ESL Learner Experience Using Electropalatographic Biofeedback

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A project submitted to the faculty of Brigham Young University in partial fulfillment of the requirements for the degree of Master of Arts

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ABSTRACT

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With advances in modern technology, different tools have been developed to provide second language learners with targeted pronunciation feedback. One such tool is Electropalatography (EPG), a computer-based system that provides immediate visual biofeedback to the learner and the instructor by tracking how the tongue touches the palate during speech (Fletcher, 1992; Fletcher, McCutcheon, & Wolf, 1975).

To investigate the experience of the learner in using an EPG sensor, this research reports on a study conducted with nine Asian learners of English as a second language (Korean, Taiwanese, Chinese, and Japanese) wherein quantitative and qualitative data was collected from participants who had been fitted with a SmartPalate sensor and received 12 sessions of 40-minute pronunciation instruction over a seven-week period. Surveys and interviews were conducted with the participants and the pronunciation instruction was observed.

The results revealed that the participants perceived this EPG sensor to be effective at helping them gain awareness of correct tongue placement. They also believed it was a somewhat socially acceptable tool with user-friendly software. They appreciated teachers’ individual attention and organization of activities in its use. If the price of the sensor is acceptable and its effectiveness in helping learners acquire phoneme production within an acceptable range is proven, they believed most ESL students from these Asian countries (South Korea, Taiwan, China, and Japan) would want to use the sensor. However, learners did comment on experiencing initial strangeness in adjusting to the sensor, and a sustained discomfort in its use. There were instances where learners reported the sensor initially distorting the users’ articulation of certain phonemes and examples of faulty manufacturing. The learners reported experiencing difficulties with pronouncing the phonemes and a lack of consistent use of the sensor. Suggestions for future use included having more in-class activities and adjusting the class schedule to make the course longer.

Keywords: electropalatography, ESL, L2 pronunciation, EPG sensor, learner experience
ACKNOWLEDGEMENTS

The process of finishing a project of this length over a time span of two years is exceptional. I wish to sincerely thank my advisor Dr. Mark Tanner for his guidance throughout this project and assistance to edit the manuscript. I also wish to express my gratitude to Dr. K. James Hartshorn for assisting me with statistical analysis, and to my friends Kaitlyn VanWagoner, Laura Decker, and Rui Ma for helping me during the writing process. In addition, I want to thank my translators Yoonjoo Lee and Yuri Nakamatsu as well as my family for their wholehearted support. Lastly, I want to acknowledge research grants from the Fletcher Bio-communication Endowment and from Complete Speech for providing funding for the EPG sensors and supporting the work carried out for the EGP study by Nissen et al. (2016) from which this study benefitted in its evaluation of learners’ experiences with the SmartPalate sensors.
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Preface

This project is prepared as a manuscript in compliance to BYU’s TESOL MA program guidelines. It is planned to be submitted to the *Journal of Second Language Pronunciation* because of its focus. The *Journal of Second Language Pronunciation* is a scholarly journal that publishes research in the acquisition, perception, production, teaching, assessment, and description of prosodic and segmental pronunciation of second languages in all contexts of learning. This article would meet the specifications of the journal because of its focus on the instruction of the segmental production of English using electropalatography. Manuscripts that are submitted to this journal should be prepared according to the *Publication Manual of the American Psychological Association* (APA) 6th Edition and contain approximately 8,500 words.

An alternative target journal is *Applied Linguistics*. This journal is dedicated to research into language and language-related problems in specific situations in which people use and learn languages. This article would meet the specifications of the journal because it focuses on the use of electropalatography to assist with segmental pronunciation problems. Manuscripts accepted for publication should not exceed 8,500 words and should be in Oxford HumSoc style.

A third possible journal is *Applied Language Learning*. Focusing on adult language learning for functional purposes, this journal publishes research into topics including implications and applications of research from related fields in linguistics and education, which this article would meet the specifications of. Manuscripts accepted for publication should be not exceed 6,000 words and should be in APA style.
Introduction

Sometimes when second language (L2) learners speak to native speakers of a language, they are met with, “I beg your pardon? Could you repeat that?” or “What did you say, I didn’t understand you.” These responses can make the language learner embarrassed and fearful to speak the new language. This experience illustrates some of the challenges that L2 learners face when learning a new language. Some of these challenges have to do with using the grammar correctly, selecting discourse appropriate for the context, and pronouncing words intelligibly. Research in most studies has shown that immigrants to English-speaking countries identified pronunciation as a main factor to their communication problems, but they do not receive adequate pronunciation instruction to overcome them (Breitkreutz, Derwing, & Rossiter, 2001). For speakers of Korean, Mandarin, Cantonese, and Japanese learning English, pronunciation of the target language has always been difficult as due to the limited pronunciation instruction that learners in these countries received (Kang, 2015).

Research in the field of pronunciation teaching and learning reports that there are particular sounds in English which carry a high functional load (FL) (Brown, 1991; Catford, 1987). Functional load can be defined as the number of words that a particular sound contrast in the language distinguishes (Brown 1991; Catford, 1987). For example, the contrast of /d/ and /z/ (as in road versus rose) in English distinguishes a large number of words and, hence, carries a high functional load. As part of functional load, certain sound contrasts carry more weight than others. Within the list of sound contrasts that carry a high FL, there are some particular sounds such as the /l/ and /ɹ/ contrast that are especially problematic for Japanese and Korean speakers learning English because /r/ and /l/ are not contrastive in the same way that they are in English (Goto, 1971; Borden, Gerber & Milsark, 1983). These sounds function as allophones in these
languages. When Japanese and Korean speakers of English produce these target sounds, they often use them in free variation. Hence, many Asian learners of English have difficulty perceiving and producing the difference between these sounds. Traditional auditory feedback might not be sufficient for learners to acquire these difficult sounds in order to be fluent or intelligible, as it can be challenging for them to visualize the basis of their pronunciation problems. Visualizing appropriately could correct these pronunciation problems.

With advances in modern technology, different tools have been developed that can provide students pronunciation feedback. Some of these tools physically manipulate the tongue placement in its articulation of the sounds of the language. An example of these types of instruments is that of Speech Buddies Placement Tools, which are handheld tools manufactured by Speech Buddies, Inc. These instruments use tactile biofeedback to train the tongue to make correct tongue placement by providing targets that users can feel. Research reports that tools such as these can be helpful with the production of particular sounds such as /s/ and /ɹ/ (Rogers, 2014; Rogers & Galgano, 2011). One challenge though with these types of instruments is that the change in the production of the sounds happens inside the mouth and the learners cannot visualize the progress that might be happening with the use of this type of tool.

There are other tools too that have been created to provide both physiological and visual feedback to augment traditional L2 learning approaches. One such tool is Electropalatography (EPG). This tool uses a retainer-type sensor that fits in the mouth that is attached to a computer via electrodes. The EPG sensor allows learners to see on a computer screen whether particular sounds that can be tracked by this sensor are being produced within an acceptable range. A limited number of small-scope research studies have reported on the use of EPG in second language instruction to assist adult English language learners with the successful production of
certain English consonant contrasts such as /s/ - /ʃ/, /t/ - /θ/, /l/ - /ɹ/ , /z/ - /ʤ/ (Bright, 1999; Gibbon, Hardcastle, & Suzuki, 1991; Schmidt, 2012; Schmidt & Beamer, 1998). While this technology is available, it has been slow to gain attention due to cost of the sensors and accompanying computer equipment and the time-consuming nature of the instruction. Not only does a palate sensor have to be created for each participant, but the use of the sensor also requires that each learner have an individual computer attached to the device to show the visual production of the target sounds as the tongue comes in contact with the hard and soft palate. Moreover, teachers in such a course need to be trained in using the sensors and fitted for a sensor themselves.

While quantitative research on the output produced by learners using EPG sensors has increased, few studies have been conducted to capture the shared experiences of learners using these tools in the ESL classroom for the purpose of targeting improvement in a segmental contrast. In research studies where EPG technology has been used, it would seem important to gather data regarding learners’ positive and negative comments about the device, challenges, and recommendations on undergoing pronunciation improvement training with an EPG sensor in a classroom setting. The need to study learners’ experiences with these sensors is critical if their use is to become more widespread.
Review of Literature

Asian Speakers’ Pronunciation Needs

Pronunciation is a crucial component of clear communication between interlocutors in global contexts (Derwing & Munro, 2005), but it has largely been ignored in the EFL (English as a Foreign Language) classroom. Kang (2015) found that students in what has been described as the Expanding Circle—including countries such as China, Japan, and South Korea where English is spoken as a foreign language—were particularly dissatisfied with the pronunciation instruction they received, because of the limited availability of the instruction or the lack of attention the instruction specifically gave to pronunciation. When Kang (2015) asked about pronunciation instruction in the Expanding Circle, a Japanese respondent’s answer showed the learner’s desire for pronunciation instruction. He said, “I know pronunciation is important because it affects my communication. But our teachers don’t have time for pronunciation in school.” (p. 71)

There is a myriad of specific segmental problems that Asian learners face (Swan & Smith, 2003). For Asian speakers learning English in general, word final consonants can be problematic since there are few in languages such as Chinese and Korean. They either delete the consonant at the end of a word, such as producing the word *hill* without the double *ll* while the *i* vowel is drawn out, or they add an extra vowel at the end of the word. For example, the word *church* becomes /tʃɹərtʃɪ/ according to the International Phonetic Alphabet, where an additional vowel sound is added to the end of the word, changing the coda /tʃɪ/ to an onset followed by the vowel /ɪ/ creating an additional syllable. A group of consonants with no intervening vowel (‘consonant clusters’) can be problematic as well, since there are few in Japanese and Chinese lacks this clustering of consonant sounds as they occur in English. Learners tend to break them up by...
inserting short vowels or simplifying the cluster, so that the word *dogs* may be pronounced as /dɒɡəz/ or /dɒɡ/ with the final –s sound deleted. The susceptibility of consonant assimilation to the sound environment (‘coloring’) is also an issue, where Koreans will assimilate /f/ to /p/ and /z/ to /dʒ/. Voiced fricatives seem to be avoided when possible. For example, /b/, /ʃ/, or /w/ are often used to substitute /v/, where learners say *berry* instead of *very*, *invite* as *inwite*, and *live* pronounced ‘*lif*’. While /ð/-/θ/, /l/-/ɹ/, and /v/ all present problem areas regardless of word placement or environment, the most noticeable struggle for many is the insufficient ability to differentiate /l/ and /ɹ/ sounds; learners may mispronounce *rake* and *rice* as *lake* and *lice* (Swan & Smith, 2003).

**Effects of Pronunciation Instruction on Learners’ Segmental Production**

Research shows that adult learners’ L2 pronunciation can be improved to become more intelligible as a result of instruction. Flege’s study (1980) of Saudi Arabians suggested that adult learners can alter their L2 speech production to better approximate the phonetic representations in the native language (L1). Purcell and Suter’s (1980) study of non-native speakers of English found that native language (L1), speakers’ ability to imitate oral production, length of residency, and the level of concern for pronunciation were all predictors of the eventual skill level nonnative speakers could reach. All of these factors affect their *ultimate attainment*, or when L2 learners have essentially stopped acquiring the phonology of an L2. Within these factors, the learner’s level of concern for pronunciation can be greatly affected by pronunciation instruction. Raising learners’ awareness of the importance of pronunciation during instruction can help them acquire the L2 phonology. Two empirical studies focused on the effect of pronunciation instruction also found significant changes in L2 learner’s intelligibility, comprehensibility, and degrees of accentedness as a result of instruction (Derwing, Munro & Wiebe, 1997; 1998).
Studies have indicated that although segmental instruction can be beneficial when students were asked to read sentences aloud, the effect of this instruction may not transfer to spontaneous speech (Derwing et al., 1998; Elliott, 1997). Suprasegmental instruction, on the other hand, can produce a significant positive effect on listeners' perceived comprehensibility of spontaneously produced utterances (Derwing et al., 1998). Mispronunciation of segmentals with a high FL can still compromise intelligibility and cause communication breakdowns (Lambacher, 1999). Derwing et al. (1998) hence support an instructional approach that includes both segmentals and suprasegmentals while emphasizing the prosodic elements.

Both theoretical assertions (Flege, 1995; Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Liberman & Mattingly, 1985) and empirical studies (e.g. Flege, Bohn & Jang, 1997; Flege, Mackay, & Meador, 1999; Baker & Trofimovich, 2006) have supported a close link between speech perception and speech production. For learners who are unable to perceive the difference between sounds, visual feedback is useful because it shows if the production of a sound falls into an acceptable range on a computer screen. The language learner can then associate correct tongue placements with the sounds before they can actually hear the difference clearly. It may be difficult for students to hear the difference at first, but they can feel it and see it on the computer screen. With visual feedback, they can eventually learn to connect placement of the articulators as associated with how the various contrasting sounds are produced.

**Technology Designed for Pronunciation Feedback**

Several forms of technology have been developed over the years to provide pronunciation feedback to learners. There are visual feedback programs that are software-driven, including Visi-Pitch acoustic analysis software (Kay Elemetrics, 1986), the Praat program (Boersma, Paul...
& Weenink, David, 2017), a sound spectrograph, and Automatic Speech Recognition (ASR). By displaying waveforms and intensity scales, Visi-Pitch, Praat, and a spectrograph show the production of sounds. However, these graphs can be difficult to read because the users will need basic knowledge of articulatory phonetics in order to interpret the meanings behind the graphs (Brett, 2004). ASR tools show learners in written form their utterances that the technology recognizes. However, there are still technological barriers for ASR tools to recognize varying aspects of speech, due to factors such as background noise, weak representation of grammatical and semantic knowledge, and speech variability (Benzeghiba et al., 2007).

A visual feedback tool that has been growing in demand is EPG. EPG is a computer-based system first introduced in 1975 by Fletcher, McCutcheon, and Wolf. As shown in Figure 1, it uses a custom-made artificial palate (Palatometer) that looks like an orthodontic retainer to provide immediate visual biofeedback by tracking how the tongue touches the palate during speech (Fletcher, 1992; Fletcher et al., 1975). The Palatometer contains 124 electrodes arranged in a grid pattern across its surface. When touched with the tongue, the electrodes light up on a computer screen showing the learner where the tongue and palate are in contact. In speech pathology, EPG has been shown to be useful in a one-on-one setting in remediation of speech disorders such as articulation disorders (Dagenais, Critz-Crosby and Adams, 1994; Dent, Gibbon and Hardcastle, 1995), cleft palate (Gibbon & Crampin, 2001), apraxia of speech (Hardcastle & Edwards, 1992), and hearing-impaired speech (Dagenais, Critz-Crosby, Fletcher and McCutcheon, 1994).

Advancements in EPG offer instructors of an L2 a new method of directing attention to the specifics of articulation to assist learners with oral language production. The visual representations of the tongue-palate (linguopalatal) contact patterns provides dynamic visual
biofeedback, helping the learner adjust such contact to better approximate how a native speaker of the language produces the target sounds. Due to the invention by Complete Speech (2016) of a more affordable and thinner (0.5 – 2 mm) sensor compared to previous EPG sensors (Dagenais, 1995; Sanders, 2007), the demand for the use of EPG in instruction has increased recently. The SmartPalate system consists of a mouthpiece (‘EPG sensor’) designed to contour the hard palate of a speaker and a microprocessor called a DataLink, which synchronizes the palate data with audio feedback. The system connects to the computer via a Universal Serial Bus (USB) port. (See Figure 1.)

Figure 1. The SmartPalate system, including the EPG sensor and the DataLink processor (laptop not included).


L2 learners could benefit from EPG because it could help them correct their tongue placement. L2 learners seldom suffer from speech disorders and can articulate their L1 accurately. However, they are likely to use similar sounds from their L1 when they speak the L2, resulting in a foreign accent based on listener ratings (Schmidt & Beamer, 1998). Such L1 influence will probably result in an insufficient ability to use the tongue to touch the correct
areas of the mouth to generate intelligible phonemes in their L2. Some sounds in an L2 are easier to be acquired with limited auditory instruction because they are similar to those in the L1, while some languages contain sound contrasts that are difficult to acquire by nonnative speakers (Gibbon et al., 1991), such as the English /l/ and /ɹ/ contrast for native Japanese speakers and the Russian palatalized and unpalatalized consonants for native English speakers (Hacking, Smith, Nissen & Allen, 2016). EPG can be used to develop new phonological contrasts that are lacking in the L1 but required by the L2 and modify existing phonological contrasts (Schmidt & Beamer, 1998).

A number of previous studies have shown positive effects when EPG has been used for modifying L2 segmentals in a limited scope. A study of three native Spanish speakers learning English with an EPG sensor reported a significant reduction in the speakers’ overall accent after 12 sessions of therapy based on listener ratings (Bright, 1999). Another study (Gibbon et al., 1991) found that EPG was effective in assisting two native speakers of Japanese learning English in making a consistent contrast between /l/ and /ɹ/, at least in controlled contexts during two weeks of L2 instruction. A similar study of two native Korean speakers reported success in their learning to perceive and produce the English contrasts of /s/ - /ʃ/, /z/ - /ɹ/, and /ɻ/ - /ɹ/ (Schmidt, 2012). Likewise, a study by Schmidt and Beamer (1998) reported that three Thai learners of English who utilized EPG in their English learning were successful in modifying consonant articulation of the contrasts /s/ - /ʃ/, /t/ - /θ/, and /ɻ/ - /ɹ/.

However, some problematic phonemes for Korean, Taiwanese, Chinese, and Japanese ESL learners are not detectable by an EPG sensor. It cannot detect the pronunciation of sounds that involve teeth contact with the lips, such as /v/ and /f/, and sounds that involve tongue contact with the teeth, such as /θ/ and /ð/. This means the problems in articulation need to involve
contact between the tongue and the hard palate for the sensor to be able to detect them. The detectable sounds include oral stops (‘plosives’) like /t/, /d/, /k/, and /g/; affricates such as /tʃ/; fricatives like /s/ and /ʃ/, and liquids such as /l/ and /ɹ/. The EPG sensor also does not address voicing distinctions or help with vowel production other than /ɪ/ and /iː/. (High front vowels will show up on the EPG software.) It is appropriate to use the sensor to address problems in the production of specific sound contrasts it can detect.

The Palatometry System

After the sensor is connected to the DataLink processor, inserted into the mouth, and connected to the computer, the users will receive instant visual feedback on a computer screen showing tongue-palate contact when they speak. Figure 2 shows an image of the SmartPalate software 2.0 (Fletcher, 2016) with and without such contact. The tongue touched correctly in the first three rows of dots closest to the front of the mouth; the tongue touched incorrectly in the rest of the mouth with the grey dots. In the first three rows, the empty dots showed the area where it did not make contact and the filled dots showed the area where it made contact. In the original software, the dots with correct contact were in blue and the dots with incorrect contact were in orange. The EPG software allows users to practice target sounds, create custom tongue targets for key sounds, and record and review sessions.
Figure 2. Screenshot of the EPG software during the pronunciation of a phoneme. Area nearest the front of the mouth shows correct tongue-palate contact.


**Previous EPG Research**

Research has recognized both benefits and some physical limitations to the use of EPG sensors in helping learners physically alter their production of particular segmentals in English (Schmidt & Beamer, 1998). Much of the research with EPG has been in clinical settings where the sensor has been used to describe segmental production by second language learners. Only a couple of studies have attempted to report data regarding participants’ experience with a sensor, but most of these reports have not been the focus of the research. In a study by Hickey (1992), she documented the difficulties of a 10-year-old girl in tolerating
the sensor; it was reported that she showed signs of “increased drooling” (p. 83). Others studies have also mentioned an increase in saliva production during sensor use (Hardcastle & Gibbon, 1997; Hardcastle, Jones, Knight, Trudgeon, & Calder, 1989). In a study by Schmidt (2007) where she reviews the clinical use of a new EPG system for 13 clients with different speech sound disorders, she also reported that two of 15 children using the sensor were unable to tolerate the sensor and did not continue with treatment.

Although adaptation is a potential problem for EPG users, there are only few studies that have explored the participants’ attitudes and experiences actually using an EPG sensor. No systematic analysis of learners’ qualitative experience learning from an EPG sensor has been done. McLeod and Searl’s study (2006) provides an anecdotal account of the EPG palate’s impact on seven adults, indicating that wearing the sensor had a significant alteration on speech production, tongue movement, oral sensation, and comfort, causing a third of the participants to exhibit poor adaptation, such as articulatory distortion and unnaturalness. Participants also commented on instances of gagging and increased saliva production. Other studies on adaptation to a sensor support these findings by providing additional information on the palate’s alteration on speech articulation and oral sensation.

McAuliffe, Lin, Robb, and Murdoch (2007) investigated the influence of a standard EPG sensor on three normal female speakers’ speech articulation. The patterns of adaptation among the three were varied. Two participants adapted to the presence of the palate while one did not. The presence of the palate resulted in significant changes to consonant duration for all three participants, while the articulation of /t/ was unaffected and the production of fricatives varied across the participants. A similar study by Searl, Evitts, and Davis (2006) found that the insertion of the sensor changed oral sensation and gave users an unusual feeling of the
sensor in the mouth. An initial alteration to speech production of phonemes /t/ and /s/ (up to 30 minutes) was detectable acoustically, but most speakers adapted rapidly. However, listener ratings reported minimal effects of the EPG sensors on speech. These limited qualitative findings regarding participants’ experiences with a Palatometer-type sensor suggest the need for more formalized research.

**Statement of Problem**

Due to the lack of qualitative studies exploring the use of EPG sensors and learners’ reactions to them, more systemic focused research is needed on learners’ reactions to using this technology in a classroom setting. What are students’ positive and negative comments regarding the use of an EPG sensor? What challenges do they report facing regarding their use of the sensor in a classroom setting? Do learners perceive using EPG as culturally acceptable? What are learners’ suggestions regarding their use of the sensor during a treatment period in a classroom setting?

**Significance of Problem**

It is necessary to have qualitative feedback on the aforementioned questions, because while statistical data might show that the sensor can help with the articulation of target sounds, learners may still have adaptation issues and react strongly to having the EPG sensor in their mouths. It is uncertain what Asian learners’ reactions are as they use the sensor in front of other classmates in a pronunciation class. It will be informative to know to what degree do they associate wearing it—which affects their appearance to some extent—and making pronunciation mistakes to the concept of losing “face” in Eastern culture. It would also be beneficial to know the potential challenges and recommendations of using EPG with this population in order to advise future EPG instruction.
To better understand the effectiveness of SmartPalate technology in facilitating L2 pronunciation, this study therefore collected quantitative and qualitative data to examine the experiences of nine Korean, Taiwanese, Chinese, and Japanese learners of English as a second language (ESL) using this EPG sensor while enrolled in a treatment study wherein the participants not only used the sensor during pre- and post-testing sessions, but also in 12 40-minute instructional sessions of targeted pronunciation practice over the course of seven weeks. The practice involved working with the sensor on the articulation of [l, ɹ, θ, s, ʃ, ɪ, and iː]. The focus of this research centered on the experiences and attitudes of ESL learners toward using the sensor as they received EPG feedback on the targeted sounds.

Research Questions

The following questions were asked of Korean, Taiwanese, Chinese, and Japanese ESL learners as part of this study:

1. What were the participants’ expectations regarding the use of the EPG sensor?
2. While utilizing the EGP sensor in a classroom setting, what positive comments were made regarding its use?
3. While utilizing the EGP sensor in a classroom setting, what negative comments were made regarding its use?
4. What challenges were experienced in a classroom setting while studying with the EPG sensor?
5. What were the recommendations on how the EPG pronunciation classes could be improved?
Research Design

In order to understand the participants’ experience utilizing EPG biofeedback, the method of inquiry chosen in this study was the paradigm of phenomenology. A phenomenological study explores the descriptions of what people experience and how people who have experienced a phenomenon firsthand perceive it, describe it, feel about it and judge it (Bogdan & Taylor, 1984). It studies experience including thought, memory, emotion, and desire. Creswell (2013) describes a phenomenological study as one that investigates the essence, or essential meaning of a firsthand experience. As the focus of this EPG study was to capture and describe the essence of the students’ experience using the sensor to improve pronunciation, phenomenology is utilized in this study by focusing on the shared experiences of the participants. It is a suitable paradigm for this study because the participants’ experiences using EPG can be reduced to a single and descriptive presentation by focusing on the shared themes that arise from students’ experiences.

Since there was no previous literature that has analyzed systematically the students’ quantitative and qualitative experiences learning from the EPG sensor: this study explored such experiences including the sensor’s impact on the students’ level of comfort, speech production, and appearance, as informed by McLeod and Searl’s study (2006).

Context for the EPG Study

This research study investigating learners’ experiences with the EPG sensor in an instructional setting was part of a larger project by Nissen et al. (2016), whose work examined how much (if at all) the use of the EPG sensor during a treatment period actually altered nine research subjects’ pronunciation of targeted phonemes. These research subjects were Asian ESL learners from South Korea, Taiwan, China, and Japan. They had all been previously selected for participation in the study based on an acoustical evaluation where they had been identified as
having varying degrees of difficulty producing the \[l, r, \theta, s, \mathcal{j}, \mathcal{i}, \text{ and } \mathcal{i}:]\) phonemes in English.

As part of the Nissen et al. study (2016), participants had earlier been divided into three groups based on the results of an acoustic analysis: (a) priority students who struggled the most with pronunciation of the targeted phonemes, (b) students who had fewer pronunciation difficulties, and (c) students who had minimal pronunciation difficulties and might not need to use the sensor. Only groups one and two were selected to participate because group three was determined to be of a high enough proficiency level to not warrant their participation. This grouping procedure resulted in a total of nine qualified participants.

Being selected as a participant required the subjects to visit a dental clinic where a mold was taken of their upper palate. The molds were then sent to a company, Complete Speech, where sensors were made for each participant. This process took approximately five business days for Complete Speech to finish making the sensors. Pronunciation class instruction began after the sensors were received.

These participants signed an informed consent for each study. See Figure 3 for a comparison of the instruments used in each study. The funding for the EPG sensors used in both studies was provided by research grants from the Fletcher Bio-communication Endowment and from Complete Speech.
Figure 3. Instruments of the larger study by Nissen et al. (2016) and this current study.

The present study had as its objective to evaluate the participants’ experience with the EPG sensor in the context of the diagnostic testing and subsequent treatment period. A description of the participants, quantitative and qualitative instruments used, and procedures for collecting the relevant experiential data will be reported on in the following sections.

Participants

The participants in this study were nine Korean, Mandarin, Cantonese, and Japanese speakers learning ESL. They consisted of two male (M1–M2) and seven female (F1–F7) adults ranging in age from 21 years old to 42 years old. (Refer to Table 1 for their country of origin and L1.) Participants from these language groups were selected because of the target sounds being studied in Nissen, et al. (2016) and the local availability of students learning ESL at an Intensive English program (IEP).
Table 1

Participants’ country of origin and L1

<table>
<thead>
<tr>
<th>Country</th>
<th>M1</th>
<th>M2</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
<th>F7</th>
</tr>
</thead>
</table>

Note. L1 = native language; M = male participant; F = female participant.

All of the participants had completed high school and some had completed post-secondary education in their countries of origin. All participants had resided in the United States for six months and had been studying ESL at the IEP for four months where they spent a minimum of four hours a day on average speaking English. Participants had been studying English as a foreign or second language for an average of seven years.

In addition to their time participants spent in regular ESL classroom study of reading, writing, grammar, listening, and speaking, these participants were part of a supplemental class where they received instruction and practice on particular English phonemes [l, r, θ, s, ŋ, t, and iː] utilizing an EPG sensor. Participants’ assessed language proficiency on the American Council on the Teaching of Foreign Languages (ACTFL) (2012) scale was between Intermediate Low and Advanced Low. This study was approved by the Institutional Review Board committee prior to the recruitment of participants.

Instruments

The instruments used in this experiential study were designed to capture participants’ attitudes and experiences using the sensor. This was done through the use of surveys, observations, and interviews. Each of these instruments will be further explained in the sections that follow. These instruments were implemented as shown in the EPG Research Calendar in Appendix A. By using these varied research methods (methodological triangulation) and multiple interviewers and raters (investigator triangulation), the participants’ experience using
EPG to improve pronunciation could be interpreted as directly as possible. These instruments also helped to reduce interviewer bias and enhance the validity (reflecting what we believe they reflect) and reliability (producing consistent results) of the data.

**Surveys.** The participants took a total of three surveys over the course of eight weeks, before, during, and after the pronunciation treatment instruction. The surveys were administered at week 0 (a week before the start of the pronunciation class), week 4, and week 7 (See EPG Research Calendar in Appendix A). The first survey was conducted before each participant’s acoustic recording, a procedure conducted in the study by Nissen et al. (2016) in which participants wore and recorded with the sensor for the first time; the second and third surveys were sent to the participants in an email link by the main researcher. Participants completed the surveys on a computer through Qualtrics (https://www.qualtrics.com), a web-based survey platform. Completing the surveys took from five to ten minutes (See Appendix B for the surveys).

**Interviews.** After the completion of mid-EPG-use surveys, all the participants were invited orally by the main researcher to participate in a follow-up face-to-face interview. The same occurred after the post-EPG-use survey. The interviews were conducted in an office at the IEP and were audio recorded. The interviews were semi-structured, which included a list of open-ended questions. These interviews were conducted in the participants’ L1 or in English, based on the person’s English proficiency level and personal preference. If the participant’s proficiency level was lower than Intermediate High, based on the American Council on the Teaching of Foreign Languages standards, the interviews were conducted in their L1. If participant’s proficiency level was equal to or higher than Intermediate High, the interviews were
conducted in English. The participants received candies and cards that they can exchange for goods in exchange for their time.

**Observations.** In addition to collecting survey responses and conducting interviews, all 12 40-minute pronunciation class sessions were observed by the main researcher in the instructional classroom at the IEP. Observation notes were handwritten and included participants’ comments and actions, class routine, and timing. The observations were conducted with passive participation, which means activities were observed in the classroom, but without the observers’ participation (Spradley, 1980). The main researcher introduced herself as a teaching assistant at the beginning of the course along with the teachers. During class routine steps 1 through 3 (See Figure 4), she observed while sitting in a corner of the classroom. She walked around the classroom during individual instruction (step 4) to observe each participant and occasionally assist with the pronunciation of words in the word lists with targeted sounds when called upon throughout all the class sessions. She also accompanied students to the kitchen area during sensor clean up (step 5) to informally interview participants.
**Figure 4.** EPG Pronunciation class routine flow chart

**Data Collection Procedures**

**Survey preparation.** The purpose of the surveys was to collect quantitative and qualitative data on participants’ experience utilizing EPG biofeedback. The quantitative portion of the survey included 30 Likert scale questions (with a range of 1 = strongly disagree to 6 = strongly agree) and seven other multiple-choice questions. The qualitative questions included 19 open-ended questions (See Appendix B for the surveys). The pre-EPG-use survey asked respondents about their demographic information and expectations and concerns about using the sensor. The mid- and post-EPG-use surveys both asked the participants the same questions in order to determine any change in opinions that may have occurred over time. These questions include the comfort and perceived effectiveness of the sensor, the usability of the EPG software,
the amount of feedback received from the teachers and from the software, students’ emotions during EPG use, and their suggestions for future EPG instruction.

The initial pre-EPG-use survey was piloted in a class consisting of ESL students attending the same university. According to the pilot respondents, the first survey took approximately five to ten minutes to complete. Originally, students could not select certain options on the Likert scales due to a programming issue. This technical issue was resolved following the students’ comments. Additionally, the formatting of the survey was modified to be more concise and make data collection easier: the Likert scale options were changed to be consistent across all questions (e.g. “strongly agree” in answer to “How much do you agree or disagree with the following statement: The EPG software is easy to use”) instead of catering to individual questions (e.g. “very easy” in answer to “How easy to use is the EPG software?”). Results from the piloting suggested that the respondents were generally excited to try this new tool and believed that it would be effective in helping them improve their pronunciation. Most respondents disagreed that they would be nervous about using the sensor, while some expressed their concerns about the sensor’s “accuracy” and “reliability.” Some also had the concern, “Does it look good, comfortable when I wear it?” These are valid concerns when a user is considering using the sensor.

**Interview preparation.** In the semi-structured interviews, general questions such as “How was your experience with the EPG sensor in these seven weeks?” were asked to every participant, while specific questions were tailored to each participant’s survey response: “You answered, ‘I think it’s a good [class] program. If it can be longer than now, it will be better.’ How long do you think this course should be?”
Transcription and translation of interview data. A native speaker of Korean and a native speaker of Japanese were recruited to (a) translate interview questions and surveys from English to the subjects’ L1; (b) translate survey responses from the subjects’ L1 back to English; (c) conducted interviews with the subjects’ in their L1; (d) transcribe and translate interviews from the subjects’ L1 to English. Because of the Korean speaker’s unavailability at the scheduled interview times, the main researcher, who could speak intermediate Korean, conducted the interviews in Korean. The translator translated the questions from English to Korean beforehand to aid the main researcher. The Korean speaker was a student pursuing a master's degree in Linguistics at a prominent university in the western United States. The Japanese speaker was a student pursuing a bachelor’s degree in English Language at the same university. They were recruited based on their knowledge of the English language and their L1 language abilities.

Data Analysis

Quantitative data. A one-way repeated measures Analysis of Variance (ANOVA) was computed on SPSS (IBM Corp., 2016) to examine any difference in a single group of participants’ responses in the pre-, mid-, and post-EPG-use surveys. The means and standard deviations were calculated to measure the central tendencies of the responses.

Qualitative data. Qualitative data included survey and interview responses as well as observation notes. The open-ended responses from the surveys were collected; those in participants’ L1 were translated to English. The recordings from the interviews were transcribed; the ones in the participants’ L1 were transcribed and translated into English by the L1 translators. An additional translator double-checked the translation for each L1 to ensure accuracy. This qualitative data was then coded in a Microsoft Office Excel spreadsheet based on emerging themes and patterns. Both themes relevant to the research questions and new insights not derived
from the research questions were considered. Data with similar themes were grouped together and given headings, where subcategories were created based on opinions that more than one participant agreed upon (Mackey & Gass, 2005). A taxonomy that illustrates the participants’ EPG experiences with comments was subsequently created according to the research questions. Attention was given to positive feedback, negative feedback, challenges, and suggestions in creating the taxonomy. A second rater, pursuing a master’s degree in TESOL (Teaching English to Speakers of Other Languages) assisted in the inter-rater reliability check. A 14% randomized sample of the mid- and post-EPG-use interview comments were randomly selected by the main researcher. This collection of comments included 20 statements from the mid-EPG-use interviews and 20 from the post-EPG-use interviews. The second rater utilized the taxonomy to sort the comments. Overall, 36 out of 40 comments (or 90%) of the second rater’s categorization matched the categories identified by the main researcher. For the remaining 10%, the categories selected by the main researcher were used to code the responses.

The students’ comments revealed the nature of their experience using the sensor in a pronunciation class. The data will be shared in the results section.
Results

Of the 27 total surveys (pre, mid, and post) that were distributed, 24 (88.9%) were returned. To better understand the results for this study, the answers to each research question will be discussed. Because the quantitative and qualitative results for research question one are interrelated, they will be presented together. The results relevant to research questions two through four will be divided between quantitative and qualitative data. Research question five yielded only qualitative results.

Research Question 1

The first research question asked Korean, Taiwanese, Chinese, and Japanese ESL learners their expectations regarding the use of the EPG sensor.

To understand their expectations, it is informative to know their language learning experiences and pronunciation goals. In the pre-EPG-use survey, the respondents “strongly agreed” that when they speak English, clear pronunciation is important to them ($M=5.78$, $SD=.441$), but “somewhat disagreed” that they have often received help with pronunciation in school ($M=4.00$, $SD=1.23$). A total of 44.4% of the participants reported to be concerned about their pronunciation all the time. Example comments included “when I talk to native speaker[s], they don’t understand what I say all the time” (F5) and “I'm nervous in every situation in which I have to speak English, since if I don't say something right or pronounce something wrong, others won't be able to understand me” (F3).

As for pronunciation goals, a total of 66.6% of the participants hoped to achieve clear pronunciation or communication, supported by comments such as “even though I know the meaning of the words, I am afraid of speaking because listeners do not understand my pronunciation. I do not want to repeat [myself]. I just want to have a conversation naturally
without having a problem [speaking]” (F6). 33.3% wanted perfect pronunciation, supported by comments such as “I want to improve my pronunciation [to be] like [a] native speaker, and also have a good skill [with] it” (M2).

Considering their language learning experiences and pronunciation goals, the respondents expressed the following expectations and concerns about sensor use. They expected that by using the sensor, they could achieve goals such as “I will be able to find out how my tongue is moving during pronunciation, so I think I will be able to fix my pronunciation” (F3) and “I can learn where I should put my tongue for each [word I pronounce]” (F6). They had, however, expressed concerns about the side effects and effectiveness of using the sensor, asking “Is it safe for my [health]?” (F6) and “I've never used [it] before, and I'm worried that I won't be able to use it properly. I don't know how to use [it]. Is it helpful to me” (F5)? Even though they did not mention their desire to achieve perfect pronunciation with the sensor, some of their comments on the goal of perfect pronunciation reveal that it might be an underlying expectation for their use of the sensor.

**Research Question 2**

The second research question asked Korean, Taiwanese, Chinese, and Japanese ESL learners their positive comments while studying with the EPG sensor in a classroom setting.

**Quantitative data.** An overview of this data will be discussed first, and the specific results will be discussed later. Overall, the quantitative data showed that the sensor was a somewhat socially acceptable tool that most of the participants were excited about or did not seem to mind its presence in their mouths as long as they could improve their pronunciation. They believed that the sensor was an effective tool that provided enough feedback and had a
somewhat acceptable level of comfort. They reported that the software was easy to use. Lastly, there was no significant teacher effect in this study.

One result of the quantitative data is that the number of participants indicating a high level of excitement to see their progress in the use of the sensor was significant. (It decreased from 75% to 57.1% over the seven-week period.) Two of seven respondents (28.6%) reported that people other than those in the study had noticed positive changes in the students’ pronunciation.

Results from the repeated measure ANOVA revealed that none of the response scores significantly differed across pre-, mid-, and post-EPG-use. According to Table 2, there were no statistically significant differences for participants’ (a) confidence about their overall pronunciation; (b) motivation to improve their pronunciation; (c) opinion on the effectiveness of the sensor; (d) opinion on the comfort of the sensor before, during, and after the seven-week EPG instruction.

Table 2

Participants’ experiences before, during, and after use of the EPG sensor

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>6th session</th>
<th>12th session</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>F</td>
<td>df</td>
</tr>
<tr>
<td>Confidence</td>
<td>3.06</td>
<td>1.24</td>
<td>3.25</td>
<td>1.17</td>
<td>4.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Motivation</td>
<td>5.44</td>
<td>1.01</td>
<td>5.50</td>
<td>.535</td>
<td>5.29</td>
<td>0.76</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>4.78</td>
<td>0.67</td>
<td>5.13</td>
<td>0.65</td>
<td>5.14</td>
<td>0.90</td>
</tr>
<tr>
<td>Comfort</td>
<td>4.00</td>
<td>0.76</td>
<td>4.63</td>
<td>0.92</td>
<td>4.29</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Note. 1 = strongly disagree; 2 = disagree; 3 = somewhat disagree; 4 = somewhat agree; 5 = agree; 6 = strongly agree.

According to Table 3, there were no statistically significant differences over time for participants’ opinions on whether (a) they received enough feedback from the EPG software to help them
improve their pronunciation; (b) they felt embarrassed about using the sensor in the classroom with other students watching; (c) the EPG software was easy to use; (d) their learning affected by which one of the two teachers was teaching the class that day; (e) they accepted that the sensor helped them improve their pronunciation, even though it affected their appearance.

Table 3

Participants’ experiences during and after use of the EPG sensor

<table>
<thead>
<tr>
<th></th>
<th>6th session</th>
<th>12th session</th>
<th>F</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedback</td>
<td>5.25 .463</td>
<td>4.71 1.11</td>
<td>1.56</td>
<td>1,13</td>
<td>.234</td>
</tr>
<tr>
<td>Embarrassment</td>
<td>3.00 1.51</td>
<td>2.29 1.60</td>
<td>.788</td>
<td>1,13</td>
<td>.391</td>
</tr>
<tr>
<td>Software use</td>
<td>5.25 .886</td>
<td>4.86 1.61</td>
<td>.606</td>
<td>1,13</td>
<td>.450</td>
</tr>
<tr>
<td>Teacher effect</td>
<td>3.63 1.51</td>
<td>4.00 1.73</td>
<td>.201</td>
<td>1,13</td>
<td>.661</td>
</tr>
<tr>
<td>Appearance</td>
<td>5.25 .707</td>
<td>4.86 1.07</td>
<td>.723</td>
<td>1,13</td>
<td>.410</td>
</tr>
</tbody>
</table>

Note. 1 = strongly disagree; 2 = disagree; 3 = somewhat disagree; 4 = somewhat agree; 5 = agree; 6 = strongly agree.

According to the mean responses of the participants over time in Table 2 (calculated by averaging the mean scores of the pretest and the 6th and 12th sessions), the participants “agreed” that they were motivated to improve their pronunciation, even though they were neither confident nor diffident in their overall pronunciation. They “agreed” that the sensor was effective in improving their pronunciation. They “somewhat agreed” that the comfort of the sensor was acceptable. According to the mean responses of the participants over time in Table 3, calculated with the same method, participants “agreed” that they had received enough feedback from the EPG software to help them improve their pronunciation. They “agreed” that the EPG software was easy to use. They “somewhat disagreed” that their learning was affected by which one of the
two teachers was teaching the class that day. They “agreed” that even though the sensor affected their appearance, they accepted this fact because it was helping them improve their pronunciation. They “somewhat disagreed” that they felt embarrassed about using the sensor in the classroom with the presence of other participants.

**Qualitative data.** The qualitative data supported most of the quantitative data in that the sensor was easy to use, had perceived effectiveness, and did not create much social awkwardness over time. It also supported the data that showed there was not much teacher effect on the participant’s learning in this study. However, it contradicted the opinion that the comfort of the sensor was acceptable. The data provided additional information on the sensor’s initial strangeness of use, revealed that it took time for the participants to adjust to the sensor, and documented instances of faulty manufacturing. It also informed about the perceived willingness of ESL students from their same country to use the sensor in the classroom. Lastly, it showed participants’ appreciation to teachers’ individual attention and organization of activities. See Appendix C for examples in the Taxonomy of Experiences.

Regarding the social aspect of the use of the sensor, a total of 75% of the participants reported to find safety in numbers. An example comment that showed safety in numbers is “I don’t feel embarrassed, because everyone is using it. If I am the only one using it, I will get embarrassed” (F7).

Overall, they believed the sensor was socially acceptable. A total of 33.3% of the participants mentioned they disregarded others’ opinions and they were excited to use it, a conclusion supported by comments including “I just want to improve myself, so I didn’t care about others” (M2) and “In the beginning I think it's very special and I feel very [excited]. And now I still feel [excited] because I want to improve my pronunciation [more]” (M2).
In terms of the perceived effectiveness of the sensor, participants reported that they had either gained more awareness of tongue placement or received reinforcement on their pronunciation from others. 77.8% of the participants thought the sensor was a useful tool. An example comment is “I think [the] sensor helped me a lot, because it can show me the [location] of my tongue. And I can modify it to pronounce better by myself” (M2). Moreover, 88.9% of the participants believed the sensor had helped them gain awareness of tongue placement, supported by comments such as the following:

I could know better what I was supposed to do. Because I heard /l/ sounds a lot. [The teacher said] do it like this and do it like this. But I couldn’t understand it, because I couldn’t see inside of [the mouth]. But because I could see [my tongue placement on the screen as I use the sensor], I could understand better. (F3)

Besides gaining awareness of tongue placement, two of seven respondents (28.6%) reported that other people had noticed changes in their pronunciation. One commented,

Just in daily conversations with teachers and friends, now they can tell [if] I am pronouncing /ɹ/ or /l/. This makes me feel like I am getting better. Before, every time I say words that have /ɹ/ and /l/ sounds, they were like ‘What?’ It makes me happy when they understand which word I am saying. (F7)

The other reported:

[The] tutor can understand [me] a lot. I always talk to [the tutor]. [The] tutor said /ɹ/ and /l/, /v/ and /b/ [were my problematic sounds]. But now he didn’t say [anything] about my pronunciation. (F2)
In terms of the use of the sensor, most participants agreed that the software was easy to use. A total of 87.5% of the participants agreed that the software was easy to use, a conclusion supported by comments including “[The] software wasn’t hard. It was easy to use” (F4).

Participants reported that the factors that positively affected their use of the sensor were being part of a larger instructional group, personality, and orthodontic experience. F7 expressed that she found safety in the number of participants: “Japanese people sometimes feel embarrassed when people act different[ly], but this class was good, because people act[ed] [the] same, so I didn't feel embarrassed.” F1 believed her carefree personality made her experience less worrisome, “I feel like my personality is kind of different [from] other Asian[s]. I don’t care [about] anything [including looking strange with the sensor in place or pronouncing words incorrectly].” F5 claimed her orthodontic experience made wearing the sensor not uncomfortable, “I [got a retainer] in Korea. Sometimes I used it, [now I finished using it.] It’s like [an EPG sensor], so I didn’t feel [the sensor] was that uncomfortable.”

When the participants were asked what were their perceptions on whether ESL students from their same country in the United States were willing to use the sensor during classroom instruction, most comments suggested that the sensor was useful and most ESL students from these countries would want to use it to improve their pronunciation, supported by comments such as “Maybe they want [to use the sensor], because it’s hard to communicate [with] each other [because of] vocabulary, culture, but [also] pronunciation. When we live here. We have to communicate [with] American people” (F2). Two participants were concerned about the price of the sensor being too expensive ($225 U.S.), while one mentioned whether Chinese students in the United States are willing to use the sensor depends on how much improvement they can make, claiming that “If people can see a big improvement on that, they probably are willing to
spend that kind of money and tell [their] friend[s]. If they spend like [a] couple hundred dollars and only see a little bit improvement, it’s [probably] not worth it.” Another participant suggested that Korean students who are attending universities in the United States would not need the sensor because they have good pronunciation, but students in a language school will need it.

Regarding the positive feedback on teacher instruction, 100% of the participants appreciated the personal attention they received from teachers and 33.3% expressed that they enjoyed the organization of class activities, including conversations for sensor adaptation and *minimal pair* activities, where teachers had learners differentiate pairs of English words that differ in only one phonological element (such as a phoneme) and have distinct meanings. Example comments included “[I liked that] the teachers told us to have normal conversation[s] before we started to get used to the [sensor]” (F7) and “[I liked the quiz the teachers gave us. They pronounced a word that sounds similar to another word which has a different meaning, then had us guess which word was pronounced” (F7). Besides, 85.7% of the participants also commented that their learning was not affected by which one of the two teachers was teaching the class that day. An example comment was, “The way of their teaching was exactly same” (F6).

**Research Question 3**

The third research question inquired about Korean, Taiwanese, Chinese, and Japanese ESL learners’ negative comments while studying with an EPG sensor in a classroom setting.

**Quantitative data.** While more students were either excited or didn’t mind using the sensor, a small number of participants mentioned being anxious and discouraged. A total of 28.6% of the participants reported to be nervous while they were using the sensor in the classroom throughout the seven-week instructional period. In addition, 25% expressed frustration that they made little to no progress in the mid-EPG-use survey. In the post-EPG-use survey,
however, one of these two said she did not know if she had made progress while the other participant did not participate in the survey. Nonetheless, it was only a small number of participants who had these specific negative feelings about the use of the sensor.

**Qualitative data.** An overview of this data will be discussed first, and the specific results will be discussed later. The qualitative data did not agree with the quantitative data on the participants’ frustration and sustained nervousness, but instead indicated an initial strangeness that decreased over time. A possible explanation for their frustration could be the lack of the skills to interpret the EPG feedback received. The qualitative data also revealed some students’ opinion that reading the word lists repeatedly is uninteresting and some had received insufficient feedback from the teachers. The qualitative data also revealed information on the other negative comments regarding the use of the sensor, namely that it was uncomfortable, it took time to adjust to, it distorted the users’ articulation initially, and two sensors were manufactured incorrectly.

One result of the qualitative data revealed an initial strangeness of the use of the sensor that subsided over time, even though quantitative data indicated that the two participants’ nervousness was sustained over the instructional period. A total of 37.5% of the participants expressed an initial strangeness in its use due to its effect on the participants’ appearance and its initial articulatory distortion. One commented,

I was concerned about how [classmates and teachers] would look at me [if I wore the sensor] at first, but it would feel natural as time goes by. When I said nervous, I mean I feel nervous when I used [the sensor] by myself and other people looked at me a bit weird, but I think I can use it. (F5)

Another reported:
One day, I [realized that] this bottom [of the sensor has a] blue bar. We can see each other [biting the blue bar when we were speaking to each other]. So funny. I laughed in my mind. Funny appearance. Now it doesn’t feel funny anymore. (F2)

The main researcher’s observation revealed that the participants initially felt strange about the sensor. After the first session, F5 saw the main researcher closing the door of the kitchen where all the participants were cleaning up the sensors and said “Are you ashamed? I am ashamed [to be seen cleaning up the sensor].”

Participants reported that the factors that negatively affected their use of the sensor were its appearance, the participants’ L1, and the participants’ age. The appearance of the sensor made F2 feel awkward: “I feel awkward when I [take] the [sensor out because it looks] like fake teeth.” M2 commented that the lack of similar phonemes in Mandarin compared to English made his learning with the sensor more difficult, “The only factor is my native language, because I never use this sound in my language.” F6 thought her age made it difficult to change the habitual movements of her tongue, “I think that age affected my experience with the [sensor]. I cannot change my tongue position easily even though I know where it should be.”

However, no participant expressed frustration in making little to no progress in the interviews. One possible explanation to this disagreement in the data could be due to participant confusion about the EPG feedback received, that they either could not interpret the visual feedback or effectively adjust their tongue placement based on the feedback. A related comment by F4 showed her insufficient ability to understand the feedback. She said that the dots on the EPG software did change a bit as she adjusted her tongue placement, but it was a bit more confusing. She tried to correct her tongue placement based on the feedback, but when she tried to pronounce difficult sounds she became more confused. It was okay when she tried to pronounce
easy sounds, but it was a bit more difficult with difficult sounds. She mentioned “... honestly if we [use the sensor] by ourselves we are not sure if it’s right or wrong... there are some words that we don’t know how to pronounce at all” (F4).

Besides confusion, 55.6% of the participants also mentioned repeatedly reading the word list was boring either because of repetition or because they were practicing by themselves. Example comments include:

“Actually [you] don't need to spend more than 10 minutes [on the list]. I just sit there [and] do nothing, because the list is the same. You have already [gone] over [it] like four or five times. Because you already kind of know what is the correct pronunciation for this list, but [the teachers] just [said to] go over [it] again. (M1)

Another participant claimed that self-practice was boring, “For me, sometimes it's kind of boring. I will … sit there and practice by myself” (F1). Classroom observations also identified that after some participants practiced by themselves for seven minutes, they became distracted and started chatting or using their cellphones as early as when there were still 13 minutes left for individual practice.

A total of 22.2% of the participants also reported to have received insufficient feedback. F4 commented that the feedback she received was not clear. She thought she had pronounced a word the same way twice, but the teacher said this pronunciation was correct and the other was not. She did not know which pronunciation was right and which one was wrong. Moreover, F1, a participant with fewer segmental issues, believed she did not receive as much assistance from the teachers as others: “Because I don't have really big problem[s] I guess, the teacher will help other people.”
In terms of other negative comments on the use of the EPG sensor, some participants suggested the sensor was uncomfortable, some mentioned it took time to adjust to its presence in their mouths, and some commented on its initial articulatory distortion. Moreover, two participants reported faulty manufacturing. A total of 75% of the participants claimed that it was uncomfortable to use the sensor, including reasons such as it being “stuck in your mouth” (25%), “tight” (25%), and that using it while they were having a cold made them gag (25%). What follows is a sample of participants' responses:

When I caught a cold, it seemed very uncomfortable to use it. When I keep [the sensor] in my mouth, it feels like I'm about to throw up. When [I] had a cold, [I] coughed, but then I had this in my mouth so I felt a bit uneasy. So it wasn’t like I was really going to throw up, but just had that feeling? So I read, stopped and restarted again. It was okay to stop, but I couldn't read [the word list] consistently like I used to do other days and [reading without stopping] was a bit uncomfortable. [Reading] it word by word was okay. But that day I was feeling really bad. So I think it would've been better if [the cold] wasn't that bad. (F4)

Classroom observation supported the findings that the sensor can stick to a user’s mouth, which made it difficult to remove.

In addition, a total of 62.5% of the participants said it took them time to adjust to the sensor with comments as such:

It was weird at first. I thought I couldn't pronounce like I do normally, but the teachers told us to have normal conversation [with the sensor in our mouths] before we started [class instruction] to get used to the [sensor]. Because of that effort, I didn’t really feel uncomfortable in the class, even though it was hard to pronounce or speak. I didn’t feel
comfortable using [the sensor]. I guess the [sensor] is that kind of thing. I got used to it as I used it. (F7)

Two participants (22.2%) noted that the sensor was manufactured incorrectly since it hurt the mouth of one of one person and for the other person, the sensor broke. Their comments were “It hurt. I hurt the upper side of the mouth [the] first time (F2)” and “I had a problem with my teeth [being somewhat crooked]. So I was a bit worried when I needed to keep my mouth closed.” F3 reported that she heard a sound of the sensor breaking during the sixth session. The main researcher’s observation supported this argument. She observed that the bottom line electrodes on F2’s sensor did not light up on the computer screen when F2 tried on the sensor during the first session. Also, a line of electrodes in the middle of the sensor did not light up after F3’s broken sensor was replaced.

Lastly, a total of 33.3% of the participants mentioned the sensor initially distorted their articulation of some fricative consonants including /f/, /v/, and /θ/, and made it difficult to pronounce /ɹ/. An example comment is as follows:

It’s hard to pronounce some sounds, because when you put the [sensor in] your mouth, in the beginning you cannot really pronounce the /v/ sound and /θ/. Sometimes when you pronounce /ʌ/, [there is] something in the middle of your, I don’t know, in the top [of the mouth]. It hurts your tongue, but not too bad. (M1)

The main researcher’s observation validated this argument. As M2 attempted to speak with the sensor in his mouth in the first session, his articulation was distorted. He described it as “a little uncomfortable, difficult to pronounce” then.
Research Question 4

The fourth research question asked Korean, Taiwanese, Chinese, and Japanese ESL learners the challenges experienced while studying with the EPG sensor in a classroom setting.

Quantitative data. Over the 12 instruction sessions, more learners reported experiencing difficulties with pronouncing the phonemes, including speech perception, speech production, and speech acquisition. In the mid-EPG-use survey, two of eight respondents (25%) had problems pronouncing the difference between two sounds and two had problems remembering where to place their tongue to produce the correct sounds. In the post-EPG-use survey, four of seven respondents (57.1%) had problems pronouncing the difference between the sound contrasts and two (25%) had problems hearing the difference between two sounds. A possible explanation for such result could be that they were not aware of the root of their pronunciation problems at the mid-point, but understood it sometime between the mid- and final-point of the seven-week period.

Qualitative data. The qualitative data supported the quantitative data that the participants had problems with speech perception, production, and acquisition. The qualitative data also revealed challenges of using the sensor consistently and having a dry mouth.

The interview data provided evidence to support that the participants had the aforementioned pronunciation problems and also revealed another problem of the lack of consistency of use of the sensor. A total of 62.5% of the participants commented on having difficulties with hearing, speaking, and acquiring the difference between the targeted sound contrasts. An example comment suggested that despite using the sensor, speech perception was difficult was:
I thought the difference of pronunciation between *eat* and *it* was how long you pronounce the sound. I was surprised when I found out that I needed to move my tongue differently. I can't really hear the difference, but the teachers who are native speakers say they are totally different. (F7)

A comment that showed the difficulty in speech production was “I couldn't pronounce /ɹ/ and /θ/ accurately. The screen image of the [sensor] when the teacher pronounced these sounds was different from mine, and mine was incorrect. I thought it was a bit difficult” (F5). Evidence that indicated the difficulty in speech acquisition was that when she made a post-EPG-use recording for acoustic analysis in study by Nissen et al. (2016), “I know how to [pronounce the words], but I focused [on] the story or the sentence, I just forgot [to] move the tongue [in certain ways]” (F2). Conversely, a participant commented on sometimes focusing on pronunciation resulted in the failure to understand the meaning of an article, as follows:

I have to focus on my tongue and my mouth, because I have to focus on [articulating the] /ɹ/ or /l/ sounds [correctly] when I [see them in a word.] Sometimes I focus on my pronunciation and it's difficult to understand the [meaning of the] article. (M2)

Classroom observations verified such pronunciation difficulties arose, as some participants were unable to differentiate sound contrasts such as /i:/ - /i/ and /ɹ/ - /l/ while M1 commented “I can hear the difference, but I cannot pronounce it” during the eighth class session and F6 mentioned during the last session that she could just pronounce the word by itself, but when it was in a sentence, it was hard for her to pronounce.

In addition to the difficulties differentiating sounds, a total of 44.4% of the participants commented that they did not have the opportunity to use the sensor in a consistent manner since
the actual practice time was 20 minutes on average per EPG session. What follows is a sample of participants' responses:

During the class, I feel I can make a different sound. But we have just less than 30 minutes [to] use it, and then we don’t use it [for the rest of the] day. And then, maybe my pronunciation [goes] back to my original pronunciation. (F6)

Moreover, a total of 22.2% of the participants reported having a dry mouth while they were using the sensor. They commented, “Inside of the mouth becoming dry” (F5) and I want to take [the sensor] out and I want to drink some water, but it’s hard to drink water with the [sensor] in the mouth. No, [I can't drink water directly from the bottle with the sensor on], but I want [to]” (F4).

**Research Question 5**

The fifth research question inquired about Korean, Taiwanese, Chinese, and Japanese ESL learners’ recommendations on how the EPG pronunciation classes could be improved.

The participants made two suggestions on how the EPG instruction could be improved, including having more in-class activities and adjusting the class schedule to make the course longer. Rather than repeatedly practicing the word list on their own, a total of 33.3% of the participants expressed their preference to have more pronunciation activities. The following is an example comment:

Doing a few other activities would make [the students] more focused in class. Some [activities] including practicing pronunciation or checking each other’s pronunciation with a partner to see if I am pronouncing /i:/ or /ɪ/, or I [pronounce] something and [the partner] writes. I think it [would] be nice if we did things together [with] either a partner or the entire class. [Instead of just reading word lists,] I like something active. (F3)
In addition, 55.6% mentioned this class could benefit from adjusting the schedule. They disagreed on the length of a class session, but 22.2% mentioned that the instructional period should be either one semester or half a year for them to see more significant improvement in pronunciation. A comment that illustrated the reason is “Maybe [this class should be] at least six months, because you need to accommodate the pronunciation [of these phonemes], it’s difficult to learn it in a short time. You need to practice more” (M2). Even though the participants suggested that the course be longer, it is noteworthy that based on observations, F4, F6, M1, and F1 were absent from class from one to three days of the twelve sessions due to illness. While F3 was present during all sessions, she could not use the sensor during two sessions because it was broken.

**Discussion**

The preliminary findings of this study were: First, the EPG sensor was felt to be an effective tool in helping the learners gain awareness of the correct tongue placement. Participants also felt that the EPG sensor was also a somewhat socially acceptable tool with user-friendly software. Participants appreciated the teachers’ individual attention and organization of activities in its use. If the price of the sensor is within an acceptable range ($150 to $250 U.S. (M1) or $50 to $60 U.S. (M2)) and its effectiveness in helping learners acquire phoneme production within an acceptable range is proven, participants believed most ESL students from South Korea, China, Taiwan, and Japan would want to use the sensor. However, learners did comments that those using the sensor could experience an initial strangeness—which took time to adjust to— as well as a sustained discomfort in its use. There were instances within the study where the sensor initially distorted the users’ articulation of certain phonemes and some devices failed due to faulty manufacturing. Over time, more learners reported experiencing difficulties with pronouncing the
phonemes, including speech perception, speech production, and speech acquisition. A lack of consistent use of the sensor was also a challenge. Suggestions of having more in-class activities and adjusting the class schedule to make the course longer were offered.

The findings of this study can only be compared to previous research that has related anecdotal accounts of language learners using EPG sensors because of the limited past research. In accordance with past research, this study found that the EPG palate could result in alteration of speech production and comfort as well; it also showed instances of gagging. Moreover, this study supported findings reported in previous literature where some learners’ articulation of phonemes such as fricatives such as /f/, /v/, and /θ/ were initially distorted. Discomfort in using the sensor was also prominent (McAuliffe, Lin, Robb & Murdoch, 2007; McLeod & Searl, 2006). Moreover, comments of using the sensor and gagging during a cold were mentioned, which corresponded to participants’ anecdotal accounts in McLeod and Searl’s study (2006). However, F2’s comment that the participants’ appearances were funny because they could see each other biting the blue bar at the bottom of the sensor contradicted a participant’s account of “I must admit I looked in the mirror and couldn’t notice it [the EPG sensor] was in” in McLeod and Searl’s study (2006).

Although the clinical applications and instructional use of EPG has been studied for decades, most of the current literature on the experience of EPG use has been anecdotal, where the focus was on adaptations to an EPG sensor and the influence of such a sensor on speech and articulation. Few studies have addressed the shared experiences of learners using these tools in the ESL classroom for the purpose of targeting improvement in a segmental contrast. Such is the purpose of this study. This study explored issues beyond the factors assessed in existing literature, such as the sensor’s level of comfort, influence on speech, and the time taken to adapt
to such a sensor. By describing the experiences of Korean, Taiwanese, Chinese, and Japanese ESL learners using the sensor for second language acquisition, this research provides a quantitative and qualitative perspective regarding the effectiveness of the sensor to future students and their teachers who are thinking about using EPG biofeedback to improve their pronunciation of English phonemes. This research highlighted students' opinions on the effectiveness of EPG visual instruction versus traditional auditory instruction, which can then be used to advise future L2 pedagogy. Both positive and negative comments about the use of the sensor were included, challenges were mentioned, and suggestions were offered.

Implications

The research findings indicate that a total of 33.3% of the participants had a false expectation of the possibility to achieve perfect pronunciation after using the EPG sensor. While studies show that such sensors can assist in modifying users’ pronunciation of phonemes, it is important to realize the essential role that suprasegmentals play in one’s pronunciation. These prosodic elements accounted for 50% of the variance in oral proficiency and comprehensibility ratings in iBT TOEFL (Test of English as a Foreign Language; Kang, Pickering, & Rubin, 2010). Moreover, research has shown that after puberty, the likelihood of acquiring a native-like accent is extremely slim (Flege, Frieda, & Nozawa, 1997; Flege, Munro, & MacKay, 1995; Scovel, 1988). Learners should come to the understanding that the sensor is likely to help them though they are unlikely to achieve native-like accent, since the underlying premise of the sensor is to assist in the production of phonemes by adjusting the user’s tongue position. It is advised that they should set the goal of using an EPG sensor as the accurate production of targeted phonemes.

Admittedly, 12 40-minute EPG class sessions over the course of seven weeks might be too short for students to acquire the accurate production of all seven phonemes [l, r, θ, s, ʃ, ɪ, and
i:]. However, students had expressed that they learned to recognize the correct tongue placement over just a few weeks. It is possible that they will acquire these phonemes with additional practice, such as with a longer EPG pronunciation course that is more frequent (e.g. one semester long and three times a week).

In terms of course design, future EPG instruction can benefit from these considerations. It would be fair for instructors to evenly distribute one-on-one time with each student rather than allotting their time according to student needs. During individual practice time, teachers can assist a pair of adjacent students so that once they are finished working with them, those students could spend five minutes on practicing reading word lists. After that, they could spend the rest of the individual practice time working together to implement the teachers’ feedback (15 minutes in this case). Distributing individual practice time this way could ensure that students receive appropriate software feedback and learn from each other.

Even though wearing the sensor will likely incur discomfort and distort speech initially, learners should keep in mind that the goal of utilizing such a sensor is to generate comprehensible and intelligible phonemes and speech without the sensor. Learning to read the EPG software output, effectively adjusting tongue positions accordingly, in combination with the inclusion of pronunciation activities to help learners differentiate sound contrasts, will likely assist them in achieving such a goal.

Moreover, both the Complete Speech company and the dental clinics are advised to perform quality checks to ensure fewer occurrences of faulty manufacturing. They need to ensure that all the electrodes will light up on the computer screen and the sensor will be an appropriate fit or will not break easily.
Limitations

While the findings from this study are quite informative regarding participants’ experiences with the EPG sensor, there are some limitations that need to be discussed. First, the study was a descriptive case study with only nine subjects who represented four different L1 groups. A more robust number of participants would make the data much more representative. For instance, only one participant was Japanese and one was Chinese while there were five Korean participants. Initially, 29 students expressed interest in participating in the research study by Nissen et al. (2016). However, the research study by Nissen et al. (2016) had to conduct an acoustic analysis to determine if a student struggled with the targeted sounds that the sensor is able to detect. Some of the students who had previously expressed interest and were returning to the school the following semester decided not to participate after the acoustic analysis, further reducing the participant numbers. Therefore, only the nine students who participated in this study were deemed qualified to participate in the study by Nissen et al. (2016). However, previous EPG studies have been cost-prohibitive, also limiting the number of the participants. This limitation can hopefully be addressed in future studies when a larger number of participants are available to respond.

Second, the EPG pronunciation class was only seven weeks long due to time constraints. A total of 12 40-minute class sessions were likely not long enough for participants to master all seven phonemes. The reason that the class had to be finished within one semester was because some participants were not planning to return to the IEP the next semester. One semester is 15 weeks long; however, it takes a minimum of 2 weeks for the sensor to be manufactured. Moreover, the study by Nissen et al. (2016) had an original plan to administer a delayed post-test to analyze the carryover of accurate phoneme production after the course finished, further
limiting the length of the course. Furthermore, since the study by Nissen et al. (2016) needed to control the use of the sensor to accurately measure the progress made within the 12 class sessions, the participants were not allowed bring the sensor with them after class for additional practice. These restrictions on course length and the use of the sensor may not have been ideal for learners’ progress.

**Directions for Future Research**

Future research would benefit from the inclusion of greater participant numbers, participants from different language and cultural backgrounds, a longer instructional EPG course, and the development from single-word practice to spontaneous speech. The intent in this study was to look at the quantitative data and qualitative comments about the use of the EPG sensor in a classroom setting and explore the challenges and suggestions for future EPG instruction. As such, the results are informative about the experience of using such a sensor. However, course length, and the number and ethnic backgrounds of the participants were dependent on the ones in the study by Nissen et al. (2016). A future study that examines learner experience with a larger number of participants and with a longer course would be necessary to better understand the proportion of individuals who might or might not benefit as much from EPG instruction and whether their classroom experience improves with a longer course. More complete understanding of how speakers from different demographic, language and cultural backgrounds, such as native speakers of Spanish and Portuguese, respond to the instructional use of a sensor should be pursued to facilitate the understanding of the use of such a sensor for other speakers who can benefit in EPG technology. This information would be important as these learners might differ from Asian learners in the situations they are willing to endure to improve their pronunciation, or they might adapt faster or better to such sensors.
Finally, future research could explore the development from single-word practice with the EPG sensor to spontaneous speech. In this pronunciation class, the students were not consistently asked to remove the sensor and practice without the sensor in place due to time constraints. In future EPG instruction, a sequence of distributed practice is suggested. The learners would practice with the sensor in place for five minutes, take it out and attempt to say the same practice discourse without the sensor in an effort to see if they can achieve proper tongue-palate production. This sequence would continue in an effort to help the learner better approximate the proper location of tongue and palate to accurately produce the target sound being practiced.
Conclusion

The significance of the current study lies in the fact that it describes learners’ experience using EPG biofeedback for second language acquisition purposes. The findings not only provide additional evidence to support an EPG sensor’s alteration on speech production and comfort, it also confirmed the possibility of the sensor inducing gagging when the participant has a cold.

In summary, the current study sought to determine Korean, Taiwanese, Chinese, and Japanese ESL learners’ experience concerning the use of the EPG sensor in an instructional setting. Based on the results of this study, there was clear evidence to suggest that the individuals participated in this study were positive about the overall use of the sensor in a pronunciation class. They believed it was a somewhat socially acceptable tool that, although it can cause discomfort, will prove effective with additional practice and a longer course. While small in participant numbers, the present research represents a future step in improving our understanding of the quantitative and qualitative aspects of the instructional use of the EPG sensors.
References


doi:10.1016/j.wocn.2015.09.007


doi:10.1080/14015430500390961


### Appendix A: EPG Research Calendar

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
</tr>
</thead>
<tbody>
<tr>
<td>9—May</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
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<tr>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>EPG class 2</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>Holiday, no class</td>
<td>30</td>
<td>31</td>
<td>1—June</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>EPG class 5</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>EPG class 7</td>
<td>Mid-EPG-interview</td>
<td>13</td>
<td>EPG class 8</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>EPG class 9</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>27</td>
<td>EPG class 11</td>
<td>27</td>
<td>28</td>
<td>29</td>
<td>30</td>
</tr>
</tbody>
</table>
Appendix B: EPG Surveys

Pre-EPG-use Survey

Q1. Student ID number:

Q2

<table>
<thead>
<tr>
<th></th>
<th>Years (1)</th>
<th>Months (2)</th>
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<tbody>
<tr>
<td>2. How long have you been</td>
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<tr>
<td>studying English? (1)</td>
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<td></td>
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<tr>
<td>3. How long have you lived in</td>
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<tr>
<td>the United States? (2)</td>
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</table>

Q3. About what percentage (%) of time do you speak English each day (rather than your native language)?
- 0-20% (1)
- 20%-40% (2)
- 40%-60% (3)
- 60%-80% (4)
- 80%-100% (5)

This is an EPG sensor. After you put the sensor in your mouth, you will receive instant visual feedback on a screen showing your pronunciation of English consonants. The blue area on the computer screen is where your tongue touched correctly (shown in this picture); the orange area is where your tongue touched incorrectly (NOT shown in this picture). Please answer honestly. Your survey answers will NOT affect your participation in the EPG study in any way.
Q4. Please choose your level of agreement with the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>strongly disagree (1)</th>
<th>disagree (2)</th>
<th>somewhat disagree (3)</th>
<th>somewhat agree (4)</th>
<th>agree (5)</th>
<th>strongly agree (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) When I speak English, clear pronunciation is important to me.</td>
<td></td>
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<td>(2) I have often received help with English pronunciation in school.</td>
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<td>(3) I am confident about my overall English pronunciation.</td>
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<td>(4) I am motivated to improve my pronunciation.</td>
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<td>(5) To improve my pronunciation, I would rather work in a group than work on my own.</td>
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<td>(6) I am excited to use the sensor. (Please explain the reason you chose your answer.)</td>
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<tr>
<td>(7) I am nervous about</td>
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</tbody>
</table>
Q5. In what situation(s) are you most concerned about your pronunciation (for example, conversations on the phone, with native English speakers, in a professional setting, in office hours with a professor)? Please describe the situation(s) and explain why you are concerned.

Q6. Why do you want to improve your pronunciation? (What are some specific reasons or goals?)

Q7. What worries do you have, if any, as you get ready to use the sensor?

Q8. What other feelings or comments do you have about the sensor? Please explain.
Mid-EPG-use Survey

Q1. Student ID number:

Q2. Please choose your level of agreement with the following statements. Please answer honestly. Your survey answers will NOT affect your participation in the EPG study in ANY WAY.

<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Somewhat disagree (3)</th>
<th>Somewhat agree (4)</th>
<th>Agree (5)</th>
<th>Strongly agree (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am confident about my overall pronunciation.</td>
<td>○</td>
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<td>2. I am motivated to improve my pronunciation.</td>
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<td>3. I am receiving enough feedback from the teachers to help me improve my pronunciation.</td>
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<tr>
<td>4. I am receiving enough feedback from the EPG software to help me improve my pronunciation.</td>
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<td>5. When I first used the sensor, the level of comfort was acceptable.</td>
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<td>6. Now when I use the</td>
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<td>Q3: How do you feel about using the sensor in the classroom with other classmates? Choose one or more answers.</td>
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<td>sensor, the level of comfort is acceptable.</td>
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<td>7. I feel embarrassed about using the sensor in the classroom with other students watching.</td>
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<td>8. I feel the sensor is effective in improving my pronunciation.</td>
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<td>9. The EPG software is easy to use. (Please explain the reason you chose your answer.)</td>
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<td>10. My learning is affected by which teacher is teaching the class that day.</td>
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<tr>
<td>11. Even though the sensor affects my appearance, I accept this because it is helping me improve my pronunciation.</td>
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</table>

○ ○ ○ ○ ○ ○ ○ ○
Q4. What emotions or difficulties have you had while receiving feedback from the software? Choose one or more answers.
- I have been excited to see my progress (1)
- I have been frustrated that I have made little to no progress (2)
- I have had problems using the EPG software (3)
- I have had problems hearing the difference between two sounds (4)
- I have had problems pronouncing the difference between two sounds (5)
- I have had problems remembering where to place my tongue to produce the correct sounds (6)
- Other [Please explain.] (7) ____________________

Q5. After this study is completed, how often will you use the sensor in the future?
- Daily (1)
- 2-3 times a week (2)
- Once a week (3)
- 2-3 times a month (4)
- Once a month (5)
- Less than once a month (6)
- Never (7)
- Other [Please explain.] (8) ____________________

Q6. What do you think about your experience using the sensor?

Q7. How have factors —such as culture, personality, background, age, or other things— affected your experience with the sensor? Please explain.

Q8. What suggestions do you have on how using the sensor in the classroom could be improved?
Q9. Do you think students in your home country would be willing to use the sensor in the classroom? Why or why not?

Q10. What other feelings or comments do you have about the sensor? Please explain.
Mid-EPG-use Survey

Q1. Student ID number:

Q2. Please choose your level of agreement with the following statements. Please answer honestly. Your survey answers will NOT affect your participation in the EPG study in ANY WAY.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Somewhat disagree (3)</th>
<th>Somewhat agree (4)</th>
<th>Agree (5)</th>
<th>Strongly agree (6)</th>
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</thead>
<tbody>
<tr>
<td>1. I am confident about my overall pronunciation.</td>
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<td>(1)</td>
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<td>2. I am motivated to improve my pronunciation.</td>
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<td>(2)</td>
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<td>3. I am receiving enough feedback from the teachers to help me improve my pronunciation.</td>
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<td>(3)</td>
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<td>4. I am receiving enough feedback from the EPG software to help me improve my pronunciation.</td>
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<tr>
<td>(4)</td>
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<td>5. When I first used the sensor, the level of comfort was</td>
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<td>○</td>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
6. Now when I use the sensor, the level of comfort is acceptable. (5)

7. I feel embarrassed about using the sensor in the classroom with other students watching. (7)

8. I feel the sensor is effective in improving my pronunciation. (8)

9. The EPG software is easy to use. (Please explain the reason you chose your answer.) (9)

10. My learning is affected by which teacher is teaching the class that day. (10)

11. Even though the sensor affects my appearance, I accept this
Q3. What emotions or difficulties have you had while receiving feedback from the software? Choose one or more answers.

- I have been excited to see my progress (1)
- I have been frustrated that I have made little to no progress (2)
- I have had problems using the EPG software (3)
- I have had problems hearing the difference between two sounds (4)
- I have had problems pronouncing the difference between two sounds (5)
- I have had problems remembering where to place my tongue to produce the correct sounds (6)
- Other [Please explain.] (7) ____________________

Q4. How do you feel about using the sensor in the classroom with other classmates? Choose one or more answers.

- Excited (1)
- Don’t care as long as I can improve my pronunciation (2)
- Strange (3)
- Embarrassed (4)
- Nervous (5)
- Annoyed (6)
- Other [Please explain.] (7) ____________________

Q5. After this study is completed, how often will you use the sensor in the future?

- Daily (1)
- 2-3 times a week (2)
- Once a week (3)
- 2-3 times a month (4)
- Once a month (5)
- Less than once a month (6)
- Never (7)
- Other [Please explain.] (8) ____________________
Q6. What do you think about your experience using the sensor?

Q7. How have factors —such as culture, personality, background, age, or other things— affected your experience with the sensor? Please explain.

Q8. What suggestions do you have on how using the sensor in the classroom could be improved?

Q9. Do you think students in your home country would be willing to use the sensor in the classroom? Why or why not?

Q10. What other feelings or comments do you have about the sensor? Please explain.
Post-EPG-use Survey

Q1. Student ID number:

Q2. This survey re-assesses your overall experience with the EPG sensor after six weeks of pronunciation instruction. Please choose your level of agreement with the following statements after you finished the pronunciation class. Please answer honestly.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Somewhat disagree (3)</th>
<th>Somewhat agree (4)</th>
<th>Agree (5)</th>
<th>Strongly agree (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) I am confident about my overall pronunciation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) I am motivated to improve my pronunciation.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>3) I received enough feedback from the teachers to help me improve my pronunciation.</td>
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<tr>
<td>4) I received enough feedback from the EPG software to help me improve my pronunciation.</td>
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<tr>
<td>5) To improve my pronunciation, I would rather work with the EPG software in a group than on my own.</td>
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</tr>
</tbody>
</table>
6) Now when I use the sensor, the level of comfort is acceptable.

7) I felt embarrassed about using the sensor in the classroom with other students watching.

8) I feel the sensor was effective in improving my pronunciation.

9) The EPG software was easy to use. (Please explain the reason you chose your answer.)

10) My learning was affected by which one of the two teachers that was teaching the class that day.

11) Even though the sensor affects my appearance, I accept this because it is helping me improve my
Q3. What emotions or difficulties did you have when you were receiving feedback from the EPG software? Choose one or more answers.

- I was excited to see my progress (1)
- I was frustrated that I made little to no progress (2)
- I had problems using the software (3)
- I had problems hearing the difference between two sounds (4)
- I had problems pronouncing the difference between two sounds (5)
- I had problems remembering where to place my tongue to produce the correct sounds (6)
- Other [Please explain.] (7) ____________________

Q4. How do you feel about using the sensor in the classroom with other classmates? Choose one or more answers.

- Excited (1)
- Don’t care as long as I can improve my pronunciation (2)
- Strange (3)
- Embarrassed (4)
- Nervous (5)
- Annoyed (6)
- Other [Please explain.] (7) ____________________

Display This Question:

If How do you feel about using the sensor in the classroom with other classmates? Choose one or... Embarrassed Is Selected

Q5. How would you rate your level of embarrassment when using the sensor in the classroom with other students watching?

- Somewhat embarrassed (1)
- Embarrassed (2)
- Very embarrassed (3)
- Extremely embarrassed (4)
- Other [Please explain.] (5) ____________________

Display This Question:

If How do you feel about using the sensor in the classroom with other classmates? Choose one or... Embarrassed Is Not Selected

Q5. How did you overcome your embarrassment, if any, of using the sensor in the classroom with other students watching?
Q6. How often will you use the SmartPalate on your own in the future?
○ Daily (1)
○ 2-3 times a week (2)
○ Once a week (3)
○ 2-3 times a month (4)
○ Once a month (5)
○ Less than once a month (6)
○ Never (7)
○ Other [Please explain.] (8) ____________________

Q7. Have other people noticed any changes in your pronunciation? If yes, what did they say or do to let you know?
○ Yes. (Please explain) (1) ____________________
○ No (2)
○ Other: [Please explain.] (3) ____________________

Q8. What other feelings or comments do you have about the sensor? Please explain.

Q9. What do you think about your experience using the sensor?

Q10. How did factors — such as culture, personality, background, age, or other things — affect your experience with the sensor? Please explain.

Q11. What suggestions do you have on how using the sensor in the classroom could be improved?

Q12. Do you think students studying in your country would be willing to use the sensor in the classroom? What about students from your country that are studying in the United States? Why or why not?
Appendix C: Taxonomy of Experiences

*Examples of Participants' Experiences Using EPG within the Taxonomy of Experiences*

<table>
<thead>
<tr>
<th>Taxonomy</th>
<th>Comments expressed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive</strong></td>
<td></td>
</tr>
<tr>
<td>About the EPG sensor</td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
<td>&quot;I don’t feel uncomfortable&quot; (F5).</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>&quot;It was [a] pretty good experience because I could know where my tongue should be located when I say some words&quot; (F6).</td>
</tr>
<tr>
<td>Ease of use of the software</td>
<td>&quot;[Software use] is easy. Just click the button and just I can [see] the software&quot; (F3).</td>
</tr>
<tr>
<td><strong>Emotions experienced when using the sensor in the classroom</strong></td>
<td></td>
</tr>
<tr>
<td>Disregard of others’ opinions</td>
<td>&quot;I will not care about other people's saying because everybody has problems to say some words. Since I am a learner of second language, it is O.K to use the [sensor] as long as I can improve my sounds&quot; (F6).</td>
</tr>
<tr>
<td>Safety in numbers</td>
<td>&quot;I don’t feel embarrassed. Because everyone is using it. If I am the only one using it, I will get embarrassed&quot; (F7).</td>
</tr>
<tr>
<td>Favorable feelings</td>
<td>&quot;In the beginning I think it's very special and I feel very exciting. And now I still feel exciting because I want to improve more about my pronunciation&quot; (M2).</td>
</tr>
<tr>
<td>Feedback on teacher instruction</td>
<td></td>
</tr>
<tr>
<td>Personal attention and demonstration</td>
<td>&quot;[The teachers connect their sensors to the laptop] and then they [spoke], so I can compare with my pronunciation with their picture of the [sensor], so it was good&quot; (F6).</td>
</tr>
<tr>
<td>Organization of activities</td>
<td>&quot;I liked the quiz the teachers gave us. They pronounced a word that sounds similar to another word which has a different meaning, then had us guess which word was pronounced&quot; (F7).</td>
</tr>
<tr>
<td><strong>Self-perception of progress</strong></td>
<td></td>
</tr>
<tr>
<td>Gained awareness of tongue placement</td>
<td>&quot;I didn't know how my tongue was moving, but in this class, I was able to see which pronunciation requires which tongue movement. I learned some pronunciation that I did not know before. I understood easily where should I put my [tongue]&quot; (F7).</td>
</tr>
<tr>
<td>Peer reinforcement, or lack thereof</td>
<td>&quot;I actually don’t know [if I made any progress]. Because I think it’s really hard to see your own progress. No one tell me like 'Oh, your pronunciation has progressed&quot; (F1).</td>
</tr>
<tr>
<td><strong>Negative</strong></td>
<td></td>
</tr>
<tr>
<td>About the sensor</td>
<td></td>
</tr>
<tr>
<td>Discomfort</td>
<td>&quot;It is still uncomfortable for me now to use it. [Over time, the level of comfort is] pretty much the same&quot; (M1).</td>
</tr>
<tr>
<td>Time to adjust</td>
<td>&quot;At the beginning of using it, it was uncomfortable for me. But I got used to be O.K more and more&quot; (F6).</td>
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<td>---------------</td>
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<tr>
<td>Initial articulatory distortion</td>
<td>&quot;It’s hard to pronounce some sounds, because when you put the [sensor] in your mouth, in the beginning you cannot really pronounce the /v/ sound and /θ/. Sometimes when you pronounce /ɹ/, something in the middle of your, I don’t know, in the top. It hurts your tongue, but not too bad&quot; (M1).</td>
</tr>
<tr>
<td>Faulty manufacturing</td>
<td>&quot;It hurt. I hurt the upper side of the mouth first time&quot; (F2).</td>
</tr>
<tr>
<td>Emotions experienced when using the sensor in the classroom</td>
<td></td>
</tr>
<tr>
<td>Boring repetition</td>
<td>&quot;Practicing pronunciation is good, but sometimes, for example, practicing just one word or a list [of words] repeatedly for 10 minutes or 15 minutes would be boring. I think that would be boring if we did just reading [the word list out loud]&quot; (F3).</td>
</tr>
<tr>
<td>Initial strangeness</td>
<td>&quot;I was concerned about how [classmates and teachers] would look at me [if I wore the sensor] at first, but it would feel natural as time goes by. When I said nervous, I mean I feel nervous when I used [sensor] by myself and other people looked at me a bit weird, but I think I can use it&quot; (F5).</td>
</tr>
<tr>
<td>Feedback on teacher instruction</td>
<td></td>
</tr>
<tr>
<td>Insufficient feedback</td>
<td>&quot;Because I don't have really big problem I guess, the teacher will help other people&quot; (F1).</td>
</tr>
</tbody>
</table>

| Challenges experienced in the pronunciation class | |
| Lack of consistency of use | "Because we just can practice in the class. We can’t practice in our home or anytime. So I think this is a difficulty way" (M2). |
| Dry mouth | "I want to take [the sensor] out and I want to drink some water, but it’s hard to drink water with the [sensor] in the mouth. No, [I can't drink water directly from the bottle with the sensor on], but I want [to]" (F4). |
| Difficulties distinguishing sounds | "Last class we learned about the difference between /ɪ/ and /ɨ:/ sound. But actually I couldn’t make /ɨ/ sound. Like, I can say seat, but I cannot say sit" (F6). |

| Challenges experienced in the pronunciation class | |
| Lack of consistency of use | "Because we just can practice in the class. We can’t practice in our home or anytime. So I think this is a difficulty way" (M2). |
| Difficulties distinguishing sounds | "Last class we learned about the difference between /ɪ/ and /ɨ:/ sound. But actually I couldn’t make /ɨ/ sound. Like, I can say seat, but I cannot say sit" (F6). |

| Suggestions |
| Having more in-class activities | "[The class] was good yesterday. It’s better to have some other activities as well, rather than just practicing [the word list for] 30-40 minutes over and over again. If you do something like that [minimal pair activity], it will be [more] interesting" (F3). |
| Adjusting class schedule | "The class should be one semester [for me to improve]" (F5). |

*Note. See Table 1 as a key to the countries of origin and L1 for the participants.*