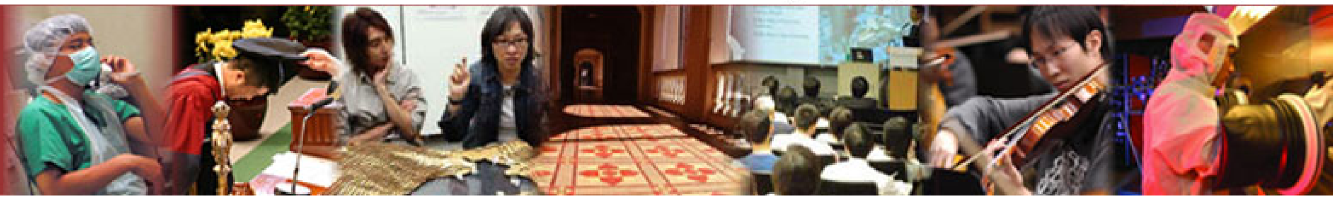

Title	Effects of feedback-induced focus of attention on motor learning of a "relaxed phonation" task
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Effects of feedback-induced focus of attention

on motor learning of a "relaxed phonation" task

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Abstract

The study examined the effects of focus of attention induced by feedback on motor learning of a relaxed phonation task. Thirteen vocally healthy individuals were randomly assigned into two groups: internal focus group and external focus group. The participants were instructed to read aloud sentence stimuli and were given the surface EMG values measured at their thyrohyoid site as biofeedback. The internal focus group was told that the values represented the muscle tension at the thyrohyoid site. Whereas, the external focus group was informed that the values represented the strained quality of their voice. All the participants were asked to minimize the EMG values for each sentence stimulus. Results revealed motor learning for the trained stimuli at both thyrohyoid and orofacial sites by the reduction in EMG voltages in the delayed retention test. Generalization was also demonstrated to reading against background noise at thyrohyoid site. Nevertheless, the results failed to show differences in motor learning for different foci of attention.

Keywords: Attentional focus, EMG biofeedback, voice motor learning, constrained action hypothesis, transfer tests

Introduction

Hyperfunction voice disorder is characterized by excessive laryngeal muscle tension that results in over-adduction of vocal folds during phonation (Aronson, 1990). It may lead to phonotrauma, resulting in various vocal pathologies (such as vocal nodules, vocal polyps, edema and contact ulcers) that would disturb one's voice quality (Ramig & Verdolini, 1998; Stemple, Weiler, Whitehead, & Komray, 1980). One of the therapy techniques for hyperfunctional dysphonia is relaxed phonation exercise, which aims at reducing laryngeal muscle tension during phonation to improve voice quality (Colton, Casper, & Leonard, 2006; Pannbacker, 1998; Ramig & Verdolini, 1998). The exercise involves motor learning since learners are acquiring new skills in manipulating their phonatory system in order to maximize their phonation efficiency with minimal efforts (Boone, McFarlane, & Von Berg, 1999).

Motor learning is defined as "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement" (Schmidt & Lee, 1999, pp. 264). Therefore, learning refers to a permanent change in the performance, which should be studied using long-term retention test (Magill, 1998). Any transient variation in performance within a single training session should not be inferred as learning.

In research studying motor learning, efforts have been devoted to investigate the effects of learner's attentional focus on motor skills learning. Focus of attention can be categorized into internal and external foci. Internal focus of attention refers to the attention towards one's own biomechanics of body movement (such as swing of arm in golf playing) while external focus of attention refers to the attention towards its movement effect (such as swing of club in golf playing) (Wulf, HoB, & Prinz, 1998). Recent literatures have documented consistent findings that an external focus of attention is more advantageous over an internal one in terms of motor skill learning.

The learning benefits of external focus of attention are explained by the “constrained action hypothesis” (McNevin, Shea, & Wulf, 2003). It suggests that internal focus of attention leads to conscious control of movement by the learner. This constrains the motor system by intervening the automatic motor process that efficiently and effectively regulates movement coordination (Wulf, 2007b). In contrast, external focus of attention promotes higher degree of automaticity in movement control. This enables more frequent corrective adjustment on the motor processes and thus promotes learning and performance (Wulf, McNevin, & Shea, 2001).

Induction by instructions: Wulf and her colleagues (1998) conducted a study to demonstrate the advantages of external focus of attention. Their study required the participants to perform a slalom-type movement on a ski-stimulator. The internal and external focus group was instructed to exert force on their foot and on the platform’s wheels respectively. Their results indicated better learning for the external focus group than the internal focus group. In their second experiment using a balancing task on a stabilometer, the participants' task was to keep the platform that they stood on in a horizontal position. The internal focus group was instructed to keep their feet at the same height whereas the external focus group was instructed to keep the red markers on the platform at same height. The benefits of external attentional focus were also demonstrated in this study. In the field of sport sciences, Wulf, Lauterhach, and Toole (1999)'s study on golf learning compared instruction that focused on arm swing (internal focus) and instruction that focused on club swing (external focus). Their results demonstrated the generalization of benefit of external focus instruction to golf learning.

Induction by feedback: The advantages of external attentional focus were also shown in that induced by feedbacks, as demonstrated by Shea and Wulf (1999) using a balancing task on a stabilometer. In their study, the participants stood, with their feet positioned behind two yellow lines, on a platform. They were given feedback by a computer screen, which showed two blue horizontal references lines (one on each side of the screen) and a pink line representing the deviation of the platform from the horizontal. The internal and external focus group was told that the pink line represented their feet and represented the yellow lines in front of their feet respectively. Results indicated better learning for the group of participants who received feedbacks of external focus. In the field of sport sciences, Wulf, McConnel, Gartner, and Schwarz (2002)'s study used feedback statements from volleyball textbooks (which referred to player's body movement) and their revised version (which contained the same content but focused more on the player's movement effect) as feedbacks for the internal and external focus group, respectively. They demonstrated the advantages of external focus feedback in learning of volleyball skills.

In the field of voice motor learning, however, no formal study has been carried out to investigate the effects of focus of attention. Yet, there has been study addressing this issue. Yiu, Verdolini, and Chow (2005) examined the effects of the timing (concurrent versus terminal) of a surface electromyographic (surface EMG) biofeedback on learning a relaxed phonation task. The learners were instructed to reduce the surface EMG waveform amplitude, which was interpreted to them as the muscular activity of their laryngeal muscles. The results demonstrated an accidental learning at the unattended control oro-facial site, rather than the attended thyrohyoid site. One of the arguments the authors made was that the learners attended to the biomechanics (i.e., internal focus of attention) in the motor learning for the thyrohyoid site, and thus degraded learning. On the contrary, the oro-facial site which did not receive much attention benefited from learning. Therefore, it would be of interest to empirically examine if the benefits of external focus of attention could be generalized to voice motor learning.

The present study investigated the effects of focus of attention induced by feedback on motor learning of a relaxed phonation task. It was hypothesized that feedback that directs learners' attention to the effects of laryngeal relaxation (external focus of attention) would facilitate better learning than the feedback that directs learner's attention to their biomechanics of laryngeal relaxation (internal focus of attention). The results of the present study would contribute to optimizing the effectiveness of the relaxed phonation therapy for patients with dysphonia.

Methods

Participants

Thirteen vocally healthy individuals (11 females and two males) (mean age = 22.08 years, SD = 5.02, range = 19 – 38 years) were recruited from The University of Hong Kong and the researcher's social circle. The participants: 1) were aged between 18 and 50 years, 2) were able to speak and read Cantonese fluently, 3) had no history of voice problem, and 4) had no prior experience with voice training and the use of surface EMG. Participants were excluded from the study if they 1) had current or history of respiratory problems, 2) failed the hearing screening test at 25dB HL for the octave frequencies between 250Hz and 8000Hz, 3) had present speech, language or neurological disorders.

Experimental set-up

The surface EMG system (AD Instrument PowerLab Unit, ML 780 with an eight-channel and Dual Bio Amp Model ML 135) and silver-plated electrodes (10mm in diameter) with electrolyte gel were used. The PowerLab Chart 5 program was used for recording the surface EMG signals. The stimuli were presented using the Labview program. The Labview program also provided a real time calculation of the root-mean-square (RMS) values for the surface EMG voltage at the thyrohyoid site and displayed it to the participants as biofeedback.

Abrasive scrub was applied to the participant's orofacial and thyrohyoid site to clean the skin surface. Electrodes (Figure 1), with electrolyte gel to reduce the electrode-skin impedance, were then positioned. One pair was placed at the orofacial site (which is at 1cm away from the lip corner on each side of the face) while the other pair was placed at the thyrohyoid site (which is at 0.5cm away from the midline of the thyrohyoid membrane) (Figure 2). The two sites were selected as the points of measurement since they enabled relatively stable surface EMG signals to be captured (Yiu, et al., 2005). After that, a dry earth strap was wrapped around the participant's wrist to provide a reference voltage point for the surface EMG. After all the set-up, the participant was asked to rotate their head to ensure no movement artifact was shown on the surface EMG signal.

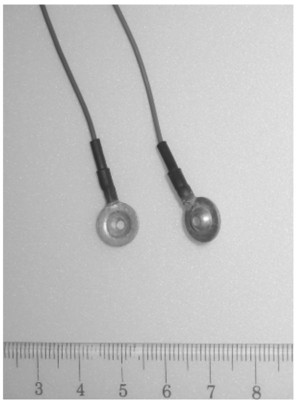

Figure 1. The silver-plated electrodes for the surface EMG (Yiu, et al., 2005)

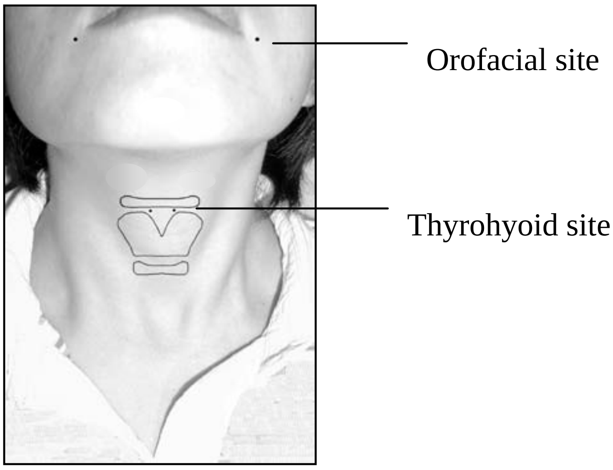

Figure 2. Two sites of surface electrode placement in this study (Yiu, et al., 2005)

Training stimuli

The training list consisted of 24 Cantonese target characters (as adapted from Yiu, et al., 2005) (Appendix A), which were embedded in the Cantonese carrier phrase /ji_1 kO_3 hAi_6 (target character)/, meaning “This is (target character)”, to form sentence stimuli. The characters covered all the phonemes (19 consonants, 8 vowels, 10 diphthongs) and 6 lexical tones in Cantonese.

Procedure

Each participant attended eight training sessions on relaxed phonation therapy twice per week, plus one pre-training and one post-training measurement session. The number of training sessions was determined based on the studies by Carding, Horsley, and Docherty (1999) and by MacKenzie, Millar, Wilson, Sellars, and Deary (2001), both of which examined the effectiveness of voice therapy for functional dysphonia. They implemented an eight-session voice therapy program on a weekly basis and demonstrated treatment effect.

The participants took part individually in the experiment in a sound-treated booth. They sat approximately one metre from the 17-inch computer monitor, which displayed the stimuli and the biofeedback. The experimental design of the study was outlined in Appendix B.

Pre-training baseline (session 1). The participants were required to read aloud four blocks of stimuli (24 sentences per block). Within each participant, the stimuli in each block were presented in random order, whereas the order of presentation of stimuli across participants was fixed. They were also required to read aloud the paragraph “北風和太陽” (North Wind and the Sun) (Yiu & Chan, 2003) (Appendix C). They were instructed to read aloud the stimuli at their most comfortable pitch and loudness. No feedback was given during the baseline phase but the EMG signals for each sentence were saved for later analysis.

Training phase (session 2 – 9). The Labview interface (Figure 3) was introduced to each participant at the beginning of the experiment. The interface presented the sentence stimuli and prompted the participants to read aloud each word in the sentence. The root-mean-square (RMS) value of the EMG voltage at the thyrohyoid site for each sentence was calculated instantaneously after reading each sentence. It was then shown as a numerical value at the top of the interface as biofeedback.

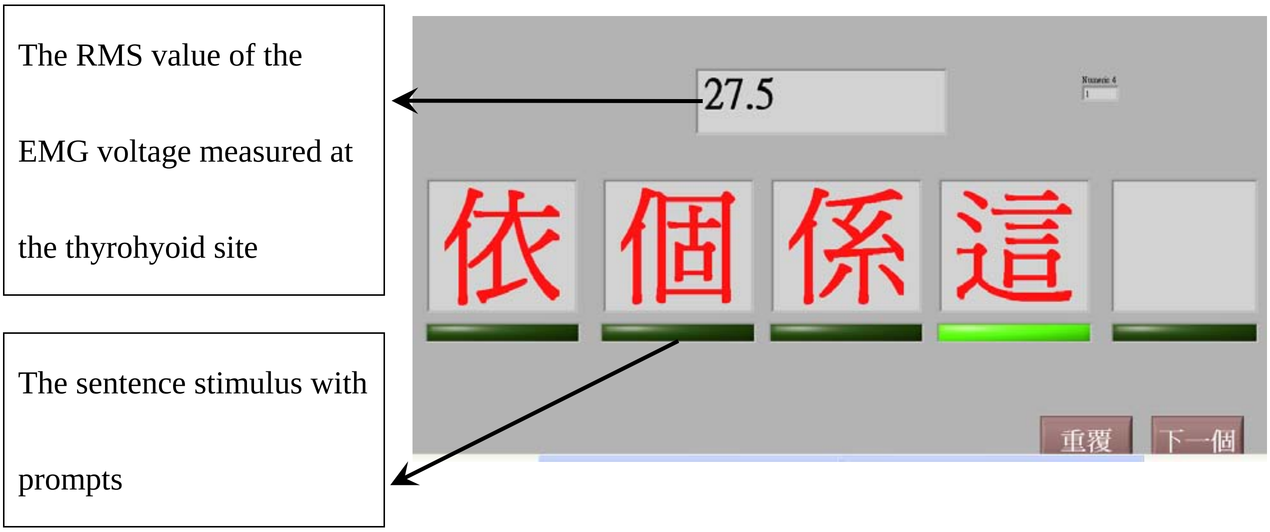

Figure 3. The Labview interface

The participants were randomly assigned into two groups: internal focus group (seven participants) and external focus group (six participants). They were trained on the four blocks of stimuli. Both groups were shown the RMS values of the EMG voltage at the thyrohyoid site as biofeedback through the Labview interface after reading every two sentences. However, interpretation of the feedback was different (Wulf, 2007a). The internal focus group was told that the values represented the muscle tension at the thyrohyoid site. The larger the number the more tension was in the thyrohyoid area. The external focus group was informed that the values represented the strained quality of their voice. The larger the number the more strained was their voice. Both groups were instructed to reduce the RMS values for every stimulus. Each participant was reminded the interpretation of the feedback at the beginning of every stimuli block (i.e., every 24 sentences). The instructions given to each group was shown in Appendix D.

Post-training measurement (session 9 – 10). An immediate retention test using the trained stimuli was carried out 15 minutes after the last training session (session 9). A delayed retention test using the trained stimuli was administered one week after the last training session. Two transfer tests were also conducted. The first one was reading the untrained paragraph "北風和太陽". The second transfer test was reading the four blocks of trained stimuli against background noise. No feedback was given, but the EMG signals for each sentence were saved for later analysis.

When reading against background noise, the participants were presented a noise recorded at a Chinese restaurant of average level of 60dB through an open headphone (AKG K601). They were shown a figure which was placed one metre away in front of them and they were instructed to imagine that the figure also experienced the same restaurant noise. They were then instructed to read aloud the 24 trained sentences so that the figure could hear what they said. In order for the participant's speech to be audible to the figure, their loudness must be at least 15dB above the average noise level (Boothroyd, 2004). Therefore, the participant's voice loudness was monitored to be at least 75dB when measured at one metre away. The participant's voice was recorded through a microphone (AKG C420) placed at 5cm from their mouth corner. The labview programme was pre-calibrated to figure out a reference to the target loudness level of 75dB. Their voice loudness was then compared with the reference. If the participants failed to reach the target loudness level for a particular stimulus, that trial would be discarded and the participants would be required to repeat that particular trial.

Results

Learning Effects

A three-way within- and between-subjects analysis of variance (ANOVA) was used to determine the learning effects. The within-subject variables included the time (11 measurement points across baseline, training and retention tests) and the electrode sites (orofacial and thyrohyoid sites). The between-subject variable included the focus of attention (internal focus and external focus).The dependent variable included the root-mean-square values of the EMG voltage (averaged from each sentence).

The data violated the assumption of sphericity, as demonstrated by the result of the Mauchly's Test of Sphericity (p = 0.0001). Therefore, multivariate statistics results were used for analysis (Pallant, 2005). The multivariate Pillai's trace ANOVA was used to examine the main effects of the independent variables and the interaction effects between these variables, as it was regarded as a robust test against violation of assumptions in multivariate tests (Coakes, Steed, & Price, 2008). The level of significance p = 0.05 was set for the statistical analysis. Table 1 lists the means and standard deviations of the surface EMG voltages for both groups of participants across the 11 measurement phases.

Table 1. *Means (and standard deviations) in microvolt of the root-mean-square of the surface EMG voltage at the orofacial and thyrohyoid sites for internal and external focus group across the 11 measurement time points.*

	Baseline	Training								Immediate Retention	Delayed Retention
		1	2	3	4	5	6	7	8		
INTERNAL FOCUS GROUP											
Pooled data	**34.50**	**28.85**	**40.56**	**34.21**	**31.82**	**32.83**	**37.95**	**51.52**	**30.29**	**35.38**	**32.65**
Thyrohyoid site	15.72	14.43	13.84	13.84	14.72	13.57	13.15	14.17	13.86	13.63	13.89
	(5.48)	(4.06)	(3.81)	(4.06)	(5.35)	(3.76)	(3.43)	(5.12)	(3.71)	(3.44)	(2.96)
Orofacial site	53.27	43.26	67.27	54.57	48.92	52.08	62.75	88.86	46.71	57.13	51.40
	(10.36)	(12.22)	(34.80)	(23.18)	(11.81)	(14.42)	(38.68)	(88.56)	(10.67)	(14.92)	(11.07)
EXTERNAL FOCUS GROUP											
Pooled data	**41.88**	**38.91**	**36.68**	**36.24**	**37.42**	**43.96**	**39.28**	**34.12**	**50.92**	**47.78**	**33.20**
Thyrohyoid site	19.63	16.53	15.94	15.94	16.24	16.15	17.58	17.80	15.94	17.89	16.07
	(4.45)	(2.32)	(3.28)	(2.70)	(4.35)	(3.70)	(5.00)	(4.73)	(3.29)	(6.05)	(3.34)
Orofacial site	64.13	61.29	57.41	56.54	58.59	71.76	60.97	50.44	85.89	77.67	50.32
	(19.92)	(32.47)	(25.38)	(29.35)	(29.89)	(35.92)	(22.13)	(18.01)	(66.91)	(48.29)	(16.54)

Time effect. The multivariate Pillai's trace ANOVA revealed that the main effect of time was significant [F (10, 2) = 25.61, p = 0.04]. From the pooled data, reduction of EMG voltage was seen across the baseline and the delayed retention test for both groups, demonstrating motor learning across time.

Group effect (focus of attention). The main effect of group was not significant [F (1, 11) = 0.51, *p* = 0.49]. The statistical analysis failed to show better learning for one type of focus of attention over another.

Site effect. There was significant main effect of site [F (1, 11) = 67.63, *p* = 0.001]. The thyrohyoid site had a significantly lower EMG voltage than the orofacial site.

Interaction effects. None of the interactions attained the significant level of 0.05 (time by group interaction, F = 5.69, *p* = 0.16; site by group interaction, F = 0.10, *p* = 0.76; time by site interaction, F = 2.14, *p* = 0.36; and time by site by group interaction, F = 1.97, *p* = 0.38).

Generalization Effects

Two transfer tests were carried out. One studied the effect of generalization of motor learning to reading of untrained paragraph "北風和太陽", while the other studied the transfer of motor learning to reading against background noise.

A three-way within- and between-subjects analysis of variance (ANOVA) was used to examine the generalization effects. The within-subject variables included the time (two measurement phases) and the electrode sites (orofacial and thyrohyoid sites). The between-subject variable included the focus of attention (internal focus and external focus).The dependent variable included the root-mean-square values of the EMG voltage (averaged from each sentence).

<u>Reading of paragraph</u>

Table 2 shows the means and standard deviations of the surface EMG voltage for the internal and external focus group across two measurement phases that were used to study the generalization effect to paragraph reading.

Time effect. There was no significant main effect of time [$F (1, 11) = 2.49$, $p = 0.14$]. The statistical analysis failed to demonstrate generalization of laryngeal relaxation to reading paragraph at the end of the training.

Group effect (focus of attention). The main effect of group was not significant [$F (1, 11) = 3.16$, $p = 0.10$]. The internal and external focus groups were not different in generalization performance of laryngeal relaxation to reading paragraph.

Site effect. There was significant main effect of site [$F (1, 11) = 63.30$, $p = 0.001$]. The thyrohyoid site had a significantly lower EMG voltage than the orofacial site.

Interaction effects. None of the interactions attained the significant level of 0.05 (time by group interaction, $F = 0.31$, $p = 0.59$; site by group interaction, $F = 0.15$, $p = 0.71$; time by site interaction, $F = 0.11$, $p = 0.75$; and time by site by group interaction, $F = 0.04$, $p = 0.84$).

Table 2. *Means (and standard deviations) in microvolt of the root-mean-square of the surface EMG voltage at the orofacial and thyrohyoid sites for internal and external focus group across two measurement phases for paragraph reading.*

	Pre-training baseline (Reading of paragraph)	**Transfer test (Reading of paragraph)**
INTERNAL FOCUS GROUP		
Pooled data	**21.36**	**19.51**
Thyrohyoid site	12.88	10.90
	(4.95)	(3.40)
Orofacial site	29.84	28.12
	(4.82)	(5.75)
EXTERNAL FOCUS GROUP		
Pooled data	**27.43**	**23.56**
Thyrohyoid site	18.30	13.86
	(6.90)	(3.99)
Orofacial site	36.55	33.26
	(8.88)	(15.77)

<u>Reading against background noise</u>

Table 3 shows the means and standard deviations of the surface EMG voltage for the internal and external focus group across two measurement phases that were used to study the generalization effect to reading against background noise.

Table 3. *Means (and standard deviations) in microvolt of the root-mean-square of the surface EMG voltage at the orofacial and thyrohyoid sites for internal and external focus group across two measurement phases for reading against background noise.*

	Pre-training baseline (Reading of sentences at quiet environment)	**Transfer test (Reading of sentences against background noise)**
INTERNAL FOCUS GROUP		
Pooled data	**34.50**	**44.69**
Thyrohyoid site	15.72	15.88
	(5.48)	(5.00)
Orofacial site	53.27	73.49
	(10.36)	(22.66)
EXTERNAL FOCUS GROUP		
Pooled data	**41.88**	**49.31**
Thyrohyoid site	19.63	18.45
	(4.45)	(3.70)
Orofacial site	64.13	80.16
	(19.92)	(43.99)

Time effect. The main effect of time was significant [F (1, 11) = 8.36, $p = 0.02$]. The pooled data showed that the muscle tension measured at the transfer test was higher than that at baseline for both groups.

Group effect (focus of attention). The main effect of group was not significant [F (1, 11) = 0.74, $p = 0.41$]. The internal and external focus groups were not different in generalization performance of laryngeal relaxation to reading against background noise.

Site effect. There was significant main effect of site [F (1, 11) = 63.35, p = 0.001]. The thyrohyoid site had a significantly lower EMG voltage than the orofacial site.

Time by site interaction. The ANOVA result revealed that the time by site interaction effect was significant (F = 6.29, p = 0.03). Figure 4 shows the pooled group data of the change of muscle tension measured at baseline and at transfer test of reading against background noise for the two electrode sites. Maintenance of EMG value across time was observed at the thyrohyoid site while increase in EMG value was noted at the orofacial site.

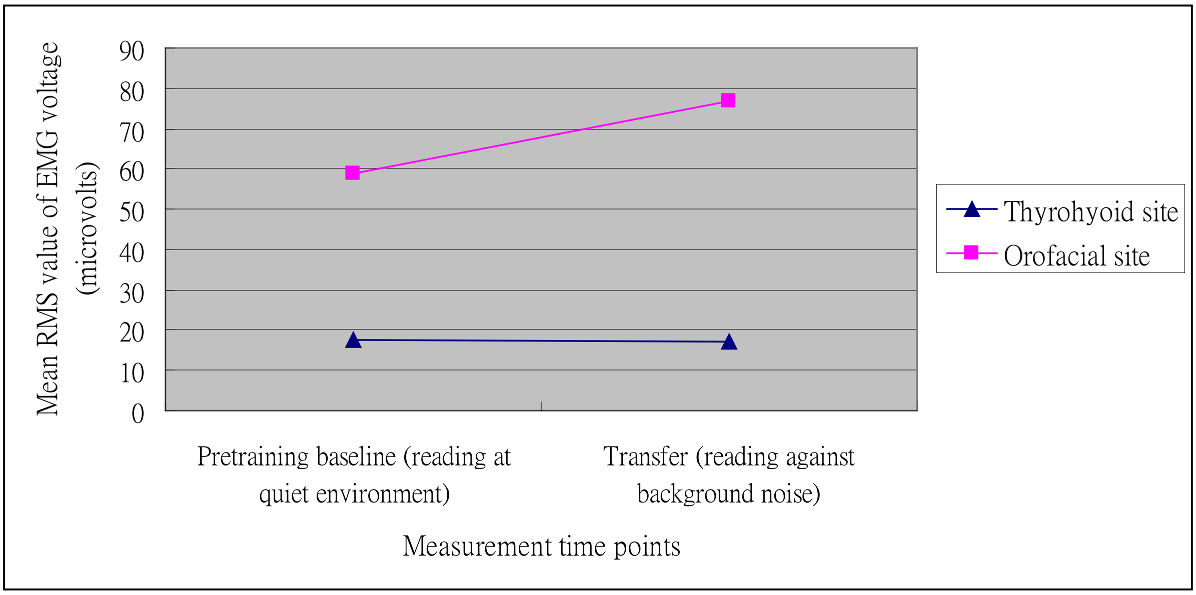

Figure 4. Change of muscle tension of the participants across two measurement time points at thyrohyoid and orofacial sites.

Other interaction effects. None of other interactions attained the significant level of 0.05 (time by group interaction, F = 0.21, p = 0.66; site by group interaction, F = 0.19, p = 0.67;

and time by site by group interaction, F = 0.04, $p = 0.85$).

Discussion

The present study aimed at investigating the effects of focus of attention induced by feedback on motor learning of a relaxed phonation task. It was hypothesized that feedback that directs learners' attention to the effects of laryngeal relaxation (external focus of attention) would facilitate better learning than the feedback that directs their attention to the biomechanics of laryngeal relaxation (internal focus of attention). Nevertheless, the results did not support the hypothesis. The internal and external focus group did not differ in the motor learning of the relaxed phonation task. A possible explanation for the present findings was associated with the interaction between focus of attention and task difficulty.

Wulf, Töllner, and Shea (2007) proposed that the learning advantages of external attentional focus over an internal one would take place only when the task of practice was relatively demanding for the participants. This suggestion was made based on the "constrained action hypothesis", which was used to explain the learning benefit of external focus of attention. According to this theory, directing learner's attention to movement effects benefits learning because of its potential to promote a more automatic control process, when compared to the internal focus of attention (Wulf, McNevin, & Shea, 2001). If the relaxed phonation task was relatively easy for the participants, they would already be adopting an automatic motor process in movement control. Directing their attention to effects of laryngeal relaxation would not produce additional benefit on motor performance (Wulf, et al., 2007). Likewise, when participants' attention was directed to the biomechanics of laryngeal relaxation, they would not be tempted to intervene the already automatic motor control process that was used to perform the task (Wulf, 2007a). In contrast, if the task in this study was a relatively challenging task for the participants, it would encourage more conscious intervention to the motor control when participants' attention was directed to the biomechanics of the movement (Wulf, et al., 2007). Directing their attention to the effects of laryngeal relaxation would then promote better learning.

In the present study, vocally healthy participants rather than dysphonic patients were used. The relaxed phonation task might be considered a relatively effortless task for vocally healthy individuals while the same task might be relatively challenging for dysphonic patients. Therefore, the external focus of attention did not produce a notable benefit on the motor learning in this study. It would be interesting to replicate the present study on a group of dysphonic patients and evaluate if the advantages of external focus of attention is demonstrated.

Although the findings did not demonstrate the benefits of one types of attentional focus over another, the pooled data showed that the EMG voltage was significantly reduced across time for both groups. This indicated that the relaxed phonation task used in this study was effective in reducing laryngeal muscle tension.

Interesting findings were also noted in the transfer test of reading against background noise. Significant time by site interaction was revealed in this transfer test. From figure 4, it can be noted that the muscle tension for the thyrohyoid site in the transfer test was maintained at similar level as in the baseline, whereas the muscle tension for the orofacial site increased in the same test. Generalization of motor learning effect to the transfer test at thyrohyoid site can be demonstrated when considering the knowledge of the phonation mechanism.

When speaking against background noise, the participants would speak with increased loudness. In this case, the vocal folds had to adduct strongly to create an increased medial compression that provided an increased resistance of the laryngeal valving for appropriate air pressure level to build up (Colton, Casper, & Leonard, 2006). It would be possible that laryngeal muscle tension would increase when one tried to raise their loudness, resulting in generally greater EMG values in the transfer test of reading against background noise when compared with the baseline. After the training, however, the EMG values at the thyrohyoid site when reading against background noise was not raised, but remain almost unchanged. This indicated generalization of relaxed phonation to reading against background noise at the thyrohyoid site, for which feedback was given, so that the muscle tension would not increase with raised loudness. However, this transfer of learned skills was not seen in the orofacial site, for which feedback was not given. This suggested that at the site where feedback was given, transfer of learned motor skills was more prominent. This result, nevertheless, contradicted with that from Yiu and his colleagues (2005), which revealed better learning at the unattended oro-facial site than the attended thyrohyoid site. It would be of interest to replicate the study with the feedback given only on the oro-facial site and note if similar findings are revealed.

Another transfer test (reading the untrained paragraph 北風和太陽), however, did not yield similar significant results to indicate generalization. The differences in the participant's performance between the two transfer tests may be explained in terms of the transfer test's task similarity with the training task. Transfer of learned motor skills was related to the task similarity between the training task and the transfer task (Schmidt & Lee, 1999). Higher similarity would facilitate better transfer of skills. From the current findings, the change in the stimuli type (reading an untrained paragraph) might be considered more different from the training task when compared with the change in task environment (reading the trained stimuli against background noise). With lower similarity with the training task, the learned motor skills may not be able to transfer to reading of paragraph.

Limitations of the present study and future research directions

<u>Inclusion of dysphonic participants</u>

The learning benefits of external focus of attention may vary as a function of task difficulty. In this study, only vocally healthy individuals were used. The relaxed phonation task may be relatively easy for these participants. Therefore, the advantages of external focus of attention were not demonstrated. Dysphonic patients can be targeted in future studies in order to examine the effect of focus of attention on voice motor learning for this group, as well as to evaluate the hypothesis of interaction between focus of attention and task difficulty.

Larger sample size

In the present study, there were only 13 participants (seven participants in the internal focus group and six participants in the external focus group). The sample size may not be large enough for the effects of attentional focus to be demonstrated. Future researches should target at a larger sample size in order to reveal the group differences.

Clinical implications

The results of the present study suggested that the relaxed phonation task employed was effective in reducing laryngeal muscle tension. Generalization of relaxation at the thyrohyoid site from reading at quite environment to reading against background noise was also demonstrated. The results have important implication for carry-over of relaxed phonation skills learned in clinical settings to daily life situations.

Conclusion

This was the first study that systematically evaluated the effects of feedback-induced focus of attention in the field of voice motor learning. Although group (focus of attention) difference in learning of a relaxed phonation task was not revealed, transfer effect to reading against background noise was noted. It is recommended to further investigate the replication of these findings in dysphonic population so that the effectiveness of voice therapy could be optimized.

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Appendix A

Target characters

Target Stimuli	IPA Symbol	Order of frequency based on Ho (1993)	Target Stimuli	IPA Symbol	Order of frequency based on Ho (1993)
1. 的	tɪk$_{55}$	1	13. 情	ts^{h}ɪŋ$_{21}$	176
2. 不	pɐt$_{55}$	4	14. 每	mui$_{23}$	196
3. 有	jɐu$_{23}$	5	15. 月	jyt$_{22}$	216
4. 在	tsɔi$_{22}$	6	16. 教	kau$_{33}$	231
5. 了	liu$_{23}$	7	17. 老	lou$_{23}$	239
6. 我	ŋɔ$_{23}$	9	18. 片	p^{h}in$_{33}$	246
7. 為	wɐi$_{22}$	10	19. 給	k^{h}ɐp$_{55}$	259
8. 這	tsɛ$_{35}$	11	20. 男	nam$_{21}$	328
9. 水	sœy$_{35}$	75	21. 父	fu$_{22}$	332
10. 起	hei$_{35}$	104	22. 卻	k^{h}œk$_{33}$	461
11. 解	kai$_{35}$	117	23. 談	t^{h}am$_{21}$	464
12. 果	kwɔ$_{35}$	171	24. 群	kw^{h}ɐn$_{21}$	716

The selection of target words was based on its order of frequency (Ho, 1993)

Appendix B

The experimental design

Training phases	Tasks
Pre-training baseline (session 1)	- reading of 4 blocks of sentence stimuli - reading of paragraph (北風和太陽)
↓	
Training phase (session 2 – 9)	- reading of 4 blocks of sentence stimuli
↓ *15 minutes after session 9*	
Immediate retention test (session 9)	- reading of 4 blocks of sentence stimuli
↓ *1 week after session 9*	
Delayed retention test (session 10)	- reading of 4 blocks of sentence stimuli
Transfer test (session 10)	- reading of paragraph (北風和太陽) - reading of 4 blocks of sentence stimuli against restaurant background noise presented at 60dB

Appendix C

The paragraph stimuli in the pre-training measurement and the transfer test

北風和太陽

有一天，北風和太陽爭論說，到底誰的本領高。當他們爭論的時候，有一個人經過，他正穿著一件厚厚的黑色外衣。

因此他們便說，看看誰能脫去那人身上厚厚的外衣。

北風首先狠狠的吹。可是他越吹得狠，那個人就越把外衣拉緊。

所以，北風就放棄了。

一會兒後，太陽出來了。那個人很快便將外衣脫下來。北風只好承認太陽較他厲害。

Note: The passage was from ‘North Wind and the Sun’ of Yiu and Chan (2003).

Appendix D

Instructions and interpretation of biofeedback for the internal focus group

"A sentence will be displayed on the computer screen. You have to read aloud the sentence with a steady speed, with the help of a green indicator under each word of the sentence. A number index will be shown on the top of the screen after every twice of your productions. It represents your laryngeal muscle tension during reading. The greater the number, the tenser your laryngeal muscle is. You should aim at reducing this number throughout the session."
"每次電腦瑩光幕會顯示一句句子，你需依照每個字下的綠色燈提示，把句子均速地讀出來便可。你每讀完兩句，瑩光幕上方會顯示一個數字，它代表了你讀句子時頸部肌肉的收緊程度，數字越高，代表你的頸部肌肉收得越緊，你的目標是把這個數字的數值降低。"

Instructions and interpretation of biofeedback for the external focus group

"A sentence will be displayed on the computer screen. You have to read aloud the sentence with a steady speed, with the help of a green indicator under each word of the sentence. A number index will be shown on the top of the screen after every twice of your productions. It represents the strained quality of your voice. The greater the number, the more strained your voice is. You should aim at reducing this number throughout the session."
"每次電腦瑩光幕會顯示一句句子，你需依照每個字下的綠色燈提示，把句子均速地讀出來便可。你每讀完兩句，瑩光幕上方會顯示一個數字，它反映了你的聲線聽起來的緊張程度，數字越高，代表你的聲線聽起來越緊張，你的目標是把這個數字的數值降低。"