THE ROLE OF PRIOR KNOWLEDGE IN SECOND-LANGAUGE LEARNERS' OVERNIGHT CONSOLIDATION OF CANTONESE TONES

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ABSTRACT

This study examines the role of prior linguistic knowledge in the sleep-mediated memory consolidation of lexical ones. Memory consolidation is beneficial in learning new sounds in a second language. And new information consistent with the existing knowledge is consolidated better than that which is not during sleep. What remains unclear from the research is whether prior knowledge from a native language influences the overnight consolidation of lexical tones. The study adopts an overnight design, using two contrasts of Cantonese contour and level tones, for two perceptual learning experiments conducted separately on Mandarin and English-speaking learners. The results indicate that Mandarin-speaking participants successfully consolidated novel words contrasting in contour tones (but not in level tones) thanks to their prior knowledge of contour tones. Without prior knowledge of tones, English-speaking L2 learners did not show a difference in consolidating tones. The findings suggest a beneficial role of prior knowledge in overnight consolidation.

Keywords: Lexical tones, memory consolidation, prior knowledge, perceptual learning, Cantonese.

1. INTRODUCTION

While adult learners find it challenging to learn novel sounds from second languages (L2), sleep is well known for facilitating L2 learning through *memory consolidation* [1]. By focusing on *lexical tones* (pitch variation that signals word identity), this study investigated sleep-mediated memory consolidation (i.e., overnight consolidation). It examined the role of *prior knowledge* in the consolidation of novel Cantonese tonal contrasts by Mandarin-speaking participants (and English-speaking controls).

Accumulating evidence has demonstrated that overnight sleep, especially right after training, offers the advantage of transforming newly learned linguistic knowledge into stabilized long-term memory [2]–[4]. What remains less clear is why some linguistic information is often prioritized for consolidation [5], [6]. Previous studies proposed an effect of prior knowledge (i.e., schema) on memory consolidation, which suggests that new information consistent with the existing knowledge is encoded more strongly and then consolidated more rapidly than that which is not [7]–[9]. The beneficial effect of prior *linguistic* knowledge, that is, knowledge of familiar sounds/words in the native language (L1), on memory consolidation was found for L2 phonological and lexical learning [10], [11].

Different from schema studies in which prior knowledge was manipulated through an encoding or training phase [7], this paper aims to examine the effect of prior knowledge from L1 on the overnight consolidation of lexical tones. Lexical tones are used to contrast segmentally identical words (/si 55/ 'silk' (Tone 1 (T1)), /si 25/ 'history' (T2), /si 33/ 'to try' (T3), /si 21/ 'time' (T4), /si 23/ 'city' (T5), and /si 22/ 'matter' (T6)), for instance, in Cantonese [12]. Recent studies investigated sleep-mediated consolidation in Cantonese tone learning by Mandarin-speaking participants. The findings suggested that overnight sleep after evening training facilitated the stabilization of newly learned tonal representations through memory consolidation [13], [14].

It is well established that an individual's prior knowledge of lexical tones impacts how they learn lexical tones. Depending on L1 experience (e.g., tone or non-tone language), L2 learners may learn certain tones well but learn others poorly [15]–[17]. For instance, prior work on tone perception and learning found that Mandarin-speaking participants showed a different pattern in learning Cantonese *contour and level tones* [18], [19]. Mandarin listeners encode pitch lexically in their contour-tone system (/pa 55/ 'eight' T1, /pa 35/ 'to pull out' T2, /pa 214/ 'to hold' T3, /pa 51/ 'father' T4). They found it easier learning to differentiate contour-level tones (a low-rising tone, /23/ vs. a low-level tone, /33/) than level-level tones (a mid-level tone, /33/ vs. a low-level tone, /22/) as Mandarin does not contrast in level tones. English-speaking participants did not consistently use pitch to encode lexical meanings in their L1 and did not show such a difference in their learning of tonal contrasts. However, it remains unclear whether learners' prior linguistic knowledge, for instance, Mandarin listeners' familiarity with contour tones, will benefit its consolidation over level tones after an overnight interval. Cantonese contour and level tones are a good case for testing the effect of prior knowledge on tonal consolidation.

2. EXPERIMENT 1

2.1. Participants

Forty-six Mandarin-speaking participants (age range: 19-33 years; 11 males) were recruited from a university in Hong Kong. The participants were pre-screened to ensure: 1) they were native Mandarin speakers who do not speak Southern Chinese dialects which may contrast in level tones; 2) they had minimal exposure to Cantonese with their length of residence in Hong Kong less than 1 year; (3) they had no more than five years of professional music lessons. None of the participants reported a history of hearing impairment or neurological disorders. Participants maintained a regular sleep pattern with at least 6 hours of sleep time in the past month. The participants provided written informed consent and received monetary compensation for their participation.

2.2. Materials

The auditory stimuli are two sets of Cantonese monosyllabic words carrying different tone types: 1) **contour-level tonal contrast** (low-rising contour tone T5 /23/ vs. low-level tone T6 /22/; henceforth, contour tones), carried by two base syllables [ji] and [fan]; 2) **level-level tonal contrast** (mid-level tone T3 /33/ vs. low-level tone T6 /22/; henceforth, level tones), carried by two base syllables [jau] and [fu], as illustrated in Fig. 1. The eight tone-words had a similar syllable frequency and pronounceability based on a norming study [15]. A male native speaker of Hong Kong Cantonese who can clearly distinguish the six Cantonese tones recorded the stimuli. As seen in Fig. 1, the two tones in the contour tone set are similar in pitch height (M_{T5} = 103Hz, M_{T6} = 105Hz), but they differ only in pitch contour (T5-a rising contour and T6-a level contour). In contrast, the two tones in the level tone set differ in pitch height (M_{T3} = 114Hz, M_{T6} = 103Hz), but they both have stabilized pitch as level tones. The stimuli were normalized in duration (500 ms) and intensity (70 dB).

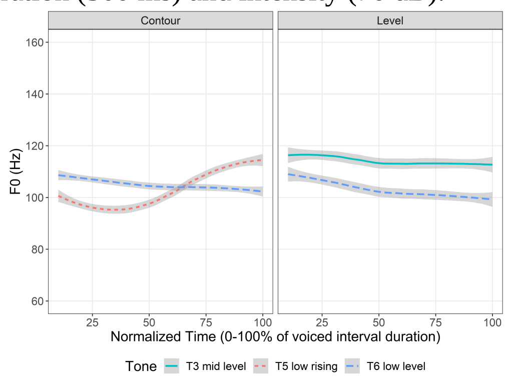

Figure 1: F0 track of a Cantonese contour-level tonal contrast (left) and a level-level tonal contrast (right) produced by a male native speaker.

There are 40 tokens (2 tones x 2 syllables x 2 sets x 5 exemplars). The eight novel words contrasting in tones, with a similar syllable frequency and pronounceability based on a norming study, were used in a novel word learning task. To minimize the influence of the Mandarin lexicon, each auditory (tone-)word will be paired with a novel object from the Novel Object and Unusual Name (NOUN) database [20]. The same word-object pairings will be used for all participants through training and tests in each experiment.

2.3. Procedure

As illustrated in Fig. 2, participants were asked to complete two consecutive experiment sessions (Day 1 and 2) with a 12-hour overnight interval. Participants' alertness levels were assessed at the beginning of each session via Stanford Sleepiness Scale (SSS) [21] to control for the time-of-day effect. On the **evening** of Day 1 (i.e., 8-10 PM), the participants went through a training in which they were instructed to learn the association between an auditory word and novel objects through feedback ("Correct" or "Incorrect"). On each trial, participants first heard an auditory word, and then they saw a pair of two novel objects on each side of the screen. Their task was to press the left or right key to choose the correct object corresponding to the word. The word pair contrasted in the level tones (T3-6) or the contour tones (T5-6). The training adopted a blocked design that each block only contained one syllable, and two syllables alternated across blocks. In total, there were six blocks (2 syllables x 3 blocks) and 40 trials (2 tones x 5 tokens x 4 repetitions) within each block.

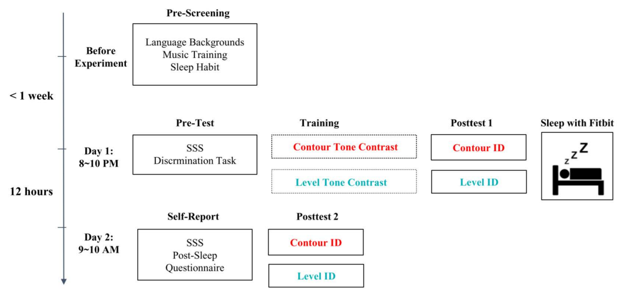

Figure 2: Experiment tasks and procedure.

Immediately following the training, participants completed the first set of word identification (ID) tests in the Posttest 1. There was no feedback in the test, and participants needed to respond when they saw two objects on the screen (1000 ms as time-out time). Participants were given 20 practice trials before the test. The ID test contains 80 trials (2 syllables x 2 tones x 5 tokens x 4 repetitions).

After the Day 1 session, participants went home to sleep wearing actigraphy (i.e., Fitbit). On the **morning** of Day 2 (i.e., after 12 hours), participants returned for another set of word identification tests in the Posttest 2, which was identical to Posttest 1. They were also asked to complete a post-sleep questionnaire, reporting their subjective estimation of sleep last night. The experiment was conducted via the Paradigm software, Perception Research Systems, Inc. The experiments lasted for around 1 hour (i.e., a 30-min training and a 20-min ID posttest) on Day 1 and around 20 minutes on Day 2. The order of the two tonal contrasts was counterbalanced in separate sessions across the participants throughout the experiments.

2.4. Statistical analysis

To examine the effect of overnight consolidation (and training) on the tonal contrasts, mixed-effects logistic regression models were run on response accuracy (binary, 1 for correct and 0 for incorrect). The models were fitted in R using the lme4 package [22]. All models followed the backward-stepping procedure to determine a maximal random effects structure best justified by the data [23]. All categorical predictors were deviation coded (−0.5, 0.5) to test for the main effects. For training data, the first and last two blocks were coded as initial and outcome blocks to track participants' performance improvement. Block (initial vs. outcome; −0.5, 0.5) and tone (contour vs. level; −0.5, 0.5) were entered as fixed effects. For data of ID tests, session (posttest 1 vs. posttest2; −0.5, 0.5) and tone (contour vs. level; −0.5, 0.5) were entered as fixed effects.

2.5. Results

To assess whether training helped Mandarin-speaking participants learn tonal contrasts, a mixed-effects logistic model was performed on participants' response accuracy. Block and tone were entered as fixed effects, with by-participant intercept and slope, and by-trial intercept as random effects. Results of the model revealed a main effect of the block (β = 0.28, SE = 0.11, z = 2.55, p = .011) and tone (β = − 0.52, SE = 0.14, z = −3.57, p < .001), but no interaction between block and tone (β = 0.21, SE = 0.16, z = 1.33, p = .184). The findings suggests that Mandarin-speaking participants' accuracy improved in both tonal contrasts throughout the training, with higher accuracy in contour tones than level tones.

To examine the overnight sleep consolidation on tonal contrasts, session and tone were entered as fixed effects, with by-participant intercept and slope as random effects, in a mixed-effects model. Results showed a main effect of session (β = 0.20, SE = 0.05, z = 4.00, p < .001) and tone (β = −0.69, SE = 0.14, z = −5.26, p < .001). Crucially, they yielded a significant interaction between session and tone (β = −0.23, SE = 0.10, z = −2.30, p = .022). As illustrated in Fig. 3, post-hoc analyses showed that the effect of the session was significant in contour tones (β = 0.32, SE = 0.07, z = 4.04, p < .001). In contrast, the effect of the session was not significant in level tones (β = 0.09, SE = 0.06, z = 1.38, p = .169). The result of the tone effect indicates that contour tones were better identified than level tones after training (i.e., two posttests). The difficulty of learning level tones may have made them more vulnerable to interference than contour tones, so some participants exhibited declining performance for level tones over time [14].

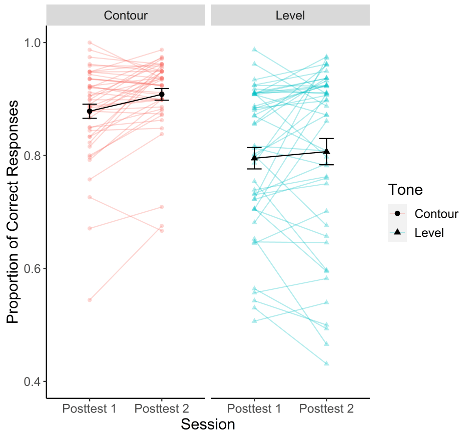

Figure 3: Mandarin-speaking participants' overnight change (Posttest 1 vs. 2) of the identification accuracy across the contour tones (left) and level tones (right) with by-participant data. Error bars indicate standard error.

The results suggest that Mandarin-speaking participants improved their accuracy in identifying novel words contrasting in contour tones, but not those contrasting in level tones, through overnight consolidation. The findings support the beneficial effect of prior knowledge on overnight consolidation. However, they do not rule out the possibility that contour tones are intrinsically better consolidated (and learned) than level tones, regardless of learners' prior knowledge. Thus, Experiment 2 examines whether Cantonese contour tones and level tones are consolidated to different degrees after an overnight interval for a control group of participants, that is, English speakers. English speakers do not have prior knowledge of lexical tones in their L1 and thus are NOT predicted to show the differential consolidation of contour and level tones.

3. EXPERIMENT 2

3.1. Participants and Methods

Twenty English-speaking participants (age range: 19-39 years; 10 males) were recruited in Hong Kong for this experiment. The participants were all native speakers of English (10 from the USA, 8 from the UK, and 2 from other English-speaking areas).

Importantly, they did not know any tone languages (e.g., Mandarin). The screening criteria (e.g., minimal exposure to Cantonese and regular sleep pattern, etc.) were identical to Mandarin-speaking participants. Experiment 2 was a replication of Experiment 1, so the procedure and statistical analyses were the same.

3.2. Results

For the model of training blocks among the English-speaking participants, block and tone were entered as fixed effects, with by-participant intercept and slope, and by-trial intercept as random effects. Results revealed a main effect of block (β = 0.29, SE = 0.12, z = 2.38, p = .017), but neither the main effect of tone (β = −0.30, SE = 0.17, z = −1.73, p = .09) nor an interaction between tone and block (β = −0.17, SE = 0.19, z = −0.89, p = .37). The findings suggest that English-speaking participants' accuracy improved in both tonal contrasts throughout the training. However, there was no difference between the two tonal contrasts.

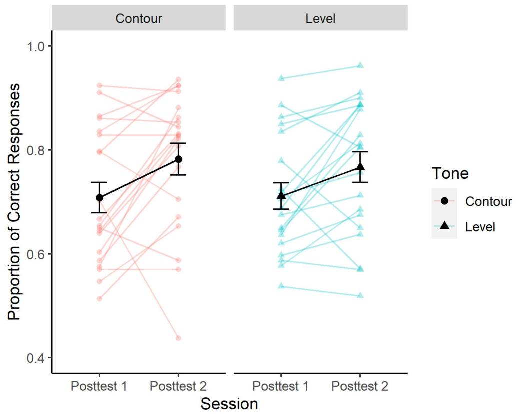

Figure 4: English-speaking participants' overnight change (Posttest 1 vs. 2) of the identification accuracy across the contour tones (left) and level tones (right) with by-participant data. Error bars indicate standard error.

For the model of ID tests among the English-speaking participants, session and tone were entered as fixed effects, with by-participant intercept and slope as random effects. The results, as illustrated in Fig. 4, showed the main effect of the session (β = 0.41, SE = 0.13, z = 3.27, p = .001) but not the main effect of tone (β = −0.04, SE = 0.06, z = −0.61, p = .54). Unlike the results of Experiment 1, they did not yield a significant interaction between session and tone (β = −0.09, SE = 0.12, z = −0.77, p = .44). The findings suggest that, unlike Mandarin-speaking participants, their English counterparts learned both tonal contrasts similarly (e.g., a similar accuracy in two posttests). Crucially, they improved their accuracy in identifying novel words contrasting contour and level tones, without a difference, through overnight consolidation.

4. DISCUSSION

This study investigated the effect of prior knowledge on L2 learners' overnight consolidation of Cantonese contour and level tones [14]. The results showed that Mandarin-speaking participants consolidated contour tones to a larger degree than level tones after an overnight interval because of their familiarity with contour tones in their L1. In contrast, a control group of participants who did not have prior knowledge of lexical tones, that is, English-speaking participants, did not show such a pattern with both tonal contrasts consolidated in a similar degree.

Consistent with prior work on tone perception and learning [18], [19], the findings about tonal contrasts indicate that contour tones were better learned than level tones among Mandarin-speaking participants who used pitch contour to distinguish native tones, but not among English-speaking participants. Importantly, the findings about overnight change suggest a beneficial role of prior knowledge with schema-related memories (i.e., contour tones) recalled better than non-schema memories (i.e., level tones) after sleep among Mandarin-speaking participants alone. Supporting the schema effect on memory consolidation [7], [10], the findings align with the model proposed by Lewis and Durrant [24], which accounts for the beneficial role of prior knowledge. The (selective) memory consolidation model states that new and old memories are replayed simultaneously during sleep, with information shared across new and old memories more strongly activated than that from only a single source.

The present findings imply that which types of tones are consolidated to a larger degree depends on learners' prior knowledge (e.g., familiarity with lexical tones in L1). They thus advanced our understanding of the mechanisms of how sleep supports successful L2 tone learning through memory consolidation. They may also facilitate tailored pedagogical applications in various educational settings. For instance, the findings enable researchers to tailor the training paradigm through the technique of re-exposure during sleep (i.e., Targeted Memory Reactivation-TMR) [25], according to L2 learners' language backgrounds. In closing, it is necessary to acknowledge the limitation of this study. A limited number of English-speaking participants, who do not have prior knowledge of lexical tones, may not be the best control group. Future studies should include a control group with a comparable number of participants who have prior knowledge of level tones (but not contour tones) in their L1 to investigate further the effect of prior knowledge on overnight consolidation of lexical tones in a different scenario.

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