<table>
<thead>
<tr>
<th>Title</th>
<th>Cantonese time-compressed speech test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Lau, Tsz-lam; 劉紫霖</td>
</tr>
<tr>
<td>Citation</td>
<td>Lau, T. [劉紫霖]. (2009). Cantonese time-compressed speech test: test creation and normative values for young adults. (Thesis). University of Hong Kong, Pokfulam, Hong Kong SAR.</td>
</tr>
<tr>
<td>Issued Date</td>
<td>2009</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/10722/173673">http://hdl.handle.net/10722/173673</a></td>
</tr>
<tr>
<td>Rights</td>
<td>This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.; The author retains all proprietary rights, (such as patent rights) and the right to use in future works.</td>
</tr>
</tbody>
</table>
Cantonese Time-Compressed Speech Test:
Test Creation and Normative Values for Young Adults

LAU Tsz Lam

A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), the University of Hong Kong, June 30, 2009.
Abstract

Few Cantonese assessment tools for (central) auditory processing disorders [(C)APD] are presently available. This study aimed at creating a time-compressed speech test in Cantonese and developing the normative data for this population. Fifty young adults participated in the test. Three lists of bisyllabic words with 0%, 45% and 65% time compression rates were presented to them. Over 95% correct word recognition scores at all three compression rates were found. Word recognition scores were very similar for 0% and 45% compression lists but a relatively large standard deviation and slight mean drop in performance were noted for the 65% compression list. There was no significant difference between left and right ears or between genders. These results were comparable to previous studies of time-compressed speech in other languages. From the findings, it was deduced that 45% is a more valid time compression rate for evaluating the auditory closure abilities of Cantonese-speaking individuals. It is concluded that the Cantonese time-compressed speech test may be clinically useful in the diagnosis of (C)APD in Cantonese clients.
Introduction

Definition of (central) auditory processing disorders

Speech perception and processing ability is a prerequisite for normal daily communication. However, processing of auditory signals appears to be a problem in individuals with (central) auditory processing disorder [(C)APD], who generally have difficulty in listening to degraded or competing signals, e.g., in noisy environments.

As the American Speech-Language-Hearing Association Technical Report (2005) stated, (central) auditory processing [(C)AP] is broadly defined as the efficiency and effectiveness of the central nervous system on the utilization of auditory information. Auditory processing involves skills in sound localization and lateralization; auditory discrimination; auditory pattern recognition; audition in temporal aspects; auditory performance in competing acoustic signals; and auditory performance with degraded acoustic signals (ASHA, 2005; Bellis, 2003; Chermak & Musiek, 1997). Difficulty in perceptual auditory processing indicated by deficits in one or more of these skills is referred to as (C)APD, which is not a result of problems in higher order language, cognitive or related factors (ASHA, 2005).

Types of (C)APD tests

Since people with normal peripheral hearing sensitivity cannot be excluded from having (C)AP difficulty, common hearing test procedures, e.g., pure-tone audiometry and tympanometry, cannot act as diagnostic tools; a battery of auditory tests is specifically designed to identify (C)APD. The battery of tests aims at examining the different central
processes stated above. Baran (2007) divided the tests into five categories, including dichotic speech tests, monaural low-redundancy speech tests, binaural interaction tests, auditory temporal processing and patterning tests, and electroacoustic and electrophysiologic measures. Tests generally comprise both non-verbal (e.g., tones, clicks and complex waveforms) and verbal stimuli (e.g., monosyllables, bi-syllables and sentences). Both behavioral and electrophysiologic measurements are equally important.

*Time-compressed speech test*

Time-compressed speech test is the most frequently used monotic CAPD test (Rabelo & Scochat, 2007). It is a low redundancy monaural test and some literature also regards it as a temporal processing test (e.g., ASHA, 2005; Rawool, 2007). Both extrinsic and intrinsic redundancy facilitates auditory processing. The former arises from multiple overlapping acoustic and linguistic cues (e.g., Liberman, Cooper, Shanweiler, & Studdert-Kennedy, 1967; Sanders & Goodrich, 1971), and the latter involves the anatomy and physiology of the various auditory pathways responsible for transmitting information across the central auditory nervous system (CANS) (Hall & Mueller, 1997). High extrinsic redundancy means the presence of more acoustic and linguistic cues in the auditory signals and high intrinsic redundancy is the adequate internal capacity of the system for auditory processing.

Time-compressed speech is formed by degrading the temporal aspect of the extrinsic redundancy of speech materials, such that the rate of speech is increased without distorting the intensity and frequency of signals (Krishnamurti, 2007). The stimuli put the listeners into
a condition of low extrinsic redundancy. Listeners with normal intrinsic redundancy are able to use their auditory closure skills to fill in the missing information in the degraded signals. On the contrary, those who have reduced intrinsic redundancy due to CANS dysfunction may exhibit remarkably poorer speech recognition performance, revealing auditory closure deficits (Krishnamurti, 2007). In addition to identifying deficits, the extent of auditory closure ability can be evaluated by manipulating the level of extrinsic redundancy (Chermak & Musiek, 1997), through varying the rate of time compression.

Apart from its contribution to the (C)APD population, other groups are expected to gain benefits. First, time-compressed speech performance aids understanding of the underlying problems or changes in auditory processing in aging populations (e.g., Gordon-Salant, Fitzgibbons, & Friedman, 2007). By the proper manipulation of the test materials, the effect of aging on auditory processing can be better evaluated. Second, as revealed by the adaptation to time-compressed speech noted in the study of Peelle and Wingfield (2005), time-compressed speech training might enhance one’s recognition of the speech stimuli despite no transfer of improvements to other compression conditions or degraded speech tasks yet found. The development of local time-compressed speech test acts as a bridge to the further exploration of these areas.

The amount of time compression is expressed as a compression rate in percentage terms, that is, the time frame the eliminated signal occupied compared to that of the original signal. Researchers have generally concluded that as the degree of time compression increases,
speech intelligibility decreases (Musiek, Baran, & Pinheiro, 1994; Wingfield & Nolan, 1980). A relatively steady fall in scores is noted from 0% to 60% time compression and particular difficulty is reported at 70% time compression and above (Wilson, Peece, Salamon, Sperry, & Bornstein, 1994).

Some studies have investigated the performance of normal hearing subjects on time-compressed speech (e.g., in English, Brazilian Portuguese), but there is a lack of comparison with individuals who have auditory processing difficulty (e.g., Beattie, 1986; Rabelo & Scochat, 2007). Wilson and his colleagues (1994), using Northwestern University Auditory Test number 6 word lists (NU-6), found normal hearing subjects had high word recognition scores at 45% compression rate but significantly lower scores at 65% compression rate, whereas remarkable difficulty was observed at 45% compression rate for (C)APD individuals. Based on such findings, Bellis (2003) suggested 45% time compression to be the standard value for clinical use in (C)APD assessment batteries.

Age-related performance on time-compressed speech stimuli has also been studied (e.g., Gordon-Salant, Fitzgibbons, & Friedman, 2007). These studies came to a consensus of a gradual decline in speech recognition with increasing age. Based on these findings, only young normal subjects would be selected in the present study. This is because at this age, the CANS is mature but has not yet entered the aging stage; in elderly individuals auditory processing performance in general tends to decline (Bellis, 2007).

Time-compressed speech materials developed are mainly monosyllabic words and
bisyllabic words, and Keith (2002) has recently developed a standardized English
time-compressed sentence test. He suggested the use of sentence stimuli because this could
better simulate a realistic daily hearing situation. However, repeating sentences as required in
the test causes extra memory load (Krishnamurti, 2007) and language load which may
confound the actual ability of the participants. The language load can especially mask over
the real performance abilities of individuals with language impairment and younger children
whose language development has not been completed. A (C)APD diagnostic test should
minimize the above confounding factors (Bellis, 2004), therefore sentence stimuli may not be
appropriate.

First language is an issue that is also a factor to consider when developing a
time-compressed speech test. It is found that in previous literature, bilingual speakers who
acquired English as a second language attained significant poorer English speech recognition
scores than the monolinguals (Von Hapsburg, Champlin, & Shetty, 2004). This indicated the
order of language acquisition could pose an effect on individual performance for
time-compressed speech recognition.

Lack of Cantonese (C)APD tests using verbal stimuli

In Hong Kong, only a few tests for (C)APD are available. Tests using nonverbal stimuli,
e.g., the Random Gap Detection test (Keith, 2000) and the Pitch Pattern Sequence test
(Pinheiro & Musiek, 1985), have had Cantonese instruction set versions created in recent
years (Tsang, 2003; Yim, 2003). However, local test tools using speech materials are rather
limited. The Cantonese Hearing In Noise Test (Wong & Soli, 2005) and the Cantonese Dichotic Digit Test (Fuente, McPherson, Chiang, & Tang, 2007) make use of sentence and digit materials, respectively, to identify speech reception performance with competing acoustic signals. Nevertheless, different dimensions of auditory processing abilities should be examined to yield a convincing diagnosis. More specific Cantonese test tools are yet to be developed.

**Nature of Cantonese**

Cantonese is a tonal dialect widely spoken in southern China region, mainly in Guangdong province. It is the official language in Hong Kong and Macau. Recent figures showed an estimated of 54.8 million native speakers of Cantonese worldwide (Gordon, 2005). Each monosyllabic character carries a meaning in Cantonese but most words are bisyllabic or polysyllabic in daily use. Bisyllabic words will be used in the present study since they are considered more meaningful than monosyllabic stimuli.

**Aim and hypotheses of the present study**

This research project aimed at developing a Cantonese time-compressed speech test, with 0%, 45% and 65% time compression rates, for the evaluation of auditory closure ability. Results at these three levels would illustrate the impact of increasing time compression on Cantonese speech intelligibility. Based on the previous literature (e.g., Bellis, 2003; Wilson et al., 1994), the most suitable time compression rate should be between 45% and 65%, these two percentages were thereby chosen for investigation. The test would mainly serve to give
more evidence in evaluating the auditory processing of Cantonese-speaking adults. It would also be applicable for evaluating central auditory changes in older populations.

The research questions addressed in this study were as follow:

(1) How were the results in the Cantonese time-compressed speech test similar or different from those obtained in English?

It was hypothesized that results of Cantonese time-compressed speech test would follow similar patterns as in English language data, which were decreasing word recognition scores with increasing compression rate and significant fall in performance at 65% compression condition.

(2) Which time compression rate will be more suitable for evaluating the auditory processing ability of Cantonese-speaking adults?

The hypothesis was that 45% time compression rate would be the most suitable value for this use. Cantonese speech stimuli at this compression rate are expected to show the difference between people with and without auditory processing difficulty as in English language studies.

**Method**

**Participants**

A total of 54 participants, 27 males and 27 females, were recruited in this study. They were mainly undergraduates in the Division of Speech and Hearing Sciences, the University of Hong Kong (n=38), and the rest (n=16) were recruited from the social circle of the author.
They were aged from 19 to 25 years and were all right handed. All participants were residents in Hong Kong and had received at least five years of secondary education. Their participation was on a voluntary basis. They had signed informed consent forms prior to data collection.

Participants needed to speak Cantonese as their first language for inclusion in the study. In the present study, first language was defined as the dominant language used at home during early childhood. Two female participants were excluded from the study since they did not fulfill the first language criteria. Participants also were required to have normal hearing thresholds in both ears for inclusion. Two male participants failed the pure-tone screening and thus did not continue the test. In total, 50 participants took part in the time-compressed speech research program, with a mean age of 21.5 for men (range=19-25 years, SD=1.53) and 21.6 for women (range=19-24 years, SD=1.19). 36 were Speech and Hearing Sciences undergraduates and 14 were not.

Stimuli

Three digital recordings of Cantonese bisyllabic words, Tracks 8, 9 and 10, from the Brigham Young University Cantonese speech audiometry CD (Conklin, 2007) were used. The stimuli were selected by the CD’s author according to frequency of use and familiarity and were spoken by a male native Cantonese talker. The three lists of words had been made psychometrically equivalent. Bisyllabic words were used, as Conklin explained, for the reason that Cantonese vocabulary items more often appear in this form than in a monosyllabic form.
Three lists of 48 words each were used. The original lists were established to be 50 words each, but due to production problems detected in two items of one list, these two items were removed. Two items in the other two lists were randomly selected and removed to equalize the number of items in all three lists. Adobe Audition 1.5 software was used to create time-compressed materials. One list was uncompressed, one list underwent 45% time compression and the third list underwent 65% time compression. A 1000 Hz calibration tone at 71dB SPL intensity level, equal to the average intensity of the speech materials, was produced for calibration purposes.

**Screening**

Participants were interviewed and received hearing screening. A case history was taken to exclude participants with a clinical history of auditory processing problems and/or whose first language was not Cantonese. Pure-tone audiometry was administered to establish bilateral air conduction thresholds, using a Madsen Itera II diagnostic audiometer. The inclusion criterion was hearing sensitivity equal or better than 20 dB HL at 500, 1000, 2000 and 4000 Hz (World Health Organization, 2006).

**Procedures**

The data collection was conducted at the audiology clinic of the Division of Speech and Hearing Sciences, the University of Hong Kong. Pure-tone audiometry and the Cantonese Time-compressed Speech Test took place in a double-walled, sound-attenuated booth. A Sony CD player model D-365 connected to a Madsen Itera II diagnostic audiometer delivered the
speech materials. Stimuli were presented monaurally at 40 dB HL through Telephonics TDH-39P headphones connected to the audiometer. Presentation order was randomized, with stimuli delivered initially to either the left or the right ear.

At the beginning of the test, participants were told to interrupt the test whenever they thought it was necessary, to minimize the effects of fatigue and lack of attention. The presentation order of stimuli was fixed to 0%, 45% and then 65% time compression rates. Specific instructions were given verbally before each condition. Participants were encouraged to guess when they were not sure about the answers. Their answers were online recorded on scoring forms, either correct or incorrect. The whole test duration was approximately 15 minutes.

The word recognition score was calculated as the number of correct answers divided by the total number of items in each list, expressed as a percentage. Each participant would thus have three word recognition percentage scores, one for each of the three word lists. Correct response would only be counted when both phonemes and lexical tones were correctly recalled.

**Data analysis**

Both descriptive and inferential statistics were used for data analysis. Raw scores for word recognition at 0%, 45% and 65% time compression rates included in an SPSS 14.0 spreadsheet. Descriptive measurement consisted of means, medians, ranges and standard deviations with reference to the word recognition scores. Inferential statistics were
implemented to detect any difference in word recognition performance across three compression rates, and any possible gender and ear effects. Non-parametric tests were applied owing to ceiling effects found for the time-compressed speech scores. The confidence interval was established as 95%, with the significance level ($\alpha$) set at .05 (5%).

Results

Three time compression conditions

Figure 1 illustrates the frequency distribution for correct word recognition (%) at each compression rate for all subjects. Percent correct word recognition in all three compression conditions generally pointed towards the maximum, with a majority of the subjects achieving high scores and with few subjects obtaining relatively lower scores. The data obtained were not normally distributed and a ceiling phenomenon was observed. Table 1 presents mean (%), median (%), range (%) and standard deviations of word recognition scores at the three compression rates. It shows mean word recognition percentages correct were over 95% in all three conditions. Comparable recognition performance was noted at 0% and 45% compression rates in all four descriptive measurements. The standard deviation (SD=1.61) was the smallest at 45% compression rate. At 65% compression rate, the mean word recognition score result (mean= 95.1%) was the lowest and both the standard deviation (SD=3.40) and range (range=14.6) were the greatest. Figure 2 illustrates the mean and standard deviation of word recognition scores (%) across 0%, 45% and 65% time compression rates. The change of mean word recognition performance across conditions of
increasing time compression was derived, illustrating a slight difficulty in word recognition at the highest compression rate, i.e., 65% compression.

![Figure 1. Frequency distribution of word recognition scores at 0%, 45% and 65% time compression rates](image)

**Table 1.** Mean (%), median (%), range (%) and standard deviation of word recognition scores at different time compression rates

<table>
<thead>
<tr>
<th>Time compression rates</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>98.0</td>
<td>97.9</td>
<td>6.25</td>
<td>1.73</td>
</tr>
<tr>
<td>45%</td>
<td>98.2</td>
<td>97.9</td>
<td>6.25</td>
<td>1.61</td>
</tr>
<tr>
<td>65%</td>
<td>95.1</td>
<td>95.8</td>
<td>14.6</td>
<td>3.40</td>
</tr>
</tbody>
</table>
A non-parametric Friedman test with repeated measure of 0%, 45% and 65% compression rates was employed to investigate the difference in correct recognition performance. Statistically significant difference was found \([H= 24.5, p<0.000]\). This suggested at least two conditions were different from the other. A *post hoc* Wilcoxon’s matched pairs test was further carried out for multiple paired comparisons. Comparison between 0% and 45% was found to have no significant difference \([p=.439]\) and significant
difference was present in 0% and 45% \( p<.000 \), as well as 0% and 65% paired comparisons \( p<.000 \).

**Gender effect**

Descriptive measures including mean (%) and standard deviations of word recognition scores for different genders at three compression rates are presented in Table 2. Figure 3 shows the trend of mean (%) of word recognition scores for different genders across the three compression conditions.

Table 2. *Mean (%) and standard deviation of word recognition scores between genders at different time compression rates*

<table>
<thead>
<tr>
<th>Time compression rates (%)</th>
<th>0%</th>
<th>45%</th>
<th>65%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>98.3</td>
<td>1.80</td>
<td>98.4</td>
</tr>
<tr>
<td>Female</td>
<td>97.6</td>
<td>1.63</td>
<td>98.2</td>
</tr>
</tbody>
</table>
A Kruskal-Wallis one-way independent-sample ANOVA was conducted to evaluate gender effects on the recognition of time-compressed speech stimuli. The time compression rates and gender acted as the fixed variables and the word recognition percentage was the dependent variable. The difference between the word recognition score results for males and females was not statistically significant for 0% \( p = .097 \), 45% \( p = .675 \) and 65% \( p = .111 \) compression conditions.

**Ear effect**

Table 3 shows mean (%) and standard deviations of word recognition scores for the left and right ears at the three time-compressed signal conditions. Figure 4 illustrates the mean (%)
word recognition scores at different presentation ears across the three conditions.

Table 3. *Mean (%) and standard deviation of time-compressed word recognition scores with signals presented to left and right ears*

<table>
<thead>
<tr>
<th>Time compression rate (%)</th>
<th>Left ear</th>
<th>Right ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>97.8 1.46</td>
<td>98.3 1.97</td>
</tr>
<tr>
<td>45%</td>
<td>98.1 1.58</td>
<td>98.5 1.65</td>
</tr>
<tr>
<td>65%</td>
<td>95.3 3.48</td>
<td>95.0 3.40</td>
</tr>
</tbody>
</table>

*Figure 4. Mean (%) and standard deviation of word recognition scores at different presentation ears across the three time compression rates*
Another Kruskal-Wallis one-way independent-sample ANOVA was used to analyze ear effects on time-compressed speech recognition. The time compression rates and presentation ears were set as the independent variables and the word recognition percentage was the dependent variable. No statistically significant difference was found between the presentation ears in all three level of time compression conditions, i.e., 0% \(p=1.93\), 45% \(p=1.14\) and 65% \(p=.083\).

**Discussion**

The purpose of the present study was to create a Cantonese version of a time-compressed speech test and develop the relevant normative data for young adults. The study investigated the effect of time compression on word recognition, as well as gender and ear effects. Comparisons of results of the local time-compressed speech test with foreign studies would be made and the most suitable time compression rate for local clinical use would be derived.

*Across increasing time compression rates*

The results indicated 0% and 45% compression imposed relatively little adverse impact on word recognition. On the contrary, a more apparent threat to word recognition was present at 65% compression. This supported the previously stated hypothesis that Cantonese word recognition scores would decrease with increasing time compression rate and was consistent with previous findings in foreign languages, i.e., English (e.g., Beattie, 1986; Wilson et al., 1994) and Brazilian Portuguese (Rabelo, & Schochat, 2007). The findings could well be
explained by the fact that as the degree of time compression increases, the extrinsic redundancy of acoustic signals is gradually reduced, thus leading to word recognition difficulty. Similar patterns were observed in other languages, implying the phenomenon is not language specific.

The difficulty at 65% compression showed that this degree of compression of the acoustic message was high enough to challenge subjects’ acoustic closure ability, in this group of young adults with normal auditory processing ability. Since acoustic signals were temporally degraded to a significant extent, with one’s inability to “fill in” missing information, the chance of activating an incorrect lexical representation increased. Mapping auditory messages with non-target words was more prone to occur, resulting in a failure of word recognition. The research results agreed with previous English and Brazilian Portuguese studies (Wilson et al., 1994; Rabelo, & Schochat, 2007), which reported time compression rates above 60% imposed the largest negative effect on speech recognition.

In the present study, word recognition scores at 45% compression gave the smallest standard deviation, reflecting that this compression list was the most stable of all three lists. On the contrary, 65% compression rate gave the highest standard deviation. If this compression rate was used clinically, such as for diagnostic purpose, it was likely that the false-positive rate would be high. Therefore, 65% compression rate would be the least suitable for evaluating ones’ auditory closure ability due to its instability. Although 0% and 45% compression conditions derived comparable word recognition results, 45% compression
rate is preferred in evaluating auditory closure abilities. This is because individuals with
auditory processing deficits are expected to give remarkably lower recognition scores on
degraded auditory signals than those who have normal auditory processing ability; the higher
compression condition can reveal a more obvious performance difference between the two
groups. The compression value, 45%, would fulfill this statement better than 0%. These
suggest 45% compression rate would be preferred over the other two values for clinical use.

**Gender effect**

No significant difference in word recognition performance between genders was
obtained. This showed gender did not play a role in the recognition of time-compressed
words. No previous studies investigated a gender effect on time-compressed speech
recognition and thus no direct comparisons could be made. Nevertheless, other studies on
local (C)APD test tools including the Cantonese Dichotic Digit Test (Fuente et al., 2007) and
the Random Gap Detection Test (Yim, 2003), as in our study, derived negligible gender
difference. These implied that gender was not a factor, or only a very minor factor, in
determining ones’ auditory processing skills.

**Ear effect**

No significant difference in word recognition scores between the left and right
presentation ears was found. This indicated monotic stimulation at any one side yielded
negligible difference to the contralateral ear. This was consistent with previous findings using
time-compressed speech stimuli, either words or sentences (Keith, 2002; Rabelo, & Schochat,
2007). The test stimuli used were linguistic in nature and a right ear advantage might be presumed due to the language-dominant left hemisphere in right-handedness adult subjects. Despite this, the pre-assumption was counterbalanced by the structural features in the cortex of the central auditory nervous system. In the cortex, the corpus callosum, which connects left and right cerebral hemispheres, allows exchange of auditory information on both sides (Bamiou, Musiek, & Luxon, 2001). In other words, monaural auditory signals can activate both the ipsilaterial and contralateral pathways of the auditory nervous system. Even when signals are presented at the left ear, the rapid exchange of auditory information from the right to left hemisphere ensures immediate processing and interpretation of information, and thus neutralizes the right ear advantage. This results in negligible ear effect on recognition of monaural linguistic information found in the present study.

**Strategy used to map sound into meaning**

Apart from the above findings, the error pattern of failed items in the test was observed and briefly explored. The major type of error patterns was observed to be phonetically similar real words or non-words. For example, the item ‘後生 /hɔu6 saŋ1/’ (meaning ‘young’ in English) was recognized as real words ‘學生 [hɔk9 saŋ1]’ (student); ‘一個 /jut7 ko3/’ (one piece) was interpreted as ‘不過 [pet7 kwo3]’ (but) and ‘一次 /jet7 tsʰi3/’ (once) became ‘一致 [jet7 tsi3]’ (same); non-word examples included ‘完成 /jyn4 sin3/’ (finish) recognized as [miŋ4 sin3] and ‘更加 /kan3 ka1/’ (even more) as [fən3 kau1].

The phonetically alike answers indicated that the mapping of sound into meaning relied
heavily on phonological context. It could thus be deduced that targets with less phonetically proximal real-word neighbours were more likely to recall correctly. In addition, the real words incorrectly given were phonetically more similar to the targets than the non-words, despite mostly correct recall of tones. This showed ones’ established lexical representation played a part in facilitating sound identification, when acoustic information was degraded. The highly accurate recall of the unique tones characteristic of Cantonese, reflected tonal information was not markedly altered after time compression. It was likely that tones in Cantonese might have supplemented important phonological cues to word recognition specific to this language.

Implications

The study findings showed that word intelligibility decreased with increasing time compression rate. Significant recognition difficulty appeared at the 65% compression condition. The Cantonese test results followed similar patterns as in foreign languages. No gender effect or ear effect was found significant in the recognition of time-compressed speech materials.

As previously discussed, among the three compression rates, 45% is the most appropriate value to evaluate the auditory processing ability of (C)APD populations. This matches with Bellis’s recommendation (2003) which advised a 45% compression rate as the standard value for clinical use.

The Cantonese time-compressed speech test can serve to evaluate auditory closure
abilities. The test involves simple procedures and easily understood instructions. Little training is required for administrators to conduct the test and score the results. Moreover, it only takes approximately five minutes to complete the recall of words in one list. The test’s relatively minimal attention and comprehension loads ensure the client’s actual auditory processing abilities can be tested.

The Cantonese time-compressed speech test can be included in a local (C)APD test battery. As Baran (2007) advocated, a test battery should be applied so as to gather adequate information on client’s component auditory processing abilities for making accurate diagnosis. It is hoped that such a test battery will serve to provide a more comprehensive picture of auditory processing skills for the Cantonese-speaking population. Besides the (C)APD group, elderly individuals have also demonstrated varied degrees of auditory processing difficulty (Bellis, 2007). The test can also be applied to the local elderly population to aid understanding of age effects on auditory processing.

In addition to its value in evaluating auditory processing abilities, time-compressed speech training has recently been proposed and a learning adaptation effect with such stimuli was observed (Peelle, & Wingfield, 2005). Such training may be of clinical value in enhancing a client’s recognition of degraded or competing speech signals in daily life. The present development of Cantonese time-compressed speech materials and normative data can possibly act as the basis for investigation in this area.
Limitations of the present study

Certain limitations were noted in our study. As Baran stated (2007), tests included in the (C)APD test battery should be appropriate to the client’s age, cognitive functioning, language abilities, motivation, and potential fatigability during test administration. In the present study, an intelligence test was not conducted and the motivation of participants was uncertain. Moreover, the ability of the participants to maintain attention, which is crucial in recognizing rapidly presented stimuli, was not part of the inclusion criteria of the study. With respect to sample selection, participants in the present research were mainly undergraduates of Speech and Hearing Sciences. The educational level and location of sampling were restricted. Therefore, the somewhat biased sample might not represent the entire population of Hong Kong young adults with normal auditory processing ability. Another limitation was that test-retest reliability was not assessed in the present study. High test-retest reliability would be an important factor to deduce the utility of the test to monitor auditory processing ability over time.

Directions for future research

Only normative data for young adults with presumed normal auditory processing abilities was obtained in the study. Further replication has to be done for (C)APD populations to derive sensitivity of the test tool. Moreover, the age range of participants was limited to 19 to 25 years and further investigation of elderly and children’s recognition ability with time-compressed words is yet to be explored. Cross-sectional comparisons which help derive
age effects and the potential effects of familiarity of linguistic stimuli are worth exploring.

**Conclusion**

The present study demonstrated comparable word recognition at 0% and 45% time compression conditions and relatively greater difficulty was noted at 65%. Among the three compression rates, 45% was found to be the most suitable value for evaluating auditory processing abilities in clinical practice. Neither ear nor gender effects were a concern in word recognition of time-compressed stimuli. Further research should investigate the sensitivity of the Cantonese time-compressed speech test on populations with auditory processing difficulty. Normative data for other age groups should also be developed.

**Acknowledgement**

I wish to show my sincere gratitude to Dr. Bradley McPherson for his kind guidance, comment and support on this study, as well as Dr. Adrian Fuente, for his assistance in preparing the compressed speech materials. I would also like to thank all participants for their support during the course of this study.
References:


Unpublished Bachelor of Science (Speech and Hearing Sciences) dissertation, University of Hong Kong.


Appendix:

Informed Consent Form
Cantonese time-compressed speech test

You are invited to participate in a research study conducted by Miss Lau Tsz Lam, a forth year university student, in the Division of Speech and Hearing Sciences at the University of Hong Kong.

PURPOSE OF THE STUDY
This study is to develop a Cantonese time-compressed speech test using bisyllabic word materials. The test developed will be included in the local test battery of (central) auditory processing disorders for identification purposes.

PROCEDURES
You will first be collected a brief case history on your hearing and undergo a hearing screening, i.e., pure tone audiometry. If you pass the screening, you will proceed to hearing 3 recording tracks, each contained 48 words. You will be asked to verbally recall the word you listen after each word presentation. The whole procedure will take approximately 30 minutes. If you have history of hearing problems or fail the screening, you will be informed that the test is terminated.

POTENTIAL RISKS / DISCOMFORTS AND THEIR MINIMIZATION
You may possibly get tired during the long hour test. You are free to take some breaks at any time you think necessary.

COMPENSATION FOR PARTICIPATION
You will not receive any compensation for participation.

POTENTIAL BENEFITS
You will experience how a speech recognition test is carried out and know more about a possible test tool for central auditory processing disorders. This will be beneficial to students of Speech and Hearing Sciences in future practice as a speech therapist. For others, you will also be benefited from the hearing screening and a brief explanation on the results.

CONFIDENTIALITY
Information obtained in the study will be used for research purposes only. All personal information, except the results of testing, will be held strictly confidential and be destroyed within 6 months.
PARTICIPATION AND WITHDRAWAL
Your participation is voluntary. This means that you can choose to stop at any time without negative consequences.

QUESTIONS AND CONCERNS
If you have any questions or concerns about the research, please feel free to contact Miss Lau Tsz Lam, a forth year university student, at HKU. If you have questions about your rights as a research participant, contact the Human Research Ethics Committee for Non-Clinical Faculties, HKU (2241-5267).

SIGNATURE

I ____________________________________ (Name of Participant)

understand the procedures described above and agree to participate in this study.

___________________________________________

Signature of Participant Date:
Date of Preparation:
Cantonese time-compressed speech test
廣東話時間壓縮語音測試

<table>
<thead>
<tr>
<th>Subject no.:</th>
<th>Name:</th>
<th>(M/ F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC signal presented at: R / L</td>
<td>Date:</td>
<td></td>
</tr>
<tr>
<td>Contact no.:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Case history

Date of birth: | Place of birth: |
Dominant hand: R / L

Use Cantonese at home in early childhood (dominant language)
(兒時家中主要講廣東話): Y / N

Use of hearing aids, Y / N

Otologic problems, e.g. recent otitis media  Y / N, stated: ____________________

Presence of CAPD (中樞聽覺處理異常): Y / N

Other medical conditions (e.g. 長期病患):

Hearing Screening: PTA (15dB, AC, no masking) 聽覺篩查 純音氣導

<table>
<thead>
<tr>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scoresheet: (presented at: R / L)

<table>
<thead>
<tr>
<th>40dB HL</th>
<th>Track 1 (0%TC)</th>
<th>√/O</th>
<th>Track 2 (45%TC)</th>
<th>√/O</th>
<th>Track 3 (65%TC)</th>
<th>√/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>特別</td>
<td>考慮</td>
<td>通過</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>另外</td>
<td>現實</td>
<td>過程</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>方式</td>
<td>應該</td>
<td>文學</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>交家</td>
<td>需要</td>
<td>行動</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>當時</td>
<td>部門</td>
<td>任何</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>完成</td>
<td>選擇</td>
<td>一個</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>大學</td>
<td>作用</td>
<td>支持</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>生命</td>
<td>利用</td>
<td>注意</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>學生</td>
<td>仔女</td>
<td>單車</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>任務</td>
<td>仲有</td>
<td>最近</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>覺得</td>
<td>風扇</td>
<td>作品</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>電話</td>
<td>就算</td>
<td>醫院</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>開會</td>
<td>要求</td>
<td>一段</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>一齊</td>
<td>能夠</td>
<td>哩種</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>安全</td>
<td>同埋</td>
<td>經過</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>落去</td>
<td>希望</td>
<td>市場</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>唔想</td>
<td>先生</td>
<td>分鐘</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>相當</td>
<td>受到</td>
<td>主要</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>一步</td>
<td>計劃</td>
<td>精神</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>曾經</td>
<td>原因</td>
<td>公司</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>事實</td>
<td>小姐</td>
<td>結果</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>接受</td>
<td>時間</td>
<td>學校</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>負責</td>
<td>已經</td>
<td>更加</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>其中</td>
<td>理解</td>
<td>全部</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>問題</td>
<td>重要</td>
<td>勞動</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>基本</td>
<td>離開</td>
<td>可以</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>經驗</td>
<td>無論</td>
<td>準備</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>今日</td>
<td>承認</td>
<td>相信</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>可能</td>
<td>技術</td>
<td>一種</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>繼續</td>
<td>幫手</td>
<td>活動</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>消息</td>
<td>睇到</td>
<td>經濟</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>責任</td>
<td>經常</td>
<td>手機</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>我地</td>
<td>所有</td>
<td>方向</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>清楚</td>
<td>如果</td>
<td>跟住</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>報告</td>
<td>環境</td>
<td>但係</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>自己</td>
<td>教育</td>
<td>決定</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>飛機</td>
<td>服務</td>
<td>開始</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>夜晚</td>
<td>願意</td>
<td>後生</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>努力</td>
<td>社會</td>
<td>雖然</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>引起</td>
<td>一直</td>
<td>之間</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>運動</td>
<td>意見</td>
<td>相機</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>即刻</td>
<td>文章</td>
<td>最後</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>提出</td>
<td>宣傳</td>
<td>發展</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>關係</td>
<td>星期</td>
<td>解釋</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>家庭</td>
<td>所謂</td>
<td>乾淨</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>揚到</td>
<td>一次</td>
<td>之後</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>個月</td>
<td>真係</td>
<td>知道</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>保護</td>
<td>科學</td>
<td>面對</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Result | /48 | /48 | /48 |
**Instructions**

**Cantonese time-compressed speech test:**

Track 1 (1000Hz calibration tone)

Track 2 (0% time compression rate)

You are going to hear a series of words in one ear. Please repeat each word as soon as you hear it. If you are not sure of the word that you heard, you may guess.

Track 3 (45% time compression rate)

You are going to hear a series of words presented at a faster rate in one ear. Please repeat each word as soon as you hear it. If you are not sure of the word that you heard, you may guess.

Track 4 (65% time compression rate)

You are going to hear a series of words presented at an even faster rate in one ear. Please repeat each word as soon as you hear it. If you are not sure of the word that you heard, you may guess.