various Chinese language textbooks (A Course in Contemporary Chinese, Mastering Chinese, Practical Audio-Visual Chinese).

Materials The materials for Experiment 2 were identical to those for Experiment 1.

Procedure The procedure for Experiment 2 were also identical to that for Experiment 1, except that the participants were told about the English letters but did not have to make manual responses upon their appearance.

Results and Discussion

The mean accuracy was .53 (SD= .10, Max = .67, Min = .36), which was not significantly greater than the .5 guessing rate: t(14) = 1.02, one-tailed p = .1625, Cohen's d = .42. Eight out of the 15 participants scored above .5. The mean signal detection d' was .10, (SD = .39, Max = .68, Min = -.50). Table 2 presents the proportion of responses cross-tabulated according to the type of stimulus and the type of responses.

Table 2: Crosstabulation of the proportion of the participants' responses in Experiment 2.

		Stimulus	
		"word"	"nonword"
Participants' response	seen ("word")	0.57	0.51
	not seen ("nonword")	0.43	0.49

The result of the memory test showed a mean score of 5.67 (*SD* = .49, *Max* = 6, *Min* = 5) for pinyin and 5.53 (*SD*= .64, *Max* = 6, *Min* = 4) for meaning.

The mean accuracy of .53 was identical to that observed in Experiment 1, indicating that requiring a manual response was not responsible for the lack of a statistical learning effect.

Experiment 3

Method

Participants Experiment 3 recruited yet another 15 foreign beginning learners of Chinese (8 males, 7 females; 21-65 years of age (M = 31.7, SD = 11.2). Hours of learning Chinese ranged from 45 to 150 (M = 72, SD = 31.2). Their mother languages included French, English, German, Swedish, Tagalog, and Thai. They were all at the beginners' level of learning Chinese, as inferred from the fact that they were all learning from the first book of various Chinese language textbooks (A Course in Contemporary Chinese, Mastering Chinese).

Materials The materials for Experiment 3 were identical to those for Experiment 1 except that there were no English letters in the stimulus stream.

Procedure The procedure was the same as that of Experiment 1 with two exceptions. There were no English letters in the stimulus stream. In addition, the participants were not shown and familiarized with the stimulus characters before the experimental task was given. Instead, they were told that a memory test of the characters would be given at the end of the experiment, in which they had to write down the six characters that appeared in the experimental task. When the memory test was administered, the participants were also encouraged to provide the pinyin and the meaning of each character they wrote down.

Results and Discussion

The mean accuracy was .57 (SD = .14, Max = .78, Min = .25), which was significantly greater than the .5 guessing rate: t(14) = 3.06, one-tailed p = .0042, Cohen's d = 1.16. Eleven out of the 15 participants scored above .5. The mean signal detection d' was .26, (SD = .55, Max = 1.10, Min = -.96). Table 3 presents the proportion of responses cross-tabulated according to the type of stimulus and the type of responses.

Table 3: Crosstabulation of the proportion of the participants' responses in Experiment 3.

		Stimulus	
		"word"	"nonword"
Participants' response	seen ("word")	0.56	0.41
	not seen ("nonword")	0.44	0.59

The result of the memory test showed a mean score of 3.95 (SD = 1.82, Max = 6, Min = 1) for pinyin and 4.45 (SD = 1.36, Max = 6, Min = 2) for meaning. The accuracy of the remembered characters was fairly high, with a mean of 5.85 (SD = .37, Max = 6, Min = 5).

Employing the RSVP paradigm, Experiment 3 observed a significant effect of statistical learning with Chinese characters, but Experiment 1 and 2 did not. Requiring an explicit manual response does not convincingly explain the failure of statistical learning in the latter experiments because Experiment 2 did not require it. The presence of the sporadically shown English letters obviously had something to do with the failure of statistical learning in these experiments, but it is not clear in what way. Attention might be an explanation. The sporadic appearance of an English letter among a sequence of Chinese characters might induce an attentional capture effect (Yantis, 1996), disrupt the implicit computation of the transitional probabilities between characters in the stimulus stream, and result in the failure of statistical learning. The cover task adopted in Experiment 3 served to direct the participants' attention to the characters themselves (and quite effectively, based on the high accuracy of the participants' memory of the characters) and there were no extraneous stimuli or tasks to distract their attention away from the character string. With this kind of cover task, the sequential nature of the RSVP paradigm was effective to induce computation of transitional probabilities between characters and statistical learning.

General Discussion

The present study applied the RSVP task to investigating statistical learning in reading a string of Chinese characters. The statistical learning effect (.57) observed in Experiment 3 was comparable to the effect (.57) observed with the auditory version of the Saffran et al. (1997) paradigm using Chinese syllables in our previous study (Chen & Wang, 2019). It was also similar to the effect (.58) originally reported by Saffran et al. (1997) with auditory English syllables. To our knowledge, this is the first study that reports a statistical learning effect in a task that simulates normal reading.

Although Experiment 1 and 2 were unsuccessful in producing a statistical learning effect, the failure could not be attributed to the small samples and low statistical powers. This is because Experiment 3 employed the same sample size but succeeded in observing a statistical learning effect. The effects were simply much smaller in Experiment 1 and 2 than in Experiment 3. The different sizes of the effects can only be explained by the difference in the task requirement. Experiment 1 and 2 involved task-irrelevant stimuli (English letters) that may have directed the participants' attention away from the characters, whereas in Experiment 3, the task demand required the participants to pay attention to the characters.

While the comparable effects of statistical learning in speech and print do not necessarily imply the same underlying mechanisms (cf. Siegelman & Frost, 2015), the use of the Saffran paradigm coupled with the RSVP task suggests that the same mechanisms may be responsible for the statistical learning effects in speech and print. Based on the results from the current and our previous investigations of statistical learning in reading Chinese, two mechanisms may be inferred. First, statistical learning requires sequential processing of input, and can be observed only if a task can effectively induce sequential processing. Second, statistical learning requires attention directed at the input. It might be that processing of the items in the input requires attention (and is explicit) while sequential processing that computes statistical distribution across items does not (and is implicit). This echoes that of Turk-Browne, Jungé and Scholl (2005) about the automaticity of visual statistical learning.

In reading unspaced Chinese sentences, Chinese readers likely learn to compute statistical regularities contained in the sentence, and retrieve and use that information in subsequent reading to find word boundaries and identify words. However, we quickly note that statistical learning in reading may not depend just on sequential processing. Transitional probabilities (or co-occurrence probabilities) between characters can be computed and accumulated when a string of characters that forms a word appears in isolation, as in a common word learning experience. Moreover, voluntarily reading across a line of characters as in normal reading does not seem to be an effective way of engaging sequential processing. Nonetheless, sequential processing may still be an essential characteristic of, and contribute to, statistical learning in reading.

Acknowledgments

The work reported here was supported by the MOST108-2410-H-003-043 grant awarded to the first author by the Ministry of Science and Technology, Taiwan, R.O.C. Preparation and presentation of the paper was also supported by the "Chinese Language and Technology Center" of National Taiwan Normal University (NTNU) from The Featured Areas Research Center Program within the framework of the Higher Education Sprout Project by the Ministry of Education (MOE) in Taiwan.

References

Armstrong, B. C., Frost, R., & Christiansen, M. H. (2017). The long road of statistical learning research: past, present and future. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *372*(1711), 20160047.

Aslin, R. N., Saffran, J. R., & Newport, E. L. (1999). Statistical learning in linguistic and nonlinguistic domains. In B. MacWhinney (Ed.), *The emergence of language* (pp. 359-380). Mahwah, NJ: Erlbaum.

Bai, X.-J., Liang, F.-F., Blythe, H. I., Zang, C.-L., Yan, G.-L., & Liversedge, S. P. (2013). Interword spacing effects on the acquisition of new vocabulary for readers of Chinese as a second language. *Journal of Research in Reading*, *36*(S1), S4-S17.

Bai, X.-J., Yan, G.-L., Liversedge, S. P., Zang, C., & Rayner, K. (2008). Reading spaced and unspaced Chinese text: Evidence from eye movements. *Journal of Experimental Psychology: Human Perception and Performance, 34*(5), 1277-1287.

Baker, C. I., Olson, C. R., & Behrmann, M. (2004). Role of attention and perceptual grouping in visual statistical learning. *Psychological Science*, *15*(7), 460–466.

Baldwin, D., Anderson, A., Saffran, J., & Meyer, M. (2008). Segmenting dynamic human action via statistical structure. *Cognition*, *106*(3), 1382–1407.

Cao, H.-W., Yang, K.-Y., & Yan, H.-M. (2017). Character Decomposition and Transposition Processes of Chinese Compound Words in Rapid Serial Visual Presentation. *Frontiers in Psychology, 8*, 483. DOI=10.3389/fpsyg.2017.00483

Chen, J.-Y. (1998). Word recognition during reading of Chinese sentences: Evidence from studying the word superiority effect. In A. Inhoff, J. Wang, & H. C. Chen (Eds.), *Reading Chinese script: A cognitive analysis* (pp. 239-256). N.J.: Erlbaum.

Chen, J.-Y., & Li, C.-Y. (2016, Aug.). *Technological shaping of working memory: A difference between Chinese phonology-based and orthography-based typing*. The 38th Annual Meeting of the Cognitive Science Society, Philadelphia, Pennsylvania, USA.

Chen, J.-Y., & Wang, T.-Y. (2019, Jul.). Visual statistical learning contributes to word segmentation during reading of unspaced Chinese sentences. Poster presented at the 41st Annual Meeting of the Cognitive Science Society, July 24-27, Montreal, Canada.

Cheng, C.-M. (1981). The cognitive processes of Chinese word recognition. *Chinese Journal of Psychology*, 2*3*, 137-153. (in Chinese: 鄭昭明，漢字的認知歷程)

Chuang, Y.-L. (2018). *The facilitatory effect of word-unit presentation on reading Chinese with an application in teaching Chinese as a second language*. Unpublished doctoral thesis, National Taiwan Normal University.

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review, 12*(5), 769-786. doi: 10.3758/bf03196772

Conway, C. M., & Christiansen, M. H. (2005). Modality-constrained statistical learning of tactile, visual, and auditory sequences. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *31*(1), 24-39.

Cornoldi, C., & Vecchi, T. (2003). *Visuo□spatial working memory and individual differences*. Hove, UK: Psychology Press.

Cunillera, T., & Guilera, G. (2018). Twenty years of statistical learning: from language, back to machine learning. *Scientometrics*, *117*, 1–8.

Fiser, J. Z., & Aslin, R. N. (2002). Statistical learning of higher-order temporal structure from visual shape sequences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(3), 458–467.

Frost, R., Armstrong, B. C., Siegelman, N., & Christiansen, M. H. (2015). Domain generality versus modality specificity: The paradox of statistical learning. *Trends in Cognitive Sciences*, *19*(3), 117–125.

Hamrick, P., & Rebuschat, P. (2012). How implicit is statistical learning. In J. N., Williams and P. Rebuschat (Eds.), *Statistical learning and language acquisition* (pp. 365–382). Boston/Berlin: Walter de Gruyter.

Hay, J., Pelucchi, B., Graf Estes, K., & Saffran, J. R. (2011). Linking sounds to meanings: Infant statistical learning in a natural language. *Cognitive Psychology*, *63*, 93–106.

Hoosain, R. (1992). Psychological reality of the word in Chinese. In H.-C. Chen, & O. J. L. Tzeng (Eds.), *Language processing in Chinese* (pp. 111-130). Amsterdam: North-Holland.

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.

Hue, C.-W. (1989). Word superiority effect and inferiority effect: A study of Chinese word recognition. *Chinese Journal of Psychology*, *31*, 33-39.

Kim, R., Seitz, A., Feenstra, H., & Shams, L. (2009). Testing assumptions of statistical learning: Is it long-term and implicit? *Neuroscience Letters*, *461*(2), 145–149.

Kittleson, M. M., Aguilar, J. M., Tokerud, G. L., Plante, E., & Asbøjrnsen, A. E. (2010). Implicit language learning: Adults' ability to segment words in Norwegian. *Bilingualism*, *13*(4), 513-523.
Li, X.-S., Rayner, K., & Cave, K. (2009). On the segmentation of Chinese words during reading. *Cognitive Psychology, 58*, 525-552.
Liu, I.-M., Yeh, C.-H., Wang, L.-H., & Chang, Y.-K. (1974). The effect of word spacing on reading efficiency in Chinese. *Chinese Journal of Psychology, 16*, 25-32.
Öquist, G.; Goldstein, M. (2002). Towards an improved readability on mobile devices: Evaluating adaptive Rapid Serial Visual Presentation". *Human Computer Interaction with Mobile Devices. Lecture Notes in Computer Science*, 2411, 225. doi:10.1007/3-540-45756-9_18.
Paribakht, T., & Wesche, M. (1993). The relationship between reading comprehension and second language development in a comprehension-based ESL program. *TESL Canada Journal, 11*(1), 9-29.
Peng, R.-Y., & Chen, J.-Y. (2004). Even words are right, odd ones are odd: Explaining the word segmentation inconsistency among Chinese readers. *Chinese Journal of Psychology*, *46*, 049-055. (in Chinese: 彭瑞元、陳振宇，「偶語易安、奇字難適」：探討中文讀者斷詞不一致之原因)
Perruchet, P., & Pacton, S. (2006). Implicit learning and statistical learning: One phenomenon, two approaches. *Trends in Cognitive Sciences*, *10*(5), 233–238.
Potter, M. C. (1983). Rapid serial visual presentation (RSVP): A method for studying language processing. In D. Kieras and M. Lust (Eds.), *New methods in reading comprehension research* (pp. 91-118). Hillsdale, N.J.: LEA.
Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*, *274*(5294), 1926–1928.
Saffran, J. R., Newport, E. L., Aslin, R. N., Tunick, R. A., & Barrueco, S. (1997). Incidental language learning: Listening (and learning) out of the corner of your ear. *Psychological Science*, *8*, 101–105.
Shu, X., Wang, J., Shen, X., & Qu, P. (2017). Word segmentation in Chinese language processing. *Statistics and its Interface*, *10*(2), 165-173. https://doi.org/10.4310/SII.2017.v10.n2.a1
Siegelman, N., & Frost, R. (2015). Statistical learning as an individual ability: Theoretical perspectives and empirical evidence. *Journal of memory and language*, *81*, 105-120. https://doi.org/10.1016/j.jml.2015.02.001
Tang, L. X., Geva, S., Xu, Y., & Trotman, A. (2009). Word segmentation for Chinese Wikipedia using n-gram mutual information. *Proceedings of the 14th Australasian Document Computing Symposium*, Sydney, Australia, 4 December.
Toro, J. M., Sinnett, S., & Soto-Faraco, S. (2005). Speech segmentation by statistical learning depends on attention. *Cognition*, *97*(2), B25–B34.
Turk-Browne, N. B., Jungé, J. A., & Scholl, B. J. (2005). The automaticity of visual statistical learning. *Journal of Experimental Psychology: General*, *134*, 552-564.
Yan, M., Kliegl, R., Richter, E. M., Nuthmann, A., Shu, H. (2010). Flexible saccade-target selection in Chinese reading. *Quarterly Journal of Experimental Psychology, 63*, 705–725.
Yantis, S. (1996). *Attentional capture in vision.* In A. F. Kramer, M. G. H. Coles, & G. D. Logan (Eds.), *Converging operations in the study of visual selective attention* (p. 45–76). American Psychological Association. https://doi.org/10.1037/10187-002
Yen, C. C., & Chien, Y. H. (2011). Rapid serial visual presentation display on a small screen: reading Chinese while walking. *Perceptual and Motor Skills, 112*(3), 991-1003.