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The Effects of Feedback on the Speech Motor Task

of Simulating Hypernasality

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Abstract

The aim of this study was to investigate the effectiveness of feedback on the learning of a novel speech task: simulating hypernasality. Forty participants (20 male, 20 female; age range 18-35 years) were randomly assigned into four groups, receiving different combinations of feedback type (visual or verbal) and relative frequency of knowledge of results (100% or 50%). The participants practiced hypernasal production of syllables, words and a passage during acquisition. Their performances at baseline, immediate retention, delayed retention and transfer were assessed with three different types of connected speech stimuli. The results showed that learning was took place in all feedback conditions. However, no significant difference was found across different feedback type and feedback frequency. The findings indicated that velopharyngeal closure during speech can be controlled voluntarily upon practice with appropriate feedback rendered. The findings also shed light on the treatment of hypernasality and on speech motor learning.

Introduction

Hypernasality is a type of resonance disorder. More specifically, hypernasality occurs when there is abnormal distribution of acoustic energy in the oral and nasal cavities in speech production (Kummer, 2008). It is usually caused by impaired velopharyngeal function, i.e. velopharyngeal inadequacy (VPI), due to structural anomalies (e.g., cleft palate), or physiological pathologies (e.g., flaccid dysarthria). Pharyngeal flap surgery and the use of speech appliances are common treatment for VPI (Golding-Kushner, 1995). However, both treatment methods have some drawbacks. The surgical treatment is irreversible and it may cause nasal obstruction, while the speech prosthesis may lead to allergy or inflammation to individuals (Golding-Kushner, 1995). Speech therapy would be an alternative or follow-up remediation of VPI if one has certain complete VP closure during speech production (Golding-Kushner, 1995).

Traditional speech therapy usually focuses on increasing oral resonance with various techniques for intervention of hypernasality, but researchers agreed that hypernasality is very difficult to be corrected with speech therapy (Golding-Kushner, 1995; Kummer, 2008; McWilliams, Morris & Shelton, 1990). Therefore, they have devised different therapeutic procedures in reducing hypernasality. For instance, Kuehn et al. (2000) demonstrated the efficacy of continuous positive airway pressure resistance training in reducing speech hypernasality. Other studies have investigated the use of biofeedback methods in treating

hypernasality, including auditory feedback filtering (Garber & Moller, 1979) and

nasopharyngoscopic biofeedback (Van Lierde, Claeys, Bodt & Cauwenberge, 2003; Witzel,

Tobe & Salyer, 1988). In particular, nasometry has been suggested to be a useful

instrumentation in providing biofeedback in the treatment of hypernasality (Dalston, 2004;

Kummer, 2008; Peterson-Falzone, Hardin-Jones & Karnell, 2001).

The nasometer is a computer-based equipment comprising two microphones and a

sound-separating plate, which measures the acoustic energy emitted from the nose and the

mouth, respectively. A nasalance score is calculated from the ratio of nasal to oral acoustic

energy. It is shown on the computer screen instantly upon speech input. Therefore,

nasometry can provide individuals with immediate visual feedback during speech

production. Although it is commonly used in treating hypernasality, no systematic studies

have been conducted to substantiate its treatment efficacy (Peterson-Falzone et al., 2001;

Kummer, 2008). Only preliminary studies were carried out regarding the use of Tonar II, the

predecessor of nasometer, in reduction of hypernasality and successful treatment results

were obtained (Fletcher, 1972; Fletcher, 1978).

Since nasometry renders feedback in the treatment of hypernasality, theoretically, the

frequency and timing of feedback can be manipulated to achieve maximum effectiveness in

intervention. However, no research studies have been systematically done. In order to

investigate the optimal properties of feedback for treating hypernasality, motor learning

principles can be adopted (Schmidt, 1988), as there is empirical evidence in studying the

effects of feedback on learning in the field of motor learning.

Augmented feedback, which is feedback given supplementary to one's intrinsic

feedback, is usually provided in treatment of speech disorders. Knowledge of results (KR) is

one type of augmented feedback. KR carries information about the outcome of the

movement, which is provided after the completion of the movement. Schmidt (1988)

suggested that KR is a crucial factor for motor learning. The performance and learning of a

motor task can be affected by variations in the knowledge of results (KR), in which an

increase in relative frequency of KR, i.e. percentage of trials with KR given, enhances the

motor performance during acquisition, but hinders learning in retention and transfer

(Salmoni, Schmidt & Walter, 1984). Research studies in learning motor skills have further

proved that reduced relative frequency of feedback during practice could bring about better

learning outcomes (Butki & Hoffman, 2003; Winstein & Schmidt, 1990). Besides, regarding

means of feedback, Messier and Cirillo (1989) studied the effects of verbal feedback and

visual feedback in modification of running style. They demonstrated that both means of

feedback are effective for enhancing learning of this novel motor task.

With respect to speech motor learning, there are only few studies investigating the

effects of feedback on learning a novel speech behavior or treatment efficacy, as concluded

by Maas et al. (2008), who reviewed the use of motor learning approach in remediation of

motor speech disorders (MSDs). Yiu, Verdolini and Chow (2005) compared the use of

electromyographic biofeedback as concurrent feedback (feedback offered during the

movement) versus terminal feedback (feedback provided after the movement) for learning a

voice production task. Their results showed no significant learning effect and no significant

difference among the groups. Austermann Hula, Robin, Maas, Ballard and Schmidt (2008)

showed that both delayed feedback and reduced frequency of feedback were found to

promote learning of speech skills in three patients with acquired apraxia of speech.

More relevant to the current study, Steinhauer and Grayhack (2000) examined the

effects of relative frequency of KR on a task of vowel nasalization. They used nasometry to

provide KR to participants during acquisition. The participants were divided into three

groups receiving different relative frequencies of KR (100% KR, 50% KR, No KR). It was

found that 100% KR was detrimental to both performance and learning, whereas 50% KR

and even no KR were both favorable for learning of this speech motor task.

Maas et al. (2008) suggested that more systematic research on speech motor learning

should be carried out in both normal and impaired populations with a view to further

exploring the application of motor learning principles in the treatment of MSDs. They also

advocated the use of instrumental measures of performance in clinical practice. Simulating

hypernasality in connected speech using nasometry was therefore considered a suitable task

for exploration in this study.

Simulating hypernasality is novel to most unimpaired speakers. Moon & Jones (1991) suggested that voluntary VP-control could be achieved upon training based on the plasticity and flexibility in speech motor learning (Folkins, 1985). Using connected nasalized speech in this study was intended to extend the findings of Steinhauer and Grayhack (2000), which was confined to vowel production.

The effect of different type of feedback (visual feedback, verbal feedback), and relative frequency of KR (100% KR, 50% KR) on learning nasalized speech will be examined in particular. The results and implication of this research would contribute to (1) the study of motor learning in speech motor control, (2) and may contribute to the treatment of hypernasality.

Method

Participants

Forty participants (20 females, 20 males) were recruited from the University of Hong Kong. All subjects were native Cantonese-speaking undergraduate students (mean age = 20.67 years, SD = 1.79, range = 18-25). They had no history of hearing, speech or language deficit. They were not suffering from a cold or upper respiratory track illness, which might affect their resonance in speech production, on the days of data collection. The mean nasalance score in production of oral sentences at the baseline for every participants was lower than 28.77%, which was +2SD from the mean score for normal Cantonese women (Whitehill, 2000), indicating that their nasality did not exceed the normal range.

Equipment

The Kay Elemetrics Nasometer (Model 6200) was used as the instrumentation for data collection. The nasometer was used to (1) measure the participants' performance at different time points, (2) provide information about the participants' performance to the experimenter during the experiment, and (3) provide visual feedback to the participants as appropriate.

Procedure

The participants were randomly assigned into four groups. Two groups received visual feedback from the nasometer in the experiment, with one group receiving 100% KR and the other group receiving 50% KR. The other two groups received verbal feedback, in which they were masked from the visual display of the nasometer, and they also differed in the amount of KR provided (100% KR and 50% KR). The 100% KR groups received feedback for every trial in the experiment, whereas the 50% KR groups received feedback for every other trial. Visual feedback, which was also concurrent feedback, was provided by the instant contour display with a nasalance target reference line shown on the monitor of the nasometer. Verbal feedback, which was also terminal feedback, was given verbally by the experimenter (e.g. "That sounds very hypernasal", "It is not hypernasal enough") according to the performance of the subjects based on the nasalance score observed by the experimenter.

Experimental procedures. The experiment consisted of three phases: Phase I:

Baseline, Phase II: Acquisition and Phase III: Retention/Transfer.

The nasometer was calibrated and the headgear was placed and adjusted according to the instruction manual (Kay Elemetrics, 1989) before each experiment session. Before data collection, explanation was provided to each subject about the instructions and procedures of the task. In particular, explanations about hypernasality were provided with demonstration by the experimenter.

Phase I – Baseline. The initial baseline performance was taken. The participants were first asked to produce (1) oral sentences, i.e. no nasal consonants, (2) an oral-nasal paragraph and (3) 1-minute spontaneous speech speaking normally without KR. The oral sentences and oral-nasal paragraph were those used in a study of nasalance measures in Cantonese (Whitehill, 2000). Then, the participants were instructed to produce these testing stimuli again in a hypernasal manner. The mean nasalance scores for each stimulus were obtained and noted down for later analysis.

Phase II – Acquisition. The participants were asked to practise producing the training speech stimuli with increasing complexity and difficulty according to the following hierarchy:

i. Production of CV syllables with nasal consonants for 5 consecutive times

(e.g. /ma ma ma ma ma/)

ii. Production of disyllabic words with nasal consonants for 5 consecutive times (e.g.

/mai$_5$ mAi$_5$/)

iii. Production of CV syllables without nasal consonants 5 consecutive times

(e.g. /sa sa sa sa sa/)

iv. Production of disyllabic words without nasal consonants 5 consecutive times

(e.g. la$_3$ ba$_1$)

v. Production of a reading passage

Different type of feedback with different relative frequency of KR was given to the

respective groups to assist the participants in simulating hypernasality. A mean nasalance

score of 40% was targeted before proceeding to the next level of the hierarchy. The criterion

of 40% was targeted with reference to the mean nasalance score of 44% for perceptual

judgment of moderate hypernasality (Dalston, Neiman & Gonzalez-Landa, 2003). If the

participants could not achieve the target nasalance score at a certain level, they were asked

to practise the stimuli at the previous level. The performance of nasalized speech

productions was recorded again when the targeted nasalance was achieved at level V as the

immediate retention measurement.

  Phase III – Retention/Transfer. This phase of experiment was carried out about two

weeks after phase II. The duration for the retention period varied among subjects with a

mean of 15.95 days (SD = 4.39, range = 7-26). The participants' performance in simulating

hypernasality was taken again with the same testing stimuli in phase I, constituting the

delayed retention phase. As for the transfer phase, it was intended to create a stressed condition when performing the task. The participants were asked to produce an emotionally demanding monologue, such as description of a miserable, stressful, or infuriating event in their lives, in nasalized speech for one minute with no KR.

Data analysis

There were two independent variables in this study: including the type of feedback and the relative frequency of KR. The mean nasalance score of each testing stimulus at different testing time points was the dependent variable. Hence, the mean nasalance scores were collected and used to compute group means for statistical analysis.

The three testing stimuli were analyzed independently. The mean nasalance scores of spontaneous speech were analyzed with a three-way (2 x 2 x 5) analysis of variance (ANOVA) with three independent variables: type of feedback with 2 levels (visual feedback, verbal feedback), relative frequency of KR with 2 levels (100% KR, 50% KR) and time (5 measurements across baseline, acquisition, immediate retention, delayed retention and transfer). For the oral sentences and oral-nasal paragraph stimuli, a 2 x 2 x 4 ANOVA was used because there was no transfer phase for these two stimuli. Among the independent variables, time was the within-subject factor, whereas feedback type and relative frequency of KR were the between-subjects factors. Statistical significance was assessed with $\alpha = 0.05$.

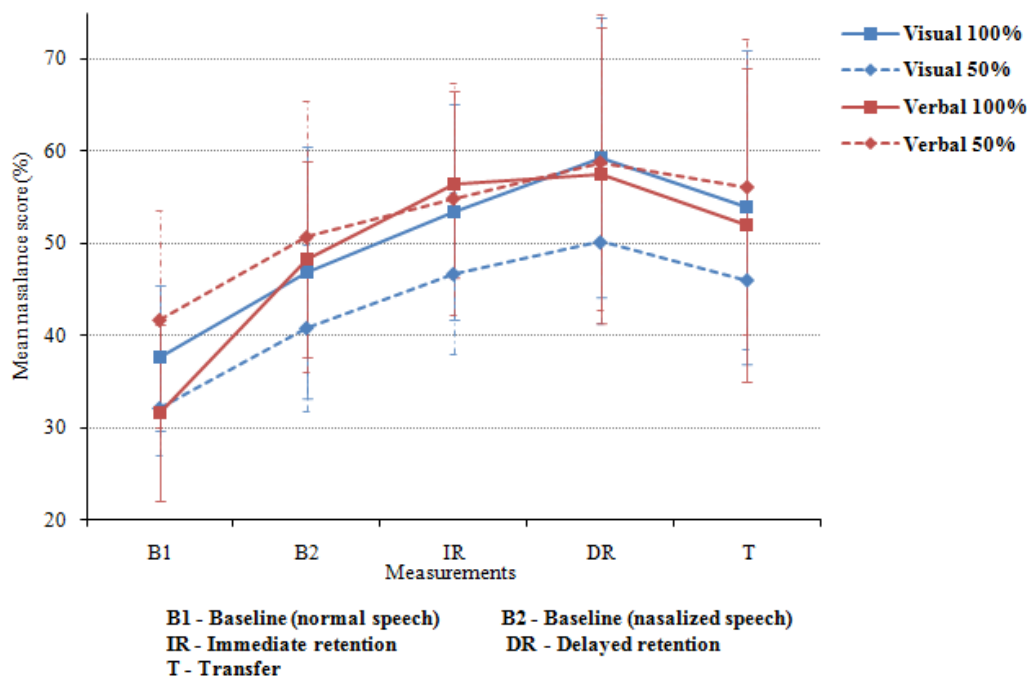# Results

Spontaneous speech

Figure 1. Mean nasalance scores and standard deviations of spontaneous speech across baseline, retention and transfer for the four groups.

Figure 1 shows the mean nasalance scores for spontaneous speech across the five measurement points for the four feedback groups. According to the results of the three-way ANOVA, the main effect of time was significant, $F(4, 144) = 36.66$, $p < 0.001$. Pairwise comparisons indicated significant increases between B1 and B2, and also between B2 and immediate retention ($p < 0.05$). The difference between immediate and delayed retention was not significant ($p < 0.05$). A significant decrease was also indicated between delayed retention and transfer phase ($p < 0.05$). No other significant main effects or interaction effects were revealed from the analysis.
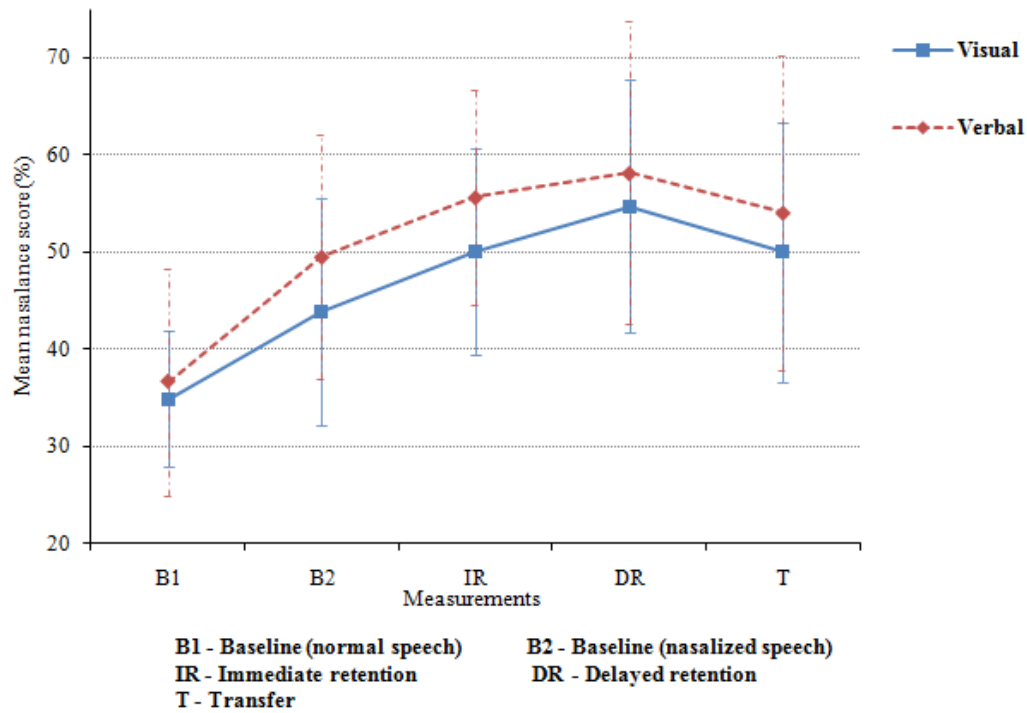
Figure 2. Mean nasalance scores and standard deviations of spontaneous speech

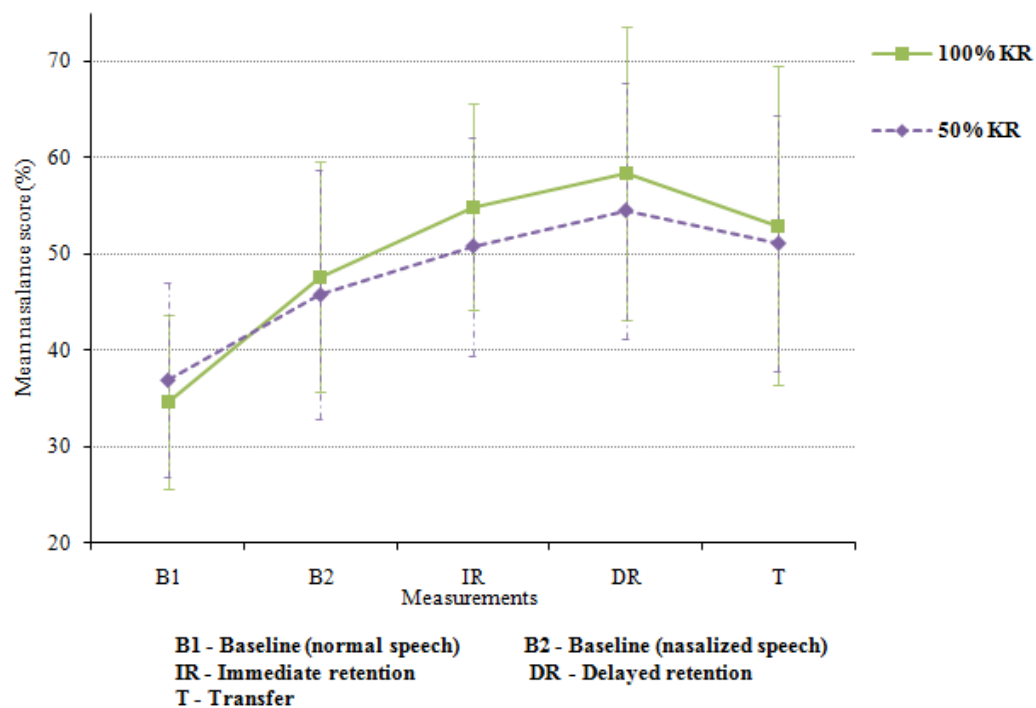across time points for visual feedback versus verbal feedback.

Figure 3. Mean nasalance scores and standard deviations of spontaneous speech

across time points for 100% KR versus 50% KR.

Figure 2 compares the means of the two types of feedback. Although there appeared to be some difference between visual feedback and verbal feedback, statistical analysis showed no significant difference between the groups, $F(1, 36) = 1.69$, $p = 0.20$. Similarly, for the comparison between the 100% KR group and 50% KR group, which is illustrated in Figure 3, there was no statistical significant difference between these two groups, $F(1, 36) = 0.36$, $p = 0.56$.
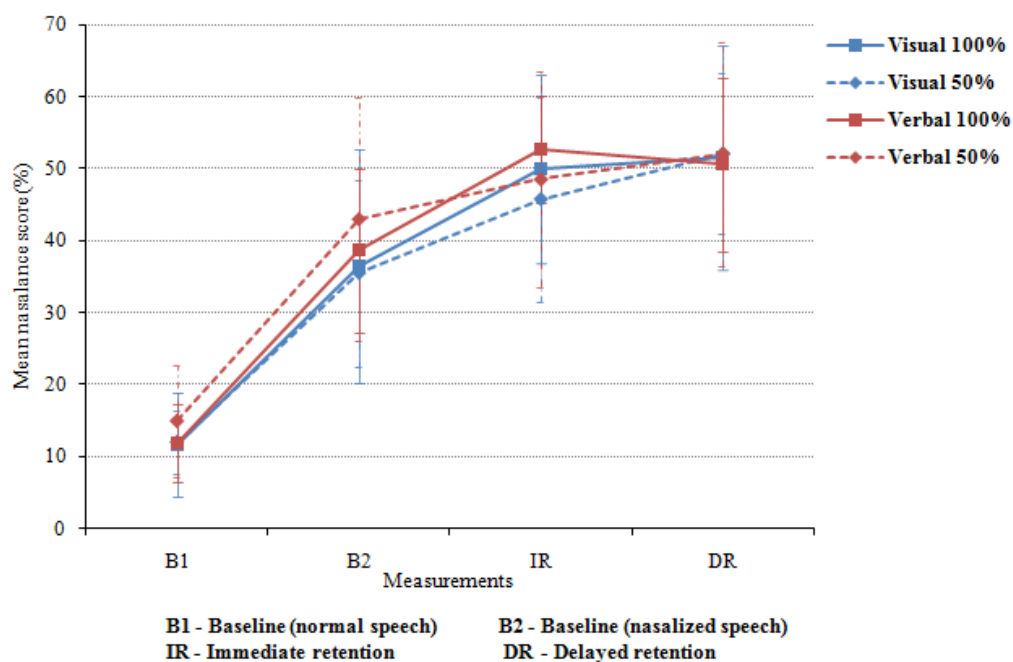
Oral sentences

Figure 4. Mean nasalance scores and standard deviations of oral sentences across time points for four groups.

The mean nasalance scores for the oral sentences for the four groups are presented in Figure 4. A significant time effect was found, $F(3, 108) = 145.46$, $p < 0.001$. The time differences were significantly different between B1 and B2, and also between B2 and

immediate retention, based on the pairwise comparisons ($p < 0.05$). No significant difference was found between immediate and delayed retention. There were no other significant main effects or interaction effects.

Oral-nasal paragraph

The data of oral-nasal paragraph is shown in Figure 5. Similar results to those found for spontaneous speech and oral sentences were found. That is, time effect was significant, $F(3, 108) = 103.49$, $p < 0.001$, but there were no other significant main effects or interactions. Significant differences were also found between B1 and B2, and also B2 and immediate retention ($p < 0.05$). There was a significant increase in mean nasalance score from the immediate retention to delayed retention ($p < 0.05$), which was not found to be statistically significant in the analyses of the other two testing stimuli ($p > 0.05$).
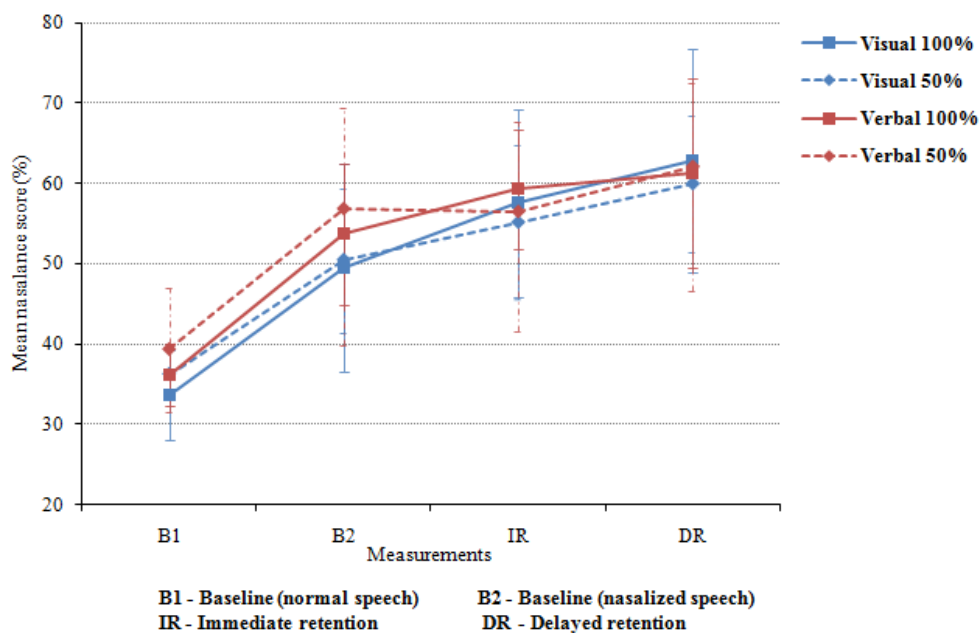

Figure 5. Mean nasalance scores and standard deviations of oral-nasal paragraph

across time points for four groups.

Discussion

The aim of this study of was to study the effects of types of feedback and relative frequency of KR on learning to simulate hypernasality. During practice, visual feedback was provided by the nasometer, which was also the concurrent feedback, while verbal feedback was given by the experimenter according to the nasalance measured, which also acted as the terminal feedback. In addition, the relative frequency of KR was manipulated as either 100% KR or 50% KR. The results revealed that the mean nasalance score increased across the baseline, immediate retention and delayed retention phases in the production of all the three testing stimuli, namely oral sentences, oral-nasal paragraph and spontaneous speech. The increase across the above time points were statistically significant, indicating that learning effect was achieved in this study. For spontaneous speech production, a significant decrement in nasalance was observed in all groups from delayed retention to the transfer phase, in which the participants were asked to produce an emotionally demanding monologue.

The results of the present study failed to provide evidence for the hypothesis that speech motor learning is affected by variation in type of feedback or frequency of KR. This finding was inconsistent with the previous empirical evidence in the motor learning literature. Firstly, regarding the relative frequency of KR, studies have shown that reduced

KR should enhance motor learning in retention relative to 100% KR (Butki & Hoffman, 2003; Steinhauer & Grayhack, 2000; Winstein & Schmidt, 1990). However, no significant group difference was obtained between the 100% KR group and 50% KR group in this study. Secondly, the concurrent feedback has been found to be less beneficial when compared to terminal feedback in facilitating the acquired skill in retention and transfer (Park, Shea & Wright, 2000; Schmidt & Wulf, 1997). However, no such group difference was observed from the results obtained. In the following section, possible explanations of the results are discussed with theoretical support.

Task complexity

The task of simulating hypernasality might have been too easy for the participants to achieve. As observed from the data, most participants were able nasalize their speech to a great extent within the baseline phase. For instance, for oral sentences, there was an increase of at least 20% nasalance among all participants from B1 to B2, indicating that the participants could produce speech in a hypernasal manner before practice. This phenomenon would be supported by the results obtained by Moon and Jones (1991), who found that individuals were able to control their VP closure without a learning period. Folkins' theory of flexibility of speech motor control stated that "when a rule system is set up through a coordinative structure, it is not necessary to go through an adaptation process to find novel solutions fitting the coordinative structure" (Folkins, 1985, p.112). Although the learning

effect was significant, the learning patterns of the participants in the four groups might be

similar, since they might have mastered the nasalized speech near their ceiling during

acquisition and retention. Nevertheless, in this study, a criterion of mean nasalance score of

40% was targeted, which was quite high and was indeed approximated to moderate

hypernasality (Dalston et al., 2003). Moreover, the testing speech stimuli were connected

speech, rather than sustained vowels or single syllables, which might have complicated the

motor task per se.

Learning effect

Substantial learning effect of simulating hypernasality was shown in this study. The

participants were able to maintain the acquired skills in immediate retention and delayed

retention. This is consistent with the results of similar studies, in which opening of VP

closure during production of vowels (Moon & Jones, 1991) and vowel nasalization

(Steinhauer & Grayhack, 2000) were targeted with different biofeedbacks and successful

learning effects were also verified.

It is also worthwhile to note the improved performance of the speech task in delayed

retention. As illustrated in the figures, all groups had an apparent increase from immediate

retention to delayed retention in all speech stimuli, although this difference was only

significant for the oral-nasal paragraph. In other words, participants appeared to have better

performance in simulating hypernasality after a retention period of about 2 weeks. This

outcome is rather novel to the field of speech motor learning, and even the motor learning

studies. In some motor learning studies, in which immediate retention and delayed retention

were included in the experiments, the performance of the acquired motor skill deteriorated

from immediate retention to delayed retention after a period of 24 hours (Anderson, Magill

& Sekiya, 2001; Anderson, Magill, Sekiya & Ryan, 2005) or 48 hours (Weeks & Sherwood,

1994). The substantial increase in this study after a period of retention might be explained by

Folkins' concept of plasticity in speech motor learning (Folkins, 1985). He proposed that

plasticity implied alterations in the speech system, whereby the effect was more long-lasting

than flexibility. Such plasticity in speech motor control with evidence of this study might

shed a light on clinical implication of treatment of hypernasality, which requires long term

maintenance as the goal. Clinical implications are further discussed in later sections.

As for the transfer phase, results showed that there was significant reduction in the

participants' nasalance score from retention to transfer phase, in which the participants need

to nasalize their spontaneous speech in a stressed or emotional condition. This result is

compatible with the investigations of motor skills under pressure, which suggested a decline

in performance of the skill during transfer in stressed conditions, especially with explicit

information rendered in acquisition (Lam, Maxwell & Masters, 2009; Masters, 1992).

A possible confound with the learning effect is the criterion target in the acquisition

phase. In traditional studies of motor learning, the data within the acquisition phase should

also be analyzed in order to trace the learning pattern and to infer the performance effect

(Schmidt, 1988). However, in this study, the participants needed to reach greater than 40%

of nasalance score in order to proceed to the next block during acquisition, implying that

each participant would at least reach the same level of nasalance after the acquisition phase.

This criterion during practice would have guaranteed the learning effect, albeit that some

participants had to practise more trials than the others in order to reach the criterion level

(see Appendix D). Further research could trace the participants' performance during

acquisition, and note whether the learning pattern would be different without a passing

criterion.

Effects of feedback

The present study showed that both the visual feedback and verbal feedback are

effective for learning the speech motor task of simulating hypernasality. An inference can be

made that the nasometer is an effective tool in adapting the change in VP motor control

during speech, no matter whether acting as a direct biofeedback or indirect objective

reference of nasality information. This finding is consistent with that of Steinhauer and

Grayhack (2000). Successful learning of speech nasalization with visual feedback from

nasometer was also demonstrated in their study. However, in order to further conclude that

the feedback can enhance learning more convincingly, a no KR group should be included for

comparison in further studies – slow or ineffective learning in the no KR group indicates

that the augmented feedbacks are truly effective for facilitating speech motor learning.

Type of feedback. Although both types of feedback had an effect in enhancing learning of the speech task, there was no significant difference between the visual group and verbal group, in spite of an apparent difference as seen in Figure 2. In terms of concurrent (visual) feedback versus terminal (verbal) feedback, similar patterns of feedback effect was inferred in previous studies, yet with significant difference between the concurrent and the terminal feedback groups (Park et al., 2000; Schmidt & Wulf, 1997). They concluded that concurrent feedback was detrimental to motor skill performance in retention and transfer. The lack of feedback timing difference would be caused by the nature of the visual feedback provided by the nasometer, which might have induced an external focus of attention to the participants during practice. When an external focus of attention is evoked by the concurrent feedback, the concurrent feedback would exceptionally enhance learning (Hodges & Franks, 2001; Shea & Wulf, 1999). The contour display and the targeted nasalance reference line might be able to bring about the external focus of attention, hence, facilitating performance without hindrance to learning of simulating hypernasality.

Relative frequency of KR. Previous studies have shown that reduced frequency of KR is more beneficial to learning in terms of retention relative to high frequency of KR (Steinhauer & Grayhack, 2000; Winstein & Schmidt, 1990). The guidance hypothesis presumes that frequent KR prevents the development of intrinsic feedback, hence, the

acquired motor skill cannot be maintained when KR is removed in retention (Anderson et al.,

2005; Salmoni et al., 1984). A discrepancy lies between the guidance theory and the result of

this study, in which no statistical difference was found between 100% KR group and 50%

KR group.

Maas et al. (2008) stated that complex interactions occurred among practice conditions

and feedback. A possible underlying reason for the observed result is that the interaction of

the feedback frequency with other factors also affects learning. Wulf & Shea (2004) asserted

that the beneficial effect of the feedback frequency would interact with the practice

variability. They claimed that the promotion of learning effect by the reduced feedback

would be limited by constant practice, which was adopted in the present study. The practice

stimuli proceeded from oral-nasal words to oral words with constant practice at each level.

This constant practice would have hindered the reduced frequency facilitation on learning.

Moreover, the attentional focus would also interact with the feedback frequency. Feedback

with an external focus of attention would require more frequent provision in order to

enhance learning instead of reduced frequency (Wulf, McConnel, Gartner & Schwarz, 2002).

As discussed before, if the feedback provided by the nasometer induces an external focus,

the frequency provision of KR would have enhanced rather than hindered the learning of the

speech motor skill. The interactions of the feedback frequency with other factors in speech

motor learning require further investigations. Besides, as aforementioned, the ease of the

speech task per se might override the effect of feedback frequency, as most participants in all

the groups might have mastered the skill at criterion level in retention phase.

The high individual variability of the participants' performance in the speech task might

have contributed to similar results in the two types of feedback, and also the two different

relative frequency of KR. With reference to Figures 1-5, the error bars for different groups at

each time point overlap with each other, meanwhile possessing large standard deviations.

Such variability may confound the data analysis, hence, resulting in a lack of significant

differences among the groups.

Clinical implication

Although the current investigation only studied the speech motor learning in normal

speakers, it offers a contribution to clinical practice by gaining a better understanding of the

speech motor control based on the motor learning principles (Maas et al., 2008). In this study,

the nasometer was found effective as instrumentation for rendering both direct biofeedback

and indirect feedback via the experimenter to the speakers for simulating hypernasality, in

which alteration of VP closure during connected speech production was involved. The

learning effect of this novel speech skill was indicated to be long-lasting as observed in the

retention phase in all groups with different type, timing and frequency of feedback.

Significantly improved performance in delayed retention was demonstrated in one of the

three speech conditions. Inference could be made that the VP motor control during speech,

which alters the nasality in speech, is subject to changes upon practice with feedback, with

reference to the concept of plasticity (Folkins, 1985). These apparent evidences are

favorable to clinical treatment of hypernasality, which VP closure during speech with good

maintenance is the ultimate treatment objective. Specifically, as Folkins (1985) suggested

that speakers with repaired palatal cleft would exploit the flexibility and plasticity of the

VP-oral system to nurture a new organization of the system for speech production, findings

from this study would suggest that hypernasality in these speakers would be efficiently

reduced upon practice with feedback given by the nasometer, as long as the structural and

physiological constraints are taken into considerations.

Further studies

In order to further investigate the clinical implications of findings of this investigation,

impaired speakers with hypernasality, such as individuals with cleft palate or MSDs, should

be recruited as participants to study whether similar results could be obtained. Besides, for

further studies, the data in the acquisition phase should also be taken into account for

analysis. A group without any KR should be included for comparison of results to further

testify the effects of the feedbacks. Meanwhile, interactions of conditions of practice and

feedback for speech motor learning can also be investigated.

Conclusion

The effects of the type of feedback and relative frequency of KR on learning a speech

motor task of simulating hypernasality have been investigated in this study. Significant

learning occurred in all participants as observed in the retention phase. In the transfer phase

of a stressed condition, as expected, the participants had a significant deterioration in their

performance. No significant superiority in any groups was attested in the comparisons

between groups with visual and verbal feedback, and also between groups with 100% KR

and 50% KR.

The findings in this study suggested that the VP closure during speech could be

controlled voluntarily upon practice with appropriate feedback provided, both directly and

indirectly by nasometry, changing the nasality in speech. The underlying rationale could be

explained by Folkins' concept of plasticity of speech motor system (Folkins, 1985). Feasible

clinical implication could be made towards treatment of hypernasality in individuals with

VPI. This study may also serve as a ground for further studies of speech motor learning, in

particular the effects of practice conditions, feedback factors, and their interactions on

performance and learning.

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Appendix A: Participant Consent Form

The Effects of Feedback on the Speech Motor Task of Simulating Hypernasality

You are invited to participate in a project entitled "The Effects of Feedback on the Motor Task of Simulating Hypernasality" conducted by Lai King Lok, Joshua under the supervision of Prof. Tara Whitehill in the Division of Speech and Hearing Sciences at the University of Hong Kong.

PURPOSE OF THE STUDY

This project aims to compare the effectiveness of different types of feedback, and the effect of relative frequency of knowledge of results on a motor learning task of simulating hypernasality in speech production.

PROCEDURES

The study will involve a task of simulating hypernasality during the production of different speech stimuli. It will be held at the Division of Speech and Hearing Sciences, The University of Hong Kong.

All participants will be required to wear the headgear of nasometer, which is used to measure the nasalance in speech, and to produce various speech stimuli with feedback provided. This is a non-invasive procedure that entails two phases. The first phase of experiment will last about an hour, whilst the second phase of the experiment will be held two weeks after the first phase and will last about 15 minutes.

POTENTIAL RISKS/ DISCOMFORTS AND THEIR MINIMIZATION

The participants may feel a little discomfort when wearing the headgear of the nasometer. A break will be given every 15 minutes to minimize the discomfort.

POTENTIAL BENEFITS

There are no direct benefits to you. However, the experiment can provide an opportunity to have an attempt of using the nasometer. Besides, the results and implication of this research project may provide valuable information for the treatment of hypernasality and the study of motor learning in speech motor control.

CONFIDENTIALITY

Any personal information obtained in this study will remain strictly confidential, and will be used for research purposes only. Codes, not names, will be used on all test materials to protect confidentiality. Participants will not be identified by name in any report of the completed study.

PARTICIPATION AND WITHDRAWAL

Your participation in this project is voluntary. This means that you can withdraw from this project at any stage, for any reason, without negative consequences. We will erase the entire information obtained, or parts of it, if you want us to do so.

QUESTIONS AND CONCERNS

If you have any questions or concerns about this research study, please feel free to contact the Principal Investigator Lai King Lok, Joshua at (5/F Prince Philip Dental Hospital, The University of Hong Kong; Tel: 9232 5658; Email: jlok1014@hku.hk), or the supervisor Prof. Tara Whitehill at (5/F Prince Philip Dental Hospital, The University of Hong Kong; Email: tara@hku.hk). If you want to know more about the rights as a research participant, please contact the Human Research Ethics Committee for Non-Clinical Faculties, The University of Hong Kong (Tel: 2241-5267).

We thank you for your interest and support.

SIGNATURE

I _____ (Name of Participant) have been given the opportunity to ask questions about this study and they have been answered to my satisfaction. I understand the procedures described above and agree to participate in this study.

_____
Subject's name (Block letter)

_____   _____
Signature of Participant   Date

Date of Preparation: 13th November, 2009
Expiration date:

Appendix B: Testing speech stimuli

i.   Oral sentences

1.   伯伯有一個大鼻哥。

     /pak$_8$ pak$_8$ jʌu$_5$ jʌt$_7$ kɔ$_3$ tai$_6$ pei$_6$ kɔ$_1$/

2.   布袋有四十四塊大石頭。

     /pou$_3$ tɔi$_2$ jʌu$_5$ sei$_3$ sʌp$_9$ sei$_3$ fai$_3$ tai$_6$ sɛk$_9$ tʌu$_4$/

3.   婆婆叫哥哥餵雞仔。

     /pʰɔ$_4$ pʰɔ$_2$ kiu$_3$ kɔ$_4$ kɔ$_1$ wʌi$_3$ kʌi$_1$ tsʌi$_2$/

4.   爸爸最怕排隊搭車。

     /pa$_4$ pa$_1$ tsʊy$_3$ pʰa$_3$ pʰai$_4$ tʊy$_2$ tap$_8$ tsʰɛ$_1$/

5.   這是一束白菊花。

     /tsɛ$_2$ si$_6$ jʌt$_7$ tsʰʊk$_7$ pak$_9$ kʊk$_7$ fa$_1$/

6.   就快落大雨，帶把遮出街。

     /tsʌu$_6$ fai$_3$ lɔk$_3$ tai$_6$ jy$_5$ tai$_3$ pa$_2$ tsɛ$_1$ tsʰɐt$_7$ kai$_1$/

ii.   Oral-nasal paragraph "Hong Kong Passage"

香港是一個繁榮的都市，有接近六百萬人口，是國際重要的金融貿易中心。香港已有「東方之珠」的美譽，它的夜景是世界馳名的。每年從世界各地來港觀光的旅客，都讚歎香港的成就是個奇蹟。由百多年前的一個平淡的漁村，演變成為今日著名的大都市，絕對不是偶然或僥倖的。由於中國傳統的刻苦耐勞及自強不息的精神，促使我們不斷的努力，才能爭取到今天的成就。

Appendix C: Practice speech stimuli

i. CV syllables with nasal consonants

    1. /ma/   2. /mɛ/   3. /mi/   4. /mɔ/   5. /mu/

ii. Disyllabic words with nasal consonants

    1. 買米 /mai$_5$ mʌi$_5$/

    2. 麵粉 /min$_6$ fʌn$_2$/

    3. 蜜糖 /mʌt$_9$ t^{h}ɔN$_4$/

    4. 新年 /sʌn$_1$ nin$_4$/

    5. 金鐘 /kʌm$_1$ tsʊN$_1$/

iii. CV syllables without nasal consonants

    1. /sa/   2. /ka/   3. /ha/   4. /pa/   5. /t^{h}a/

iv. Disyllabic words without nasal consonants

    1. 喇叭 /la$_3$ ba$_1$/

    2. 西瓜 /sʌi$_1$ k^{w}a$_1$/

    3. 叉燒 /ts^{h}a$_1$ siu$_1$/

    4. 水杯 /sʙy$_2$ bui$_1$/

    5. 讀書 /tʊk$_9$ su$_1$/

v. A reading passage

芭芭拉史翠珊是我最喜愛的一位美國女明星，她沒有如花的美貌，但她出眾的技藝在「俏郎君」一劇中發揮得淋漓盡致，使這齣戲和它的主題曲都成為傳頌一時的佳作。今天，銀圈裡的男男女女以色相自高，骨子裡只有自我宣傳的鬼主意，頻頻「車大炮」、造新聞，盼能提高知名度，而藝技高低，已與他們無關了。

Appendix D: Participants' performance during acquisition

Table 1: Number of trials for each participant to reach criterion (mean nasalance score of

40%) during acquisition

Practice hierarchy	Mean	Range
Level 1: CV syllables with nasal consonants	5.15	5 - 10
Level 2: Disyllabic words with nasal consonants	5.35	5 - 9
Level 3: CV syllables without nasal consonants	6.45	5 - 28
Level 4: Disyllabic words without nasal consonants	6.85	5 - 17
Level 5: Reading passage	1.03	1-2