Implicit learning of L2 word stress regularities

Ricky KW Chan[1,2] and Janny HC Leung[1]

[1]*School of English, University of Hong Kong*

[2]*Department of Theoretical and Applied Linguistics, University of Cambridge*

Abstract

This paper reports an experiment on the implicit learning of second language stress regularities, and presents a methodological innovation on awareness measurement. After practising two-syllable Spanish words, native Cantonese speakers with English as an L2 completed a judgement task. Critical items differed only in placement of stress. We assessed participants' awareness of the hidden stress regularities by verbal reports and a novel methodology: inclusion-exclusion production tasks adapted from Jacoby (1991) and Destrebecqz and Cleeremans (2001). Participants who remained unaware of the underlying regularities nevertheless performed significantly above chance in identifying correctly pronounced novel words. We conclude that L2 word stress regularities may be learnt implicitly.

Keywords

Introduction

There has been a growing body of research on implicit learning in second language acquisition (SLA), especially in the learning of syntax (Rebuschat & Williams, 2012; Robinson, 2005) and form-meaning connections (Leung & Williams, 2011). Relatively little work has explored implicitness in the learning of phonology, in particular prosodic features such as lexical stress, which plays an important role in the organization of speech stream and acquisition of vocabulary. The present study fills this research gap by investigating the possibility of learning L2 stress patterns without awareness. In terms of methodology, previous studies on implicit learning mainly relied on verbal reports to assess awareness, but the sole reliance on verbalization as a reflection of awareness remains controversial. Therefore, we improved the assessment of awareness by employing the process dissociation procedure, which is an objective measure of awareness. As SLA is believed to involve implicit learning (Ellis, 2004; Reber & Allen, 2000), we hypothesized that word stress regularities may also be learnt implicitly.

Implicit learning and related concepts

Implicit learning, a term coined by Reber (1967), generally refers to learning of regularities in the environment without intention and awareness, which results in implicit knowledge inaccessible to conscious introspection (See Cleeremans et al., 1998; Perruchet, 2008; Shanks, 2005 for overviews). Examples of implicit learning include perception of musical regularities and children learning their first language. Explicit learning, in contrast, involves conscious intention and mainly results in conscious knowledge (Hulstijn, 2005). Implicit learning first attracted research attention when it was demonstrated that artificial grammar may be learnt without awareness (Reber, 1967, Reber and Allen, 1978). It is regarded as the primary form of learning in human cognition (N. Ellis, 2002; Reber, 1993).

Implicit learning research should be distinguished from two closely related research paradigms, namely "incidental learning" and "statistical learning". Statistical learning was first coined by Saffran et al. (1996) to describe infants' ability to learn from distributional cues and this form of learning has subsequently been explored in various areas (e.g. tone sequence in Saffran et al., 1999; visual features in Kirkham et al., 2002; and phrase structures in Saffran, 2001). Research in statistical learning and implicit learning both investigate the same domain-general incidental learning processes (Perruchet and Pacton, 2006), yet implicit learning studies adopt measures of awareness, which are absent in statistical learning studies (Rebuschat and Hamrick, 2012). On the other hand, both "incidental learning" and "implicit learning", from a methodological point of view, involve rigorous control on experimental settings in which participants are not told to learn the underlying regularity, and both terms are used to describe the learning process where participants learn without intention to (Hulstijn, 2003, Williams, 2009). However, implicit learning research, but not incidental learning research, involves awareness measures as evidence of participants' unawareness of the learning target.

The nature of the learning process also needs to be distinguished from the nature of the resultant knowledge. Implicit knowledge is unconscious knowledge which one is unaware of possessing, whilst explicit knowledge is conscious knowledge which one is aware of possessing and may be able to verbalize (Hulstijn, 2005). Though Krashen (1981) asserts that there is no interface between implicit and explicit knowledge, many other scholars posit that they interact with each other, be the interface strong or weak (e.g. Bialystok, 1978, Sharwood Smith, 1981, DeKeyser, 1998, Ellis, 2005). For instance, implicit learning may first lead to implicit knowledge. With continuous exposure to the stimuli, one may develop an 'insight' and attain explicit knowledge of the underlying regularities. Similarly, the explicit knowledge resulted from explicit learning may, with enough practice, transform into implicit knowledge

and influence behaviour without consciousness (Williams, 2009).

Implicit and explicit learning in SLA and pedagogy

The dissociation between implicit and explicit knowledge has given increasing impetus to implicit learning research in SLA and language pedagogy. In the field of SLA, the differential success in first language (L1) and second language (L2) acquisition remains a central theoretical issue, and the distinction between implicit and explicit learning offers a potential explanation. Scholars postulated that while first language acquisition essentially hinges on implicit learning, SLA involves both implicit and explicit learning (e.g. Bley-Vroman, 1991; Ellis, 2004; Krashen, 1981; Reber & Allen, 2000). Krashen (1981, 1994) proposed that learners employ two separate mechanisms for developing L2 knowledge: language *acquisition* and language *learning*. The former is an incidental process resulting in tactic knowledge whereas the latter an intentional process resulting in conscious knowledge, and no interface exists between the two types of knowledge. According to Krashen (1994), the majority of second language acquisition is the result of implicit learning. Explicit knowledge of a rule only serves as a "monitor" of learners' output and is unrelated to the acquisition of the same rule. Therefore, he argued that more emphasis should be placed on promoting implicit learning in L2 pedagogy. Because of Krashen's controversial proposal, educationalists have expressed considerable interest in determining what may be learnt implicitly and how L2 learners might benefit most from implicit or explicit learning modes, and their potential synergy. In fact, some teaching methodologies such as the Communicative Approach are built on the assumption that learners possess the ability to implicitly extract linguistic knowledge from the environment through interactions, resembling children picking up their L1 from the environment (Nunan, 1991). Clearly, a thorough understanding of the

scope of and condition for implicit learning mechanism will serve as the foundation stone for further exploration of language acquisition theories and pedagogical methods.

Implicit learning of L2 phonology

Among the few implicit learning studies that looked into the realm of phonology (Dell et al, 2000; Onishi, 2002; Goldrick, 2004; Plante et al., 2010), most of them focused on phonology at the syllable level. Dell et al. (2000) studied the implicit learning of phonotactic constraints. In their study, participants read aloud sequences of nonsense syllables that obeyed a set of phonotactic rules which govern possible segments in only onset or coda position or both. Participants' speech errors revealed that they followed the artificial phonotactic constraints in 97.7% of all cases but they were unable to verbalize the underlying phonological constraints.

The finding has been extended by Onishi et al. (2002), who exposed participants to consonant-vowel-consonant syllables adhering to a set of phonological constraints. In a subsequent repetition task, participants' response time for legal syllables was significantly lower than that for illegal syllables, showing that constraints on consonant and vowel positions may be learnt implicitly with only brief auditory experience.

Goldrick (2004) investigated whether segment features may be acquired implicitly. Participants were exposed to phonological constraints at segment level (e.g. /f/, /s/) and at feature level (labiodental fricatives) in onset and coda of the syllable. Based on participants' speech errors, he found that both the distributional probabilities of segments and featural combinations could be learnt without awareness.

Plante et al.'s (2010) study was one of the few which investigated features above the syllable. They focused on children's sensibility to stress in a string of syllables. They found

that pre-school children, be they normal or with specific language impairment, were able to abstract and make generalizations about underlying stress patterns after exposure to streams of syllables, displaying implicit knowledge of stress placement in the given strings of syllables.

However, it remains unclear whether word stress regularities can be learnt using distributional cues without awareness, despite its important role in the organization of speech stream. Primary word stress potentially provides information about the number of words in a speech stream and indicates their relative position (Trubetzkoy, 1969). Word stress also facilitates memory of words (Bell, 1977, Culter, 1986) and serves as navigational guide for effective listening (Gilbert, 1994). Previous studies on the learning of L2 lexical stress demonstrated that learners whose L1 is a non-stress language often have a different stress system than native speakers do, leading to a non-native "accent" of stress (Archibald, 1997, Peperkamp and Dupoux, 2002). For example, Mandarin speakers associate high level tone with stress (Juff, 1990) and Cantonese learners of English pronounce English stressed and unstressed syllables as though they were high and low level tones in their mother tongue (Chao, 1980). Motivated by the importance and the challenges of acquiring L2 word stress, the first objective of the present study is to explore the possibility of learning L2 word stress rules implicitly. Specially, this study focuses on the implicit learning of Spanish stress regularities by Cantonese-English bilinguals. Despite numerous studies on the acquisition of L2 Spanish stress patterns (Face, 2000, 2005; Lord, 2004, 2007; Saalfeld, 2012), no study has directly addressed the possibility of learning L2 Spanish stress implicitly. A brief review of lexical stress systems in participants' L1 (Cantonese), L2 (English) and the target language (Spanish) is provided below.

Lexical stress in Cantonese, English and Spanish

Cantonese. Cantonese constitutes a lexical-tone system in which change in pitch contrasts the core meaning of a word (Beckman, 1986; Bauer, 1997). Modern Cantonese identifies six lexical tones, which can be represented with pitch number as /55/, /25/, /33/, /21/, /23/ and /22/. Table 1 below illustrates how the syllable /ji/ exploits the six tones to contrast meanings.

Tone	Example in Cantonese	English Translation	Phonemic Transcription
High level	衣	clothing	/ji 55/
Mid rising	椅	chair	/ji 25/
Mid level	意	idea	/ji 33/
Mid-low falling	疑	suspicious	/ji 21/
Mid-low rising	耳	ear	/ji 23/
Mid-low level	二	two	/ji 22/

Table 1: The six tones in modern Cantonese.

Similar to lexical stress, the primary acoustic correlate of lexical tones in Cantonese is fundamental frequency (Fok-Chan, 1974). When learning a stress language such as English, Cantonese speakers consistently assign high level tone to stressed syllables and lower level tones to unstressed syllables in English (Chao, 1980; Luke, 2000). Data from Cantonese loanwords also exhibit similar patterns: Cantonese speakers assign high level tone to stressed syllables, mid-level tone to unstressed syllables and mid-low level tone to epenthetic syllables in English donor words (Zhang, 1975; Lai et al. 2011). In short, Cantonese speakers exploit tone contrast to represent stress contrast in an L2 stress languages such as English and Spanish, which are to be discussed next.

English. English constitutes a lexical stress system which is quantity-sensitive: heavy syllables (when the rhyme is a tense vowel, a diphthong or closed by a consonant) attract

lexical stress (Hayes, 1995). For instance, in disyllabic words which are stressed on the final syllable, the stressed syllables tend to involve a diphthong or a tense vowel, or is closed by a consonant. Feet are trochaic (left-head) and are iteratively built from right to left, accounting for the preference for initial stress and penultimate stress in English (Hammond, 1999). In pedagogy, since the English stress rules are too complicated and have many exceptions, teachers tend to put little emphasis on the teaching of English stress patterns (Celce-Murcia, 1996; Seferoğlu, 2005).

Spanish. Spanish is a stress language which respects the trisyllabic window for stress placement (i.e. stress falls on any of the last three syllables of a word). Feet are quantity-insensitive[1] and trochaic (left-headed), with stress being placed on the rightmost foot (Hayes, 1995), accounting for the predominant penultimate stress in Spanish (Harris, 1992). Spanish words assign stress at the right edge of the metrical domain (Harris, 1992). Vowels in word final positions are extrametrical (ignored in stress assignment), resulting in monosyllabic foot in vowel-final words with penultimate stress and trochaic foot in words with antepenultimate stress (e.g. ***vota*** (s/he votes), ***borro*** (I erase) (Harris, 1992). Word-final consonants are not extrametrical except for inflectional consonants in word-final position which are extrametrical; thus, plurals such as *ojos* (eyes) verb forms such as *lanzan* (they throw) have regular penultimate stress (Harris, 1992). In L2 stress pedagogy, Spanish stress assignment is often summarized as the following rules: stress falls on the penultimate syllable for words ending in a vowel, *n* or *s* (e.g. ***toro*** (bull), *computadora* (computer), ***joven*** (young) and *zapatos* (shoes)) and on the last syllable for words ending in consonant other than *n* or *s* (e.g. *hotel* (hotel), *hablar* (to speak) and *virtud* (virtue)) (Hualde, 2005). These rules are applicable to both derived and underived forms. Exceptions to these rules carry an accent mark on the vowel in the stressed syllable (e.g. ***árbol*** (tree), ***lápiz*** (pencil)) (Hualde,

---

[1]Some linguists argue that Spanish stress assignment is quantity sensitive, for example see Harris (1991).

2005). Can these stress assignment rules be learnt without awareness?

Can language learning take place without awareness?

While first language acquisition is often assumed to be implicit since children show no explicit knowledge of their L1, the idea that second language acquisition may take place without awareness remains empirically controversial. Although SLA is generally believed to largely depend on what learners attend to and notice in the language input, awareness of abstract language rules is often absent among advanced L2 learners who possess intuitive understanding of rules that they cannot verbalize (Schmidt, 2010). How may implicit learning take place in SLA if awareness of language input is necessary? Schmidt (1990, 1995, 2001), in his noticing hypothesis, distinguishes awareness at the level of noticing from awareness at the level of understanding. "Noticing" refers to the process in which attended instances of language are consciously registered; "understanding" is a higher level of awareness involving knowledge of rules and conscious generalization across instances (Schmidt, 2010). Schmidt argues that awareness at the level of noticing is required for turning input into intake; understanding plays a facilitative role but is not necessary. When the attended instances of language are consciously registered, implicit learning of generalization beyond particular instances may take place through a basic human learning mechanism which automatically detects patterns across stimuli, leading to unaware rule knowledge which is often hard to verbalize (Schmidt, 2010).

The controversy of learning without awareness is rather heated in the realm of form-meaning connections. Williams (2004, 2005) and Leung and Williams (2011) investigated the implicit learning of form-meaning mappings between article-to-animacy and article-to-thematic roles respectively. In their studies, participants who reported no knowledge of the

target form-meaning connection in post-task retrospective verbal reports nevertheless achieved above-chance accuracy for the target form-meaning connections. Hama and Leow (2010) replicated Williams's (2005) study on the implicit learning of article-animacy mappings but they assessed awareness with think-aloud protocols during the training and testing phases instead of retrospectively. Contrary to Williams (2005), they found no learning effect for participants who reported no knowledge of animacy in the think-aloud protocols. They attributed the discrepancy mainly to the awareness measure: their online verbal reports assessed awareness during the learning process, whereas the offline retrospective verbal reports adopted by Williams (2005) assessed whether the resultant knowledge was implicit.

However, the use of either online or offline verbal reports assumes that verbalizing knowledge is a good way of capturing awareness, but this assumption may not be warranted because very low levels of awareness may escape this measure. The inability to verbalise knowledge might reflect low confidence on the part of the participants or the intrinsic complexities of a regularity (Dienes and Berry, 1997, Shanks and St. John, 1994). Thus, verbal reports alone do not seem to be sensitive enough as a measure of awareness.

Process dissociation procedure

A fundamental problem, known as the process purity problem, lies in measuring unconscious knowledge: no task is process pure and task performance is always a mixture of both explicit and implicit processes (Dunn & Kirsner, 1989; Jacoby, 1991). For instance, in a recognition task, both explicit recollection and implicit familiarity of a test item may increase the likelihood of making a correct response; thus the individual contribution of implicit and explicit processes to task performance can hardly be separated and it may be futile to attempt to design an awareness measure that taps implicit or explicit knowledge alone.

In light of the process purity problem, Jacoby (1991) developed the process dissociation procedure to disentangle the contribution of implicit and explicit processes to task performance. The goal is to determine how the two processes are independently affected by different variables. In practice, it measures intentional control as comparing how explicit processes facilitate the production of certain responses (facilitation paradigm) against how explicit processes suppress the production of those responses (interference paradigm) (Jacoby, 1993). In a stem completion task (Jacoby et al., 1993), participants are instructed to recall a previously studied word using stems as a cue, and use either that word (inclusion condition) or an alternative word (exclusion condition) to complete the stem. The probabilities of stem completion can be expressed by simultaneous equations (Curren & Hintzman, 1995):

$$Inclusion = R + (1 - R)A......(1)$$

$$Exclusion = (1 - R) A......(2)$$

where R denotes explicit memory processing, A denotes automatic influence from implicit memory, and $(1 - R)$ refers to the situation when explicit memory processing fails. Hence the contribution of explicit memory (R) = Inclusion – Exclusion.

Adopting the process dissociation procedure, Destrebecqz and Cleeremans (2001) developed the "method of opposition" to assess implicit knowledge in the serial reaction time (SRT) task. A SRT task usually involves a stimulus (e.g., a dot) moving between different screen positions and the participant has to indicate each position using corresponding keys. There is a regular pattern governing the majority of the sequences and participants are not told the pattern. Participants' reaction time for regular sequences drops steadily, but when the stimuli follow random sequences, response time and error rate increase significantly, indicating participants' implicit knowledge of the pattern. Afterwards participants are

informed that there is a hidden sequence governing the presentation of visual stimuli and they are asked to complete free-generation tasks under both inclusion and exclusion instructions. Participants are asked to press response keys in an order that follows the sequence (inclusion condition) and that does not resemble the sequence (exclusion condition) (Destrebecqz & Cleeremans, 2001; Haider et al., 2010). According to the Global Workspace theory (Baars, 2003), when knowledge becomes conscious, the possibility for voluntary control of performance is opened up. Therefore, if participants have some explicit knowledge, their performance in the inclusion condition would regularly follow the sequence but exclusion performance would not. Therefore, a difference between inclusion and the exclusion performance indicates top-down processing and thus explicit knowledge. On the contrary, people with no explicit knowledge would tend to perform equally well in both inclusion and exclusion tasks (inclusion = exclusion) as they do not have control over how the implicitly learnt knowledge influences behaviour (Curran, 2001). The current study demonstrates how the method of opposition could be employed as an awareness measure in a language learning task.

The present study

The objectives of the present study are two-fold. The first objective is to explore the possibility of implicit learning of L2 ending-phoneme-to-stress regularities using Spanish-based stress rules as the learning target. Secondly, we seek to improve awareness measurement by integrating a subjective measure and an objective measure, namely retrospective verbal reports and inclusion-exclusion generation tasks. Thus the research questions of the study are:

1) Can L2 ending-phoneme-to-stress regularities be learnt without awareness?

2) To what extent are the inclusion-exclusion generation tasks reliable as an awareness measure?

Method

Participants

Thirty-seven university students aged 19 to 26 (17 males and 20 females, *M*age = 21.8 years old) were recruited as the experimental group and fifteen university students aged 20 to 26 (7 males and 8 females, *M*age = 21.4) as the control group. All of them were native Cantonese speakers in Hong Kong with English as an L2. Their English proficiency, as reflected in a self-report questionnaire, ranged from intermediate to advanced (scale: beginner, intermediate, upper-intermediate, advanced). None of them reported any knowledge of Spanish or Portuguese (which shares similar stress rules with Spanish).

Stimuli

Possible Spanish verbs were employed as stimuli in the form of audio presentations. Most of the verbs end in *-ar* or *-o* and they follow the following simplified stress rules consisting of only two regularities:

1) Words that end in "*o*" have their stress on the penultimate syllable. Examples include *soplo* (I blow)*, busco* (I look up) and *burro* (I erase).

2) Words that end in "*ar*" have their stress on the last syllable. Examples include are *roncar* (to snore)*, gustar* (to like) and *tumbar* (to knock down).

All audio files were generated by the MBROLI speech synthesizer[2] (Dutoit et al., 1996) which allowed for manual control of the pitch and duration for all the vowels. The specific values were based on those used by Enríquez et al. (1989): 100 Hz and 60 ms for unstressed vowels and 116 Hz and 120ms for stressed vowels. Although the use of a synthesizer may undermine the naturalness of the stimuli, they were used instead of recordings by a native speaker because a Spanish native speaker is likely to sound less fluent when trying to pronounce incorrectly stressed words. There is a possibility that participants can rely on a speaker's fluency in determining the correctly and incorrectly stressed words in the testing phase, without learning the underlying regularities. With the use of speech synthesizer, such a possibility was eliminated as all stimuli sounded equally fluent to the participants (Face, 2000, 2005).

Training set. A set of 16 Spanish verbs, half of which end with *-ar* and the other half with *-o*, was repeated four times in random order. All training items with their broadly transcribed phonetic representations are listed in table 2 below (For the verbs with (*), the accentuation mark on the second syllable of the word was removed to fit the target stress patterns).

---

[2]A database which contains the recordings of a male speaker of European Spanish (es2) was chosen for generating the stimuli in the MBROLI speech synthesizer (http://tcts.fpms.ac.be/synthesis/mbrola.html).

Training Set (16 items)			
-ar ending		*-o* ending	
Spanish Word	**Gloss**	**Spanish Word**	**Gloss**
Hablar [a.'blaɾ]	talk	Soplo ['so.plo]	blow
Rascar [ras.'kar]	scratch	Marco ['mar.ko]	mark
Tumbar [tum.'bar]	knock down	Zumbo ['θum.bo]	buzz
Contar [kon.'tar]	count	*Tosto ['tos.to]	toast
Barrar [ba.'rar]	daub	Borro ['bo.ro]	erase
Roncar [ron.'kar]	snore	Busco ['bus.ko]	look up
Lanzar [lan.'θar]	throw	*Forzo ['for.θo]	forces
Gustar [gus.'tar]	like	Gasto ['gas.to]	spend

Table 2: Items in the training set.

Testing set. The testing set consisted of 24 new Spanish verbs: 16 of which were half -ar ending and half -o ending and they served as critical items; the other 8 were *-a* ending verbs which serve as extension items. The *-a* ending words, similar to the *-o* ending words, have their stress on the penultimate syllable.

Previous studies on implicit learning (Altmann, Dienes, & Goode, 1995; Gomez & Gerken, 1999; Reber, 1993) indicate that if participants have learnt the underlying abstract rules instead of solely surface chunks, they should be able to transfer their rule knowledge to novel stimuli. Participants' responses towards novel stimuli may reflect the nature of their knowledge. In the present study, the inclusion of the extension items aimed to determine the basis of participants' judgement on –ar ending words: a positive correlation between participants' accuracy on –ar ending words and that on –a ending would suggest that their judgements were based on the vowel *a*, whereas a negative correlation would suggest that their judgements were based on the -r ending.

All the critical items and extension items are presented in table 3 below.

Critical Items (16 items)			
-*ar* ending		**-*o* ending**	
Spanish Word	**Gloss**	**Spanish Word**	**Gloss**
Probar [pɾo.'baɾ]	taste	Broto ['bɾo.to]	emerge
Juzgar [xuθ.'ɡaɾ]	try	*Colgo ['kol.ɡo]	hang
Saltar [sal.'taɾ]	jump	Basto ['bas.to]	be enough
Montar [mon.'taɾ]	ride	Falto ['fal.to]	lack
Tratar [tɾa.'taɾ]	treat	Grabo ['ɡɾa.bo]	record
Firmar [fiɾ.'maɾ]	sign	Formo ['foɾ.mo]	set up
Cantar [kan.'taɾ]	sing	Pinto ['pin.to]	paint
Costar [kos.'taɾ]	cost	Junto ['xun.to]	join
Extension Items (-*a* ending; 8 items)			
Roba ['ro.ba]	rob	Cita ['θi.ta]	cite
Mata ['ma.ta]	kill	Vota ['bo.ta]	vote
Bota ['bo.ta]	kick out	Dota ['do.ta]	provide
Paga ['pa.ɡa]	pay	Toma ['to.ma]	have

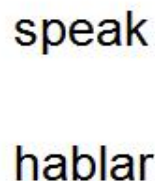**Table 3: Critical items and extension items in the testing phase.**

All stimuli in the training and testing sets start with a consonant. The number of different vowels (*a, e, o*) in the first syllable and the initial phoneme(s) in the second syllable are balanced for *–ar* and *–o* endings words. The careful control of the stimuli served to ensure participants' correct responses for critical items could only be due to the discovery of stress rules rather than other correlated features.

Procedure

The experiment consisted of 5 stages: 1) orientation, 2) training phase, 3) testing phase, 4) inclusion-exclusion tasks, and 5) retrospective verbal reports. Materials for stage 1 to 4 were presented on a computer and delivered via E-prime, and stage 5 was conducted by an interview with the experimenter. The whole session took around 20 minutes to complete.

Orientation. Participants were told that the experiment aimed to study how people learn words. To disguise the purpose of the experiment, they were also told that there would be a memory test in the second half of the experiment. They were not told anything about the pronunciation patterns of Spanish words or the target stress rules.

Training Phase. The 16 Spanish verbs in the training set were repeated four times in random order to form 64 trials. Each trial presented a Spanish word and its English translation, as shown in Figure 1 below.

speak

hablar

Figure 1: A sample trial in the learning phase.

After clicking to listen to an audio presentation of a Spanish word, participants had to repeat aloud after the recording. This promoted noticing of the ending phoneme and the stress placement of the stimuli, but no explicit information on the connection between the ending phoneme and word stress was provided. Their voices were recorded and no participants made any mistake on stress assignment. The entire training phase took 6-8 minutes to complete.

Testing Phase (Pronunciation Judgment Task). After training, participants completed a two-alternative forced choice pronunciation judgment task. Each trial included an English verb and two labels: "word 1" and "word 2", as shown in Figure 2 below.

like

Word 1   Word 2

Figure 2: A sample trial in the testing phase

Participants were instructed to listen to both word 1 and word 2 and choose the one that "sounds better" to them. As Scott and Dienes (2008) have shown that familiarity is the essential source of knowledge in artificial grammar learning, the use of preference judgment here (i.e. choose the one that sounds better) may be more suitable than an accuracy judgment such as "choose the correct one" in that the former would encourage the use of intuition and discourage rule search during the testing phase (Rebuschat & Williams, 2011).

The judgment task consisted of 40 trials. The first 4 trials which involve items in the training set served as a short practice session to familiarise participants with the procedure. Of the other 36 randomised trials, the 16 critical items and 8 extension items were novel to the participants. Sound pairs for the critical and extension items differed only in placement of stress (e.g., BUScar or busCAR) so that only by knowing the target stress rules could they choose the correct answers. Another 12 previously seen items, where the sound pairs were either totally different words or different in placement of stress, were randomly shuffled with the critical items and extension items so as to disguise the nature of the items. The testing phase took 8-10 minutes to complete. We hypothesised that if implicit learning of stress rules resulted in abstract representation, independent of the items in the training set, participants should be able to transfer such knowledge to novel items and display knowledge of stress assignment for novel *-ar* and *-o* ending words (critical items). As such, a significantly above-

chance performance for the critical items would reflect abstract knowledge of the stress rules.

Awareness measures

Two awareness measures, namely inclusion-exclusion tasks and verbal reports, were adopted to assess participants' conscious knowledge of the stress rules and classify participants into aware and unaware groups. The unaware group would be the focus for the study of implicit learning effect.

    Inclusion-Exclusion Tasks. After the pronunciation judgment task, we used inclusion-exclusion tasks to assess participants' awareness of the target stress rules. The design of the inclusion-exclusion tasks was adapted from Jacoby (1991) and Destrebecqz and Cleeremans (2001). In the tasks, the participants were presented with 16 bi-syllabic Spanish words, half *-ar* ending and half *–o* ending, under both the inclusion and exclusion conditions. Participants were asked to pronounce the first 8 words, one by one (see Figure 3), "as similarly to Spanish pronunciation as possible" (inclusion), whereas another 8 words "as differently from Spanish pronunciation as possible" (exclusion). The two word lists are presented in table 4 below.

Man.do

Figure 3: A sample trial in the inclusion and exclusion tasks

Items used in inclusion-exclusion tasks (16 items)			
Inclusion		Exclusion	
Spanish Word	Gloss	Spanish Word	Gloss
Ha.llo ['a.ʎo]	find	Chu.par [t͡ʃu.'par]	suck
Lle.vo ['ʎe.bo]	take	Ten.tar [ten.'tar]	tempt
Bre.go ['bɾe.go]	struggle	Lla.mar [ʎa.'maɾ]	call
Man.do ['man.do]	command	Cor.tar [koɾ.'taɾ]	chop
Lle.nar [ʎe.'naɾ]	fill	Ce.rro ['se.ro]	lock
Cho.car [t͡ʃo.'kaɾ]	crash	Car.go ['kaɾ.go]	load
Tum.bar [tum.'baɾ]	lie down	*Pen.so ['pen.so]	think
Tar.dar [taɾ.'daɾ]	be late	Llo.ro ['ʎo.ro]	cry

Table 4: Word lists in the inclusion-exclusion tasks

Small dots were given to indicate syllabification which serves to remind the participants that all words consist of two syllables. This prevented participants from treating the words as monosyllabic or trisyllabic. Participants placed the stress on either the first or the last syllable and the probabilities of placing the stress right and placing it wrong were equal (50%). Since the present study focuses on learning of word stress, a trial is correct when stress is placed in the right syllable, regardless of how they pronounced the segments. The number of correct trials was counted for both the inclusion and exclusion tasks and the difference between inclusion and exclusion scores was calculated. The inclusion task allows implicit and explicit processes to act in concert, whilst the exclusion task to work in opposition. In this way, the contribution of explicit processes can be calculated as the scores under inclusion condition against that under exclusion condition. The difference in the scores obtained (either inclusion > exclusion or inclusion < exclusion, the latter of which suggests the possibility of an awareness of an opposite set of rules) would indicate conscious control of the knowledge of the target stress rule, whereas equal performance under the two conditions would suggest unconscious knowledge.

Retrospective Verbal reports. After the inclusion-exclusion tasks, participants were

probed for whether they had any feelings about the pronunciation patterns. They were also told there were underlying stress patterns and if they could not report knowledge of the regularities, they would be asked to provide as many guesses as possible.

Results

Participants' performance on the pronunciation judgment task served as the measure of learning. Verbal reports and inclusion-exclusion tasks were used to determine whether the acquired knowledge was conscious or not.

Classifying aware and unaware participants

     Verbal reports. We first used verbal reports to eliminate participants with higher level of awareness on the rules: 32 out of 37 participants remained unaware of the underlying stress rules at the end of the experiment. Many of the unaware participants said they had no idea that there are phonological rules governing the pronunciation of Spanish words and were surprised when they were asked to guess the rules.

     We had used a strict criterion for awareness in our categorisation to ensure that semi-aware participants do not enter the unaware group, whose data are the focus of our analysis. One participant was able to verbalize the whole target stress rules. One guessed that the letter "*r*" is stressed. One mentioned when a word ended in "*o*", it would have a falling intonation. One stated stress seems to be related to the *-ar* ending and another said stress is related to word length. These five participants were classified as aware since they displayed full or partial knowledge of the target stress rules.

Among the other 32 unaware subjects, most of them had no idea at all about any stress regularities. Two unaware subjects guessed that the distinction between noun and verb may determine stress assignment and two mentioned stress was related to the number of syllables, even though they had been told all the words presented to them were disyllabic verbs. One subject stated that stress might be related to the meanings of words and one subject said it may be related to grammatical gender of words. Since their guesses did not overlap with the target stress rules, all these subjects were classified as unaware.

Inclusion-exclusion tasks. We adopted acoustic measures to assess participants' assignment of stress; this provided a more accurate and objective assessment of stress assignment than assessment by a native Spanish speakers. The participants' audio recordings were analysed using *Praat*. The placements of word stress in the recordings were determined based on the fundamental frequencies (F0) of the two syllables, as it was found that Cantonese speakers tend to produce stressed and unstressed syllable with high and low tones, which are manifests of F0, respectively (Chao, 1980).

The five aware participants scored higher under the inclusion instruction than the exclusion instruction (from +2 to +3), showing some congruence with their awareness level revealed in verbal reports. 15 out of the 32 remaining participants scored equally for both tasks and they were classified as our truly unaware participants. The other 17 participants who showed some difference in their scores for both tasks (from -3 to +3) were re-classified as aware and were not included in our analysis of unaware data.

Performance in the pronunciation judgment task

The accuracies on critical items for the whole experimental, control, aware and unaware

groups in the pronunciation judgment task in the testing phase are summarized in Table 5 below.

	N	Mean accuracy on critical items (%)	SD	SEM
Experimental group	37	59.6*	1.41	0.23
Aware group	22	60.2*	1.20	0.32
Unaware group	15	58.8*	1.56	0.33
Control group	15	47.1*	1.09	0.29

Table 5: Performance of the experimental, control, aware and unaware groups in the pronunciation judgment task (* denotes a significantly above-chance accuracy, $p < 0.01$)

Analysis using t-test shows that the experimental, aware and unaware groups achieved above-chance accuracies on critical items, $t(36) = 6.57$, $p \ll .001$, $d = 1.55$; $t(21) = 4.92$, $p \ll .001$, $d = 1.48$; and $t(14) = 4.37$, $p \ll .001$, $d = 1.65$ correspondingly. The control group, which completed only the pronunciation judgement task, did not achieve above-chance accuracy on critical items, $t(14) = 1.61$, $p = .065$. Importantly, the unaware participants performed significantly better than the control group, $t(28) = 4.31$, $p < 0.001$, $d = 1.63$. There is evidence of the possession of implicit knowledge of L2 ending-phoneme-to-stress rules by young Cantonese-speaking adults and such knowledge was the result of the exposure in the training phase. On the other hand, the aware participants did not perform significantly better than the unaware participants, $t(34) = 0.51$, $p = 0.31$.

The whole experimental group achieved above-chance-level performances on both –ar ending and –o ending words (see table 6), $t(36) = 4.81$, $p \ll .001$, $d = 1.13$ and $M = 55.1\%$, $SD = 1.13$, $SEM = .19$, $t(36) = 2.16$, $p = .019$, $d = .51$ respectively. Their

performance on *–ar* ending words was significantly better than that of *–o* ending words, $t(69)$ = 2.41, $p < 0.01$, $d = .57$. Similarly, the unaware participants performed significantly better than chance on both *–ar* ending and *–o* ending words, $t(14) = 2.44$, $p = .014$, $d = .92$ and $t(14)$ = 2.32, $p = .018$, $d = .88$ respectively. However, their accuracy on *–ar* ending words was not significantly higher than that of *–o* ending words, $t(28) = 0.16$, $p = 0.44$.

	Mean accuraciy on *ar*-final words	SD	SEM	Mean accuraciy on *o*-final words	SD	SEM
Experimental group	64.2%*	1.42	0.24	55.1%*	1.13	0.19
Unaware group	59.1%*	1.12	0.3	58.3%*	1.07	0.29

Table 6: Performance of the experimental and unaware groups for *ar*-final and *o*-final words (* denotes a significantly above-chance accuracy)

We also observed a medium negative correlation between the accuracy on *–ar* ending words and that of *–a* ending words, $r(35) = -0.51$, $p = .001$ for the whole experimental group and $r(13) = -0.72$, $p = .002$ for unaware participants. On the other hand, a medium positive correlation was found between their accuracy on *–o* ending words and that of *-a* ending words for both the whole experimental group, $r(35) = 0.49$, $p = .002$, and the unaware participants, $r(13) = 0.64$, $p = .001$. These results suggest that participants might have made their judgements based on the last phoneme (i.e. the *–r* ending instead of the vowel *a*) in the last syllable and they are sensitive to the distinction between open and closed syllable.

Discussion

The findings above suggest that, under incidental learning condition, participants were able to learn simplified L2 word stress regularities without explicit instruction after only short and

limited exposure. Participants were able to transfer knowledge of word stress rules to novel words, suggesting that participants derived an abstract representation of word stress rules from the training items. The resultant knowledge of word stress rules was implicit, as verified by both retrospective verbal reports and the process dissociation procedure. The findings confirm our hypothesis that L2 ending-phoneme-to-stress regularities may be learnt without awareness, and extend the existing body of evidence for the possibility of learning without awareness in SLA.

The results are in line with Schmidt's (2010) noticing hypothesis for SLA. Through reading aloud the stimuli in the training phase, noticing of the phonemes and the stress assignment of the stimuli was promoted as participants were forced to attend to the pronunciation of the stimuli. However, they were not aware of the mapping between stress and the ending phoneme. Participants who displayed no conscious knowledge of the stress rules (i.e. they showed no awareness at the level of understanding) nevertheless showed learning of the target stress patterns. This confirms Schmidt's idea that awareness at the level of noticing may serve as the basis for generalization across instances and the formation of abstract knowledge which is implicit.

The findings also suggest that the learning effects in the unaware participants can be attributed to the training they received. How could they abstract the target stress regularities implicitly with only limited exposure to Spanish words? Their prior linguistic background in Cantonese and English might have been helpful: participants' lexical tone system and knowledge in English word stress might have facilitated the perception of stress contrast of an L2 in general. Moreover, Bailey et al., (1999) show that native English speakers, when learning a novel stress pattern, had a significant bias for non-word-final stress. Culter and Carter (1987) also report a tendency for initial stress. These observations are likely to be linked to the default trochaic foot structure in English. In the present study, participants'

experience with English stress system and preference for penultimate stress may have facilitated learning of stress placement in *o*-final words. Furthermore, *-o* final words in English (many borrowed from Spanish and other Romance languages) tend to be stressed on the penultimate syllable. It is likely that participants have used such L2 English knowledge in the learning of L3 Spanish stress.

However, participants' performance cannot be explained merely by transfer, as they in general performed significantly better for *–ar* ending words than *–o* ending words. This can be explained with the notion of perceptual salience, which promotes noticing in SLA (Schmidt, 1991). In our study, when participants were asked if they had any feelings about pronunciation patterns of Spanish words, 12 participants mentioned "the intonation of the words tended to go up", "the last syllable seemed to be louder and higher in pitch" and "stress tends to lie on the final syllable", despite the fact that words with a word-final stress and a non-word-final stress appeared equally frequently in the experiment. These statements are an indication that word-final stress, which is less preferred in English, might have appeared more salient to our participants given their prior linguistic experience. In addition, English stress is arguably more quantity-sensitive (i.e. heavy syllables tend to be stressed) than Spanish (Hayes, 1995). These may explain why participants performed significantly better at *–ar* ending words (which has a heavy syllable at the end) than *–o* ending words.

Based on our data, it remains unclear whether abstract rule knowledge has been learnt. However, it is still possible to draw some preliminary inference from participants' performance on the extension items (-*a* ending words). As reported above, participants' accuracy on *–a* ending words correlated positively with that on *–o* ending words and negatively with that on *–ar* ending words, suggesting that participants were sensitive to the ending phoneme and the distinction between open and closed syllable. This serves as a piece of evidence that at least some knowledge of abstract rules, rather than merely memorized

fragments, was employed to identify stress in *a*-final words. This is consistent with Knowlton and Squire (1996)'s view that both concrete and abstract representations of stimuli are formed in implicit learning and they both influence performance in grammaticality judgment tasks.

At the methodological level, the finding further suggests that verbal reports are not a sensitive awareness measure on their own. In our experiment, verbal reports were useful in identifying 5 aware participants who were able to verbalize full or partial knowledge of the target rules. However, 15 other subjects whose awareness was not reflected in the verbal reports nevertheless performed differently in the inclusion-exclusion tasks, which appeared to be more sensitive in capturing participants with low confidence or low awareness about the rules. The findings demonstrated the usefulness of inclusion-exclusion tasks as an objective measure of participants' awareness, and their potentially higher sensitivity than verbal reports. By improving awareness measures, the present study offers a stronger piece of evidence for the possibility of implicit learning in SLA than studies which employed verbal reports only.

However, we acknowledge that the present study only assessed the implicit nature of the resultant knowledge but not the learning process. To determine whether the learning process is implicit, Leow and Hama (2013) proposed the use of online awareness measures (i.e. think-aloud protocols), but a potential mismatch between the knowledge they reported and their learning strategy still exist. Besides, the validity of think-aloud protocols is not uncontroversial (e.g., the problem of reactivity; see Bowles, 2010). Therefore, only offline measures of awareness (i.e. both the retrospective verbal reports and the inclusion-exclusion tasks) were employed in our study. Although the aware participants possessed explicit knowledge, as reflected in awareness measures after training, the learning process itself in the training phase may be implicit. These participants were excluded in our analysis of the

unaware data. On the other hand, one might imagine that the unaware participants might have employed explicit learning strategy but showed no awareness in the offline measures. Despite the fact that explicit learning may theoretically lead to implicit knowledge (Williams, 2009), it is unlikely that it leads only to implicit knowledge, and that all our unaware participants had engaged in rule deduction but had completely forgotten about it. Thus, we believe that for the unaware participants, the learning process of the target stress rules was by and large implicit.

Participants clearly showed learning of the target stress patterns shortly after training. However, the long-term learning effect, albeit important in SLA research (De Graff, 1997), was not in our research agenda. Further experiments may include delayed posttests and be longitudinal.

Conclusion

The present study bears theoretical, methodological and pedagogical significance. In terms of theoretical significance, this study extends previous findings on the implicit learning of language: apart from syllable regularity, sensitivity to lexical stress may also develop without awareness. The resultant knowledge was abstract and may be applied to novel items. The knowledge is also, to some extent, rule-based rather than merely exemplar-based. The results raise the possibility of implicit learning of other kinds of prosodic rules such as tonal rules.

The present findings have implications for acquisition of not only Spanish word stress rules but also stress patterns in other languages. Stress patterns in the present study are simpler than the original Spanish stress rules, and those in other languages with higher level of complexity and more exceptions. Nevertheless, the employment of simplified stress

patterns in experimental settings helped control potential confounding variables that might influence participants' judgment. The use of stress rules based on a real language rather than artificial stress rules allows the present findings to be transferred to other learning contexts. With the possibility of learning stress patterns implicitly established, it is likely that, given longer and richer exposure, implicit learning of more complex stress patterns in real languages is possible.

Our study is also methodologically interesting as it is, to our knowledge, one of the first successful attempts to apply the process dissociation procedure in a language learning task. While verbal reports are useful in capturing participants who could verbalise full or partial knowledge of the learning target, verbal reports are not sensitive enough for identifying participants with low confidence or low level of awareness. The process dissociation procedure offers a viable alternative for assessing low level of awareness. Future research would benefit from adopting process dissociation procedure as an effective and objective awareness measure.

From the perspective of L2 pedagogy, the present study provides an insight into how L2 stress patterns may be taught and learnt. The possibility of learning L2 stress patterns implicitly offers an alternative paradigm to explicit teaching and lends support to teaching methods which assume that learners can extract linguistic knowledge through exposure without explicit instruction. However, the present study did not address whether implicit learning is superior to explicit learning for acquiring L2 stress patterns. Future research may aim at determining the relative effectiveness of explicit and implicit teaching and learning of the same set of stress rules and exploring their potential synergetic effects under different settings.

References

Altmann GTM, Dienes Z & Goode A. (1995). Modality independence of implicitly learned
grammatical knowledge. *Journal of Experimental Psychology: Learning, Memory
and Cognition,* 21, 899-912.

Archibald J. (1997) The acquisition of English stress by speakers of nonaccentual languages:
Lexical storage versus computation of stress. *Linguistics* 35: 167-181.

Baars BJ. (2003) How brain reveals mind: Neuoimaging supports the central role of
conscious experience. *Journal of Consciousness Studies* 10: 100-114.

Bailey T, Plunkett K & Scarpe E. (1999) A cross-linguistic study in learning prosodic
rhythms: Rules, constraints, and similarity. *Language and Speech* 42: 1-38.

Bauer RS, Benedict PK. (1997) *Modern Cantonese Phonology*. Berlin: Mouton de Gruyter.

Beckman ME. (1986) *Stress and Non-Stress Accent.* Dordrecht: Foris

Bell A. (1977) Accent placement and perception of prominence in rhythmic structures. In:
Hyman L (ed) *Studies in stress and accent: Southern California Occasional Papers in
Linguistics, 4.* Los Angeles: Dept. of Linguistics, University of Southern California,
1-13.

Berry DC & Broadbent D. (1984) On the relationship between task performance and
associated verbalisable knowledge. *Quarterly Journal of Experimental Psychology*
36: 209-231.

Bialystok E. (1978) The role of linguistic knowledge in second language use. *Studies in
Second Language Acquisition* 4: 89-98.

Bley-Vroman R. (1991) The logical problem of foreign language learning. *Linguistic
Analysis,* 20, 3–49.

Celce-Murcia M, Brinton D & Goodwin JM. (1996). *Teaching pronunciation: A reference
for teachers of English to speakers of other languages.* Cambridge: Cambridge

University Press.

Chao YR. (1980) Chinese tone and English stress. In: Waugh LR & VanSchooneveld CH (eds) *The Melody of Language.* Baltimore, MD: University Park Press, 41-44.

Cleeremans A, Destrebecqz A & Boyer M. (1998) Implicit learning: News from the front. *Trends in Cognitive Sciences* 2: 406-416.

Culter A. (1986) Phonological structure in speech recognition. *Phonology Yearbook* 3: 161-178.

Culter A & Carter DM. (1987) The predominence of strong initial syllables in English vocabulary. *Computer Speech & Language* 2: 133-142.

Curran T. (2001) Implicit learning revealed by the method of opposition. *Trends in Cognitive Sciences* 5: 503-504.

Curran T & Hintzman DL. (1995) Violations of the independence assumption in process dissociation. *Journal of Experimental Psychology: Learning Memory and Cognition,* 21, 531-547.

DeKeyser RM. (1998) Beyond focus on form: Cognitive perspectives on learning and practicing second language grammar. In: Doughty CJ & Williams J (eds) *Focus on form in second language acquisition.* New York: Cambridge University Press, 42-63.

Dell GS, Reed KD, Adams DR & Meyer AS. (2000) Speech errors, phonotactic constraints, and implicit learning: A study of the role of experience in language production. *Journal of Experimental Psychology: Learning Memory, and Cognition* 26: 1355-1367.

Destrebecqz A & Cleeremans A. (2001) Can sequence learning be implicit? New evidence with the process dissociation procedure. *Psychonomic Bulletin & Review* 8: 343-350.

Dienes Z & Berry DC. (1997) Implicit learning: Below the subjective threshold. *Psychonomic Bulletin and Review* 4: 3-23.

Dunn JC & Kirsner K. (1989) Implicit memory: task or process? In Lewandowsky, S. *et al.* (Eds) *Implicit Memory: Theoretical Issues*, pp. 17–31, Erlbaum.

Dutoit T, Pagel N, Pierret N, Bataille O & Vrecken Vd. (1996) The MBROLA project: Towards a set of high-quality speech synthesizers free of use for non-commercial purposes. *Proceedings of ICSLP'96, Philadelphia* 3.

Ellis NC. (2002) Frequency effects in language processing: A review with implications for theories of implicit and explicit language acquisition. SSLA, 24, 143–188.

Ellis R. (2004) The definition and measurement of L2 explicit knowledge. *Language Learning, 54, 227–275.*

Ellis N. (2005) At the interface: Dynamic interactions of implicit and explicit language knowledge. *Studies in Second Language Acquisition* 27: 305-352.

Enríquez EV, Casado C & Santos A. (1989) La percepción del acento en español. *Lingüística Española Actual* 11: 241-269.

Face T. (2000). The role of syllable weight in the perception of Spanish stress. In C. Héctor, H. Elena, M.-F. Alfonso & J. Thomas (Eds.), *Hispanic Linguistics at the Turn of the Millennium* (pp. 1-13). Sommerville, MA: Cascadilla.

Face T. (2005). Syllable Weight and the Perception of Spanish Stress Placement by Second Language Learners. *Journal of Language and Learning, 3(1), 90-103.*

Francis AP, Schmidt GL, Carr TH & Clegg BA. (2009). Incidental learning of abstract rules for non-dominant word orders. *Psychological Research*, 73, 60-74.

Fok-Chan YY. (1974) *A Perceptual Study of Tones in Cantonese.* Hong Kong: University of Hong Kong, Center of Asian Studies.

Gilbert J. (1994) Intonation: A navigation guide for the listener. *Pronunciation Pedagogy and*

Theory: New views, New Perspectives, TESOL Alexandria: 36-48.

Goldrick M. (2004) Phonological featurs and phonotactic constraints in speech production. *Journal of Memory & Language* 51: 586-603.

Gomez RL, & Gerken L. (1999). Artificial grammar learning by 1-year-olds leads to specific and abstract knowledge. *Cognition,* 70, 109-135.

Haider H, Eichler A & Lange T. (2010) An old problem: How can we distinguish between conscious and unconscious knowledge acquired in an implicit learning task? *Consciousness and Cognition*.

Hama M & Leow RP. (2010). Learning without awareness revisited: Extending Williams (2005). *Studies in Second Language Acquisition,* 32, 465-491.

Hammond M. (1999) *The phonology of English: a prosodic optimality-theoretic approach*. Oxford: Oxford University Press

Harris J. (1991). With Respect to Metrical Constituents in Spanish. In H. Campos & F. Martínez-Gil (Eds.), *Current Studies in Spanish Linguistics*. Washington: Georgetown University Press.

Harris J. (1992) *Spanish stress: the extrametricality issue*. Bloomington: Indiana University Linguistics Club.

Hayes B. (1995) *Metrical stress theory: principles and case studies*. Chicago: University of Chicago Press.

Hualde JI. (2005) *The sounds of Spanish*. Cambridge: Cambridge University Press

Hulstijn JH. (2003) Incidental and intentional learning. In: Doughty C & Long MH (eds) *Handbook of second language acquisition.* Oxford: Blackwell, 349-381.

Hulstijn JH. (2005). Theoretical and Empirical Issues in the Study of Implicit and Explicit Second-language Learning. *Studies in Second Language Acquisition,* 27, 129-140

Jacoby LL. (1991) A process dissociation framework: Separating automatic from intentional

uses of memory. *Journal of Memory & Language* 30: 513-541.

Jacoby LL, Toth JP, & Yonelinas AP. (1993) Separating conscious and unconscious influences of memory: Measuring recollection. *Journal of Experimental Psychology: General*, 122, 139-154

Juff A. (1990) Tone, syllable structure and interlanguage phonology: Chinese learners' stress errors. *International Review of Applied Linguistics* 28: 99-118.

Kirkham NZ, Slemmer JA & Johnson SP. (2002) Visual statistical learning in infancy: Evidence of a domain general learning mechanism. *Cognition* 83: B35-B42.

Krashen SD. (1981) *Second language acquisition and second language learning,* London: Pergamon Press.

Lai WWs, Wang D, Yan N, Chan V & Zhang, L. (2011). Influence of English donor word stress on tonal assignment in Cantonese loanwords—an acoustic account. *The 17th International Congress of Phonetic Sciences*.

Leow RP. (2000) A study of the role of awareness in foreign language behaviour: Aware versus unaware learners. *Studies in Second Language Acquisition* 22: 557-584.

Leow RP & Bowles M. (2005) Attention and awareness in SLA. In: Sanz C (ed) *Mind and context in adult second language acquisition.* Washington, DC: Georgetown University Press.

Leung J & Williams JN. (2011). The Implicit Learning of Mappings between Forms and Contextually-Derived Meanings. *Studies in Second Language Acquisition,* 33(1), 33-55.

Lewicki P, Hill T & Bizot E. (1988) Acquisition of procedural knowledge about a pattern of stimuli that cannot be articulated. *Cognitive Psychology* 20: 24-37.

Lord G. (2004). The relationship between L2 perception and L2 production: The case of Spanish stress. Unpublished manuscript.

Lord G. (2007). The role of the lexicon in learning second language stress patterns. *Applied Language Learning,* 17, 1-14.

Luke KK. (2000) Phonological re-interpretation: the assignment of Cantonese tones to English words. Paper presented at the *9th International Conference on Chinese Linguistics*, Singapore, June 2000.

Nunan, D. (1991). *Language Teaching Methodology*. London: Prentice Hall International.

Onishi K, Chambers K & Fisher C. (2002) Learning phonotactic constraints from brief auditory experience. *Cognition* 83: B13-B23.

Peperkamp S & Dupoux E. (2002) A typological study of stress 'deafness'. In: Gussenhoven C & Warner N (eds) *Laboratory Phonology.* Berlin: Mouton de Gruyter, 203-240.

Perruchet P. (2008) Implicit learning. In: Byrne J (ed) *Learning and memory: A comprehensive reference: Vol. 2. Cognitive psychology of memory.* Oxford: Elsevier, 597-621.

Perruchet P & Pacton S. (2006) Implicit learning and statistical learning: one phenomenon, two approaches. *Trends in Cognitive Sciences* 10: 233-238.

Plante E, Bahl M, Vance R & Gerken LA. (2010) Children with specific language impairment show rapid, implicit learning of stress assignment rules. *Journal of Communication Disorders* 43: 397-406.

Reber AS. (1967) Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behaviour* 6: 855-863.

Reber AS. (1993) *Implicit learning and tacit knowledge,* New York: Oxford University Press.

Reber AS. & Allen R. (1978) Analogic abstraction strategies in synthetic grammar learning: A functionalist interpretation. *Cogntion* 6: 189-221.

Reber, AS. & Allen, R. (2000) Individual differences in implicit learning: Implications for the evolution of consciousness. In R. G. Kunzendorf & B. Wallace (Eds.), *Individual*

differences in conscious experience: Advances in consciousness research, Vol. 20, pp. 227–247. Amsterdam: Benjamins.

Rebuschat P & Hamrick P. (2012) How implicit is statistical learning? In: Rebuschat P & Williams JN (eds) *Statistical learning and language acquisition.* Berlin: Mouton de Gruyter.

Rebuschat P & Williams JN. (2012). Implicit and explicit knowledge in second language acquisition. *Applied Psycholinguistics.* 33(4), 829-56

Robinson P. (2005). Cognitive abilities, chunk-strength, and frequency effects in implicit artificial grammar and incidental L2 learning: Replications of Reber, Walkenfeld, & Hernstadt (1991) and Knowlton & Squire (1996) and their relevance for SLA. *Studies in Second Language Acquisition,* 27, 235-268.

Saffran JR. (2001) The use of predictive dependencies in language learning. *Journal of Memory and Language* 44.

Saffran JR, Johnson EK, Aslin RN & Newport EL. (1999) Statistical learning of tone sequences by human infants and adults. *Cognition* 70: 27-52.

Saffran JR, Newport EL & Aslin RN. (1996) Word segmentation: The role of distributional cues. *Journal of Memory and Language* 35: 606-621.

Saalfeld A. (2012) Teaching L2 Spanish stress. *Foreign Language Annals,* 45, 283-303.

Scott R & Dienes Z. (2008) The conscious, the unconscious, and familiarity. *Journal of Experimental Psychology: Learning Memory, and Cognition* 34: 1264-1288.

Seferoglu G. (2005). Improving students' pronunciation through accent reduction software. *British Journal of Educational Technology,* 36, 303-316

Shanks DR. (2005) Implicit learning. In: Lambert K & Goldstone R (eds) *Handbook of cognition.* London: Sage, 202-220.

Shanks DR & St. John MF. (1994) Characteristics of dissociable human learning system.

Behavioral and Brain Sciences 17: 367-447.

Sharwood Smith M. A. (1981) Consciousness-raising and the second language learner.

    Applied Linguistics 2: 159-169.

Trubetzkoy NS. (1969) *Principles of phonology,* Berkeley: University of California Press.

Wang Q. (2008) L2 stress perception: The reliance on different acoustic cues. *Proceedings of*

    the 4th International Conference on Speech Prosody. Campinas, Brazil, 635-638.

Williams JN. (2004) Implicit learning of form-meaning connections. In: VanPatten B,

    William JN, Rott S & Overstreet M (eds) *Form meaning connections in second*

    language acquisition. Mahwah, NJ: Erlbaum.

Williams JN. (2005) Learning without awareness. *Studies in Second Language Acquisition*

    27: 269-304.

Williams JN. (2009) Implict learning in second language acquisition. In: Williams CR &

    Bhatia TK (eds) *The New Handbook of Second Language Acquisition.* Emerald Group

    Publishing Limited, 319-355.

Zhang HN. (1972) *Xianggang Yueyu Yufa de Yanjiu [Cantonese as Spoken in Hong Kong].*

    Hong Kong: The Chinese University of Hong Kong.