JOURNAL OF
EMERGING INVESTIGATORS

Article

Determining the effects of voice pitch on adolescent perception, subconscious bias, and marketing success using electroencephalography

Emily Guan*, Katherine Monroe*, Michael T. Roche, Dawn Monroe
High Technology High School, Lincroft, New Jersey
*authors contributed equally

SUMMARY

A company's success largely depends on marketing; however, implicit biases may impact the perception and potency of advertisements. Voice pitch affects perceived authoritativeness, competency, and leadership capacity. Pitch also correlates with greater popularity in online influencers. This study employed neuromarketing techniques to quantify effects of bias caused by differences in voice pitch using affordable electroencephalogram (EEG). To determine the influence of voice pitch on marketing success, we collected subjective perception ratings (confidence, trustworthiness, and willingness to try) while subjects (n = 26) listened to sets of recordings of male-voiced and female-voiced advertisements with varying pitches. Subjects gave significantly higher ratings for male-voiced advertisements of low pitch and female-voiced advertisements of mid and low pitch. Additionally, we used EEG to measure levels of three brain wave frequency bands: theta, alpha, and beta bands. We found significant correlations between higher ratings and high levels of theta and alpha absolute power. We also found correlations between higher ratings and lower magnitude of frontal asymmetry, which measures difference in activity between the left and right prefrontal cortex. These findings suggest that examining certain measures of brain activity collected using an affordable EEG could predict advertising effectiveness, which may be invaluable in future neuromarketing research. Understanding voice pitch and other factors that cause implicit bias may allow significant advances in marketing, facilitating business success.

INTRODUCTION

Business success depends on marketing and advertising, through which companies can improve brand awareness, highlight product enhancements, and increase sales growth (1). Effective advertising targets both conscious and subconscious decision making in consumers, and as research in the marketing field expands, new techniques are being investigated to increase its reach and effectiveness (2).

Neuromarketing investigates the cognitive component of consumers' preferences and decisions. It uses various technologies and biometric data to comprehend the brain's reactions to different situations (3). In today's consumer-focused world, this field is a great asset to the success of a business and has been utilized by many top companies to uncover exactly what appeals to customers (4). Neuromarketing differs from traditional marketing, as it continues past consumer-reported responses. Rather than relying on conscious declarations, neuromarketing observes the lesser studied but equally important factor of subconscious decision making (5). Information gained in a way that reduces subjective data may be more accurate, helping companies implement better marketing strategies (6).

One of the most popular tools used to scan the brain in neuromarketing is the electroencephalogram (EEG), which reads neural activity by tracking changes in electrical activity through electrodes in contact with the scalp (6). When activity across neurons synchronizes, oscillatory activity can be detected and separated into frequency bands (**Figure 1**), or "brain waves," with the most common spectral bands being delta (1–4 Hz), theta (4–7 Hz), alpha (8–12 Hz), beta (13–30 Hz), and gamma (30–40 Hz) (7). Each frequency band may correspond to different emotional states. For example, higher levels of theta waves are associated with learning and memory, alpha waves with reflection and mental coordination, and beta waves with engagement and focus (8).

EEG devices are commonly used in neuromarketing research to study consumer preferences. Changes in brain wave frequencies demonstrate cognitive processes in response to marketing stimuli. For example, a study by Khushaba *et al*. presented subjects with different crackers that had varying qualities in shape, flavor, and topping. The researchers found a significant change in the activity of several EEG frequencies across the frontal (delta, alpha, beta), temporal (alpha, beta, gamma), and occipital (theta, alpha, and beta) regions of the brain when participants specified their preferences for a cracker type (7). This direct link between consumer preference and neural activity indicates that marketing strategies may benefit from studying the brain using EEG, pinpointing effective strategies without relying on subjective consumer response.

Greater relative left frontal activity signifies approach behavior, or a movement towards stimuli, and greater right activity has shown to correlate with withdrawal behavior, or movement away from stimuli (9). For example, Ohme *et al*. found that frontal alpha asymmetry can represent the effectiveness of televised advertisements, with more engaging advertisements generating significantly stronger left hemispheric activity relative to the right hemisphere (10). However, differences in data collection and analysis methods have led to great variety in findings (9). Therefore, additional research is needed to confirm frontal asymmetry, specifically greater relative left activity, as a reliable indicator of advertisement effectiveness.

The power of certain frequency bands is also measured in EEG research. Absolute power (μV2/Hz) and power relative to all frequency bands (%) are used to study emotion processing, medical conditions, and response to marketing stimuli. Within neuromarketing, Boksem and Smidts found that increased absolute power of beta frequency bands across all areas of the brain are successful predictors for positive responses to movie trailers (11). This suggests that the power of beta waves may indicate commercial success.

Social media marketing is a growing subfield within marketing. This particularly impacts younger generations, as studies have found that 80% of Generation Z (born after 1997) are influenced by social media when shopping (21). A previous study conducted by the student researchers, "Evaluating Effects of Voice Pitch on the Success of Online Influencers," suggested that voice pitch significantly affects the reach of social media marketing on YouTube, as measured by the subscriber count of male and female influencers. In this experiment, the implicit bias caused by pitch indicates that voice pitch may impact marketing effectiveness. The extent of such effects will only increase as advertising shifts further to online platforms.

Voice pitch is defined as "the perception of fundamental frequency (F0) and corresponding harmonics" of a person's voice (13). Voice pitch has been found to have significant impacts on the perception of a listener. Listeners perceive male voices of lower pitch to be more attractive, socially dominant, and competent (14). However, while some previous studies have found that lower-pitched female voices are perceived as more competent and dominant, they also note that lower-pitched female voices are perceived by listeners as less attractive (15). A study conducted by Klofstad *et al*. studied the effects of voice pitch on perceptions of leadership capacity (16). The researchers found that male and female candidates with lower-pitched voices may be more likely to win elected offices because listeners associate these voices with leadership qualities, including trustworthiness, authority, and competence. This demonstrates that while decisions in social engagement are considered conscious, higher-order thinking, they cannot be isolated from subconscious biases.

EEG devices usually have between 30 and 256 electrodes, but this technology is often expensive (12). The Emotiv Insight EEG used in this experiment has five electrodes and is one of the most affordable EEG headsets available for consumer and commercial use. If more accessible and less expensive EEG options, such as the Emotiv Insight, are determined suitable for research uses, benefits of neuromarketing may be more widespread and accessible.

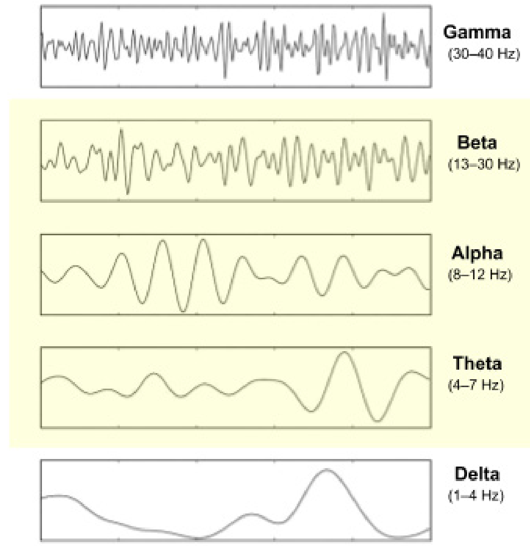

Figure 1. Brain wave frequencies with analyzed frequencies highlighted. Edited from Chatterjee, *et al* (20).

The current experiment sought to determine if low voice pitch significantly increases the effectiveness of an advertisement, in terms of perceived confidence, perceived trustworthiness, and willingness to try (WTT) an advertised product. Additional EEG analysis was used to demonstrate whether electroencephalography can be used to measure advertisement effectiveness. We hypothesized that higher effectiveness ratings would be correlated to higher absolute power and increased frontal asymmetry in three frequency bands: theta, alpha, and beta (**Figure 1**). Furthermore, the study examined if these EEG measures could be used to detect significant differences in ratings between pitches.

The study partially supported our hypotheses. Subjects gave higher ratings for male-voice advertisements of low pitch and female-voiced advertisements of mid and low pitch. In addition, we found significant correlations between higher ratings for certain effectiveness ratings and increased absolute power. We also found significant correlations between higher subjective ratings and lower magnitude of frontal asymmetry. However, EEG measures were not significantly different between voice pitches.

This study has significant applications in marketing. By identifying sources of implicit bias caused by voice pitch, companies may be able to use this information to better target consumers. Moreover, we focused on adolescents, as previous studies on marketing effectiveness towards

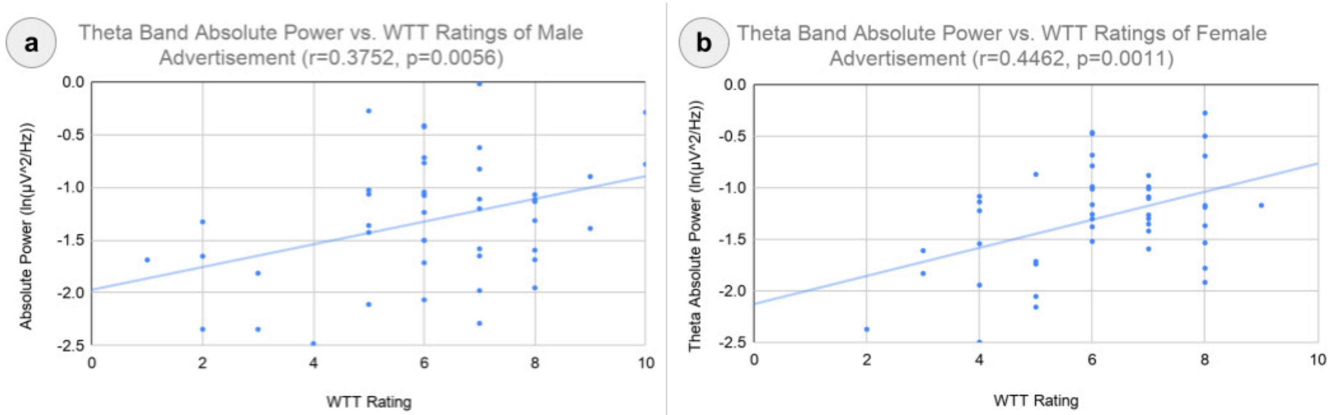

Figure 2. Examples of significant correlations between absolute power and effectiveness. a) Theta band absolute power (ln(μV²/Hz)) vs. WTT ratings of male advertisement (R = 0.3752, p = 0.0056). **b)** Theta band absolute power (ln(μV²/Hz)) vs. WTT ratings of female advertisement (R = 0.4462, p = 0.0011).

teenagers have relied on subjective data (5). We used an affordable EEG to investigate changes in brain activity, quantitatively measuring adolescent response to advertising stimuli.

RESULTS

Qualitative findings

We performed an ANOVA test for each subjective effectiveness rating between relative voice pitches, totaling in six tests. Significance was found in 4 of these tests: confidence ratings in males (p = 0.035), WTT in females (p = 0.043), and trustworthiness in both males (p = 0.006) and females (p = 0.03).

For each significant ANOVA test, we performed three t-tests—one t-test for each combination of relative voice pitches—to determine significance between each pitch. For confidence in male-voiced advertisements, significantly greater ratings were found for low pitch (p = 0.0248) and mid pitch (p = 0.0449) when compared to the high-pitched advertisement. WTT in female-voiced advertisements were significantly greater for low pitch (p = 0.0494) and mid pitch (p = 0.0254) when compared to those for high pitch. Trustworthiness ratings were significantly greater for low-pitched (p = 0.0344) and mid-pitched males (p = 0.0122) when compared to high pitch. Similarly, trustworthiness ratings were significantly greater for mid-pitched females when compared to high and low pitch (p = 0.0099). For male-voiced advertisement ratings with significant differences, low pitch always had the highest average effectiveness rating, and for females, mid pitch had the highest.

Quantitative EEG readings

Table 2 shows results of each quantitative EEG analysis. We performed a linear correlation and regression test between absolute power of each frequency band and each effectiveness rating, resulting in nine tests for each gender. All correlations were positive; examples of significant correlations can be seen in **Figures 2** and **3**. In male advertisements, we found a significant correlation between theta and trustworthiness (r = 0.292, p = 0.026), theta and WTT (R = 0.375, p = 0.006), and alpha and WTT (R = 0.280, p = 0.031). In female advertisements, we found a significant correlation

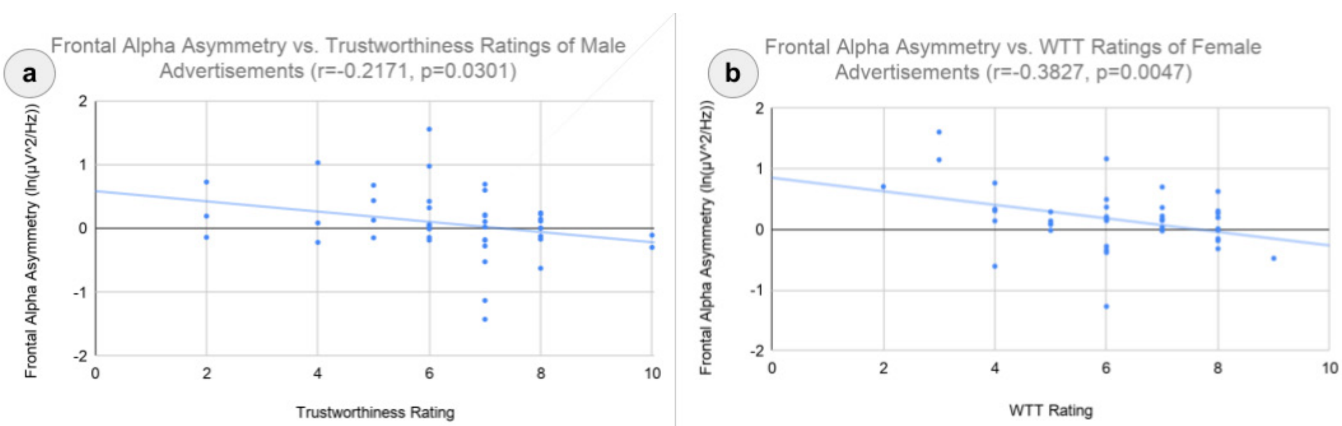

Figure 3. Significant correlations between frontal asymmetry and effectiveness. a) Frontal alpha asymmetry (ln(μV²/Hz)) vs. trustworthiness ratings of male advertisements (R = -0.2171, p = 0.0301); **b)** Frontal alpha asymmetry (ln(μV²/Hz)) vs. WTT ratings of female advertisements (R = -0.3827, p = 0.0047).

Table 1. Summary data of subject effectiveness ratings (*n* = 26).

Rating		Male Advertisement			Female Advertisement		
		High	Mid	Low	High	Mid	Low
Confidence	Mean	5.88	6.96	7.12	6.85	7.23	7.58
	St Dev	2.10	1.64	1.70	1.67	1.68	1.86
Trustworth-iness	Mean	5.65	6.69	6.73	5.36	6.69	6.23
	St Dev	1.57	1.29	1.97	1.93	1.78	1.82
WTT	Mean	5.27	6.00	6.12	5.96	6.12	4.88
	St Dev	2.05	1.77	2.18	1.80	1.80	2.05

Table 2. Regression results between effectiveness ratings and the EEG measures of absolute power and front asymmetry.

		Absolute Power (ln(μV2/Hz))						Frontal Asymmetry (ln(μV2/Hz))					
		Male-voiced Advertisements			Female-voiced Advertisements			Male-voiced Advertisements			Female-voiced Advertisements		
Rating Type		Theta	Alpha	Beta	Theta	Alpha	Beta	Theta	Alpha	Beta	Theta	Alpha	Beta
Confidence	P-Value	0.23	0.34	0.38	0.24	0.34	0.43	0.41	0.47	0.08	0.41	0.10	0.24
	R	0.11	-0.06	0.05	-0.11	0.06	0.03	0.04	0.01	0.15	0.03	0.19	-0.11
Trustworth-iness	P-Value	**0.03**	0.19	0.24	0.23	**0.04**	0.40	0.08	**0.03**	**0.05**	0.43	0.48	0.29
	R	0.29	0.14	0.11	0.12	0.26	0.04	-0.21	-0.22	-0.26	-0.03	-0.01	-0.09
WTT	P-Value	**0.01**	**0.03**	0.46	**0.00**	**0.01**	0.34	0.45	0.36	0.11	**0.01**	**0.01**	**0.01**
	R	0.38	0.28	0.01	0.45	0.34	0.06	0.02	-0.05	-0.18	-0.36	-0.38	-0.14

between theta and WTT (R = 0.446, p = 0.001), alpha and WTT (R = 0.344, p = 0.010), and alpha and trustworthiness (R = 0.255, p = 0.040). These results show that between these variables, greater absolute power was significantly related to higher ratings.

We performed a linear correlation and regression test between frontal asymmetry of each frequency band and each effectiveness rating, resulting in nine tests for each gender. For each frequency band, we calculated frontal asymmetry by subtracting absolute power in the right frontal electrode minus that in the left. Examples of significant correlations can be seen in **Figures 5** and **6**. In male advertisements, we found a significant negative correlation between alpha asymmetry and trustworthiness (R = -0.217, p = 0.030) and beta asymmetry and trustworthiness (R = -0.256, p = 0.045). Notably, the negative correlation between theta asymmetry and trustworthiness trended towards significance (R = -0.211, p = 0.083). A greater number of subjects may strengthen this trend. In female advertisements, we found a significant negative correlation between theta asymmetry and WTT (R = -0.361, p = 0.0074), alpha asymmetry and WTT (R = -0.383, p = 0.005), and beta asymmetry and WTT (R = -0.141, p = 0.012). Overall, we found significant negative correlations in male advertisements between trustworthiness and asymmetry in alpha and beta bands. Significant negative correlations in female advertisements exist between WTT and asymmetry in all bands. The results suggest that in certain frequency bands, lower overall magnitude of asymmetry is significantly correlated with higher effectiveness ratings. Because asymmetry was calculated by subtracting left activity from right activity, this indicates that a lower overall asymmetry reflects greater relative left activity.

Finally, we performed ANOVA tests for the absolute power of each frequency band between voice pitches. We also performed ANOVA tests for frontal asymmetry between pitches. We found no significance, but the p-value for absolute alpha power in females trended towards significance (p = 0.053).

DISCUSSION

An analysis of subjective ratings suggested that voice pitch significantly affects perception of male trustworthiness and confidence, as well as female trustworthiness and WTT. The low and mid pitched advertisements of both genders generally received the highest ratings. This aligns with previous literature, which found more favorable responses to lower pitched voices in a variety of settings. For example, listeners were more likely to vote for political candidates and trust research professors with lower-pitched voices (15-16). When applied to the voices of actors in advertisements, this type of listener bias may influence the success of an ad. The findings of this study suggest that companies should use voices of lower pitch to potentially increase effectiveness in their marketing campaigns, which would therefore drive

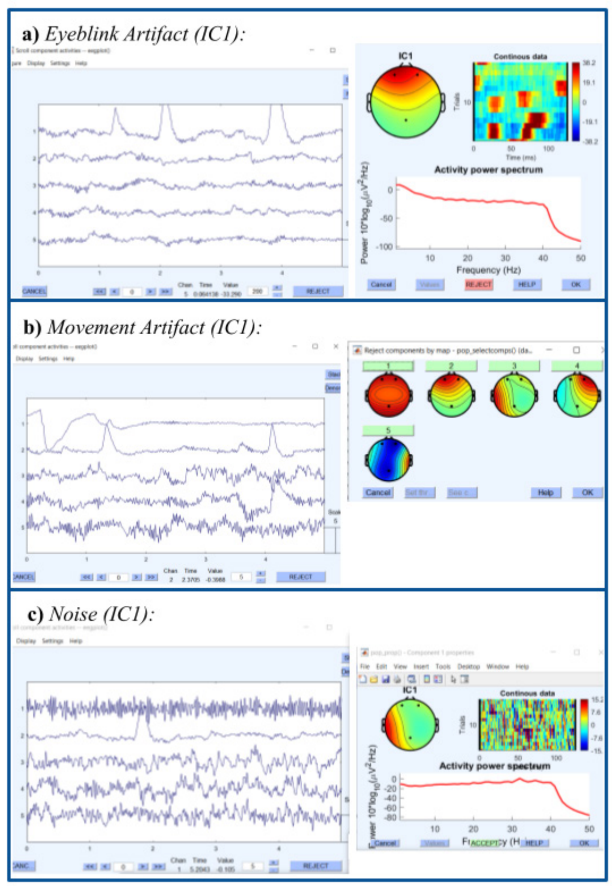

Figure 5. Screenshots of EEGLab of data from multiple subjects. **a)** Example of eyeblink artifact in independent component (IC) 1; identified by regular peaks in voltage vs. time graph. **b)** Example of movement artifact in IC1; note that IC2 also has blink artifacts. **c)** Example of noise in IC1; note that IC2 also has blink artifacts.

more sales. Because this experiment specifically tested adolescents, this application is especially relevant in advertisements targeting younger consumers.

In addition, previous literature has found radio advertisements to be dominated by male voices, regardless of the advertisement's target audience gender (17). The researchers suggest that predominance of male voices in radio advertising may be because "low-pitched voices are considered more serious, credible, safe, and powerful than high-pitched voices," which may appeal to potential buyers of a product (17). Therefore, the higher subjective ratings for lower-pitched voices found in this study may suggest a relationship between ad effectiveness and speaker gender as well. It raises interesting questions for future studies investigating how speaker and listener gender may affect perception of different types of ads.

Additionally, male and female voices have been shown to have different effects on neural activity, with voices of opposite sex generating greater activity in the auditory cortex (18). Similarly, this study found differences in brain wave frequencies during exposure to male- and female-voiced advertisements. We conducted regressions between effectiveness ratings and the EEG measurements of absolute power and frontal asymmetry. In male voices, absolute theta power may indicate perceived trustworthiness, whereas absolute alpha power may indicate this in female voices. Additionally, WTT may be indicated by absolute power of theta and alpha bands for both male and female voices. Overall, findings for absolute power suggest that lower frequencies (theta and alpha) may be indicators of subjective response, with differences in rating types for male and female voices. When examining frontal asymmetry, greater asymmetry was negatively correlated to higher ratings for some rating types. Perceived trust in male voices was negatively correlated to alpha and beta frontal asymmetry; in female voices, WTT ratings were negatively correlated to theta, alpha, and beta asymmetry. Frontal asymmetry was correlated to different measures of effectiveness for male- and female-voiced ads. Future studies could further pinpoint differences between brain wave activity in response to different genders.

ANOVA tests revealed no significance for frequency band measurements between voice pitches. This suggests that potential differences in neural activity caused by voice pitch may not be detected by affordable EEG. However, this finding might be attributed to a low number of subjects. Significance may be found with a greater number of subjects.

Overall, the results from examinations of absolute power and frontal asymmetry are encouraging. The correlations found largely support the use of affordable EEG to study cognitive responses to marketing techniques. These measurements do not contain the inaccuracies that commonly result from purely subjective marketing data (5). Thus, companies could apply them to compare the perception of different advertisements and predict their success before investing in full-scale campaigns.

A possible confounding variable in the study would be the modified voices used in the advertisements. Six separate listeners gave feedback on the advertisement clips before beginning the study, and we lowered pitch of the high female-voiced advertisement after feedback that the voice sounded artificial. Even though we utilized feedback from separate listeners, the unmodified mid-pitched voice may have still sounded more natural than the modified voices, affecting the subjective effectiveness ratings.

One limitation of the study was the low number of subjects for which EEG data was used. While subjective ratings were collected for 26 subjects, EEG data was analyzed for 15, as the rest had excess artifact contamination. Artifacts primarily included unexpected muscle movements and noise in the data caused by interference to the EEG data collection. Existing studies using affordable EEG have used sample sizes of 18 and 50 for a commercial 14-channel EEG and a sample size of 45 for a 16-channel EEG (7, 10, 22). Therefore, the current sample size may have been too small to detect certain correlations between effectiveness ratings and frequency band measures. Future studies with more subjects may improve the quality of findings by lowering variance and thus increasing significance. In addition, data in the experiment contained blink artifact contamination. While we did not analyze heavily contaminated data, data still had to be filtered. Filtered data is invariably altered to an extent (19). To improve quality and reduce necessary filtering in future trials, subjects would be instructed to close their eyes while listening to each advertisement recording, which would remove blink artifacts. The current study analyzed average neural activity across all the ratings. A future study could use event-related potentials (ERPs), which show neural immediate activity after a stimulus. In the proposed study, a questionnaire would only show one question (the stimulus) at a time, and each question would ask for a specific effectiveness rating. An EEG would measure cognitive response during each question, enabling researchers to examine EEG activity during each type of rating.

Overall, these findings suggest that voice pitch is a significant source of implicit bias that may impact marketing effectiveness towards adolescents. Neural activity measured by an affordable EEG may be used to predict advertising effectiveness. EEG may predict how certain factors help or hurt a marketing strategy before it is released to consumers. By using this method to identify sources of bias, businesses may have greater success in reaching target demographics through marketing, improving upon this essential component to their success.

MATERIALS AND METHODS

Audio files of advertisements for fictional footwear companies were obtained by recording the voices of one male and one female. The original voices of both ads fall into the population average voice pitch ranges for males (85-155 Hz) and females in the general population (165-255 Hz) (23). The

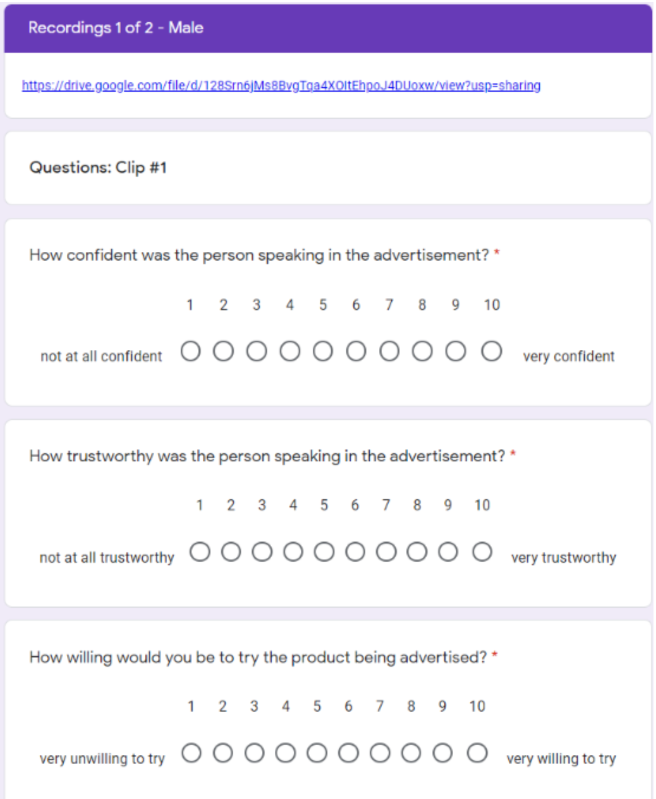

Figure 4. Questionnaire format for collection of effectiveness ratings. The same format was repeated for all advertisement clips.

male recording has an average pitch of 165 Hz, and the female recording has an average pitch of 220 Hz. Advertisement scripts for male and female advertisements differed slightly to prevent subjects from becoming accustomed to hearing the same content. To reduce bias, both advertisements were scripted for gender-neutral footwear and primarily advertised comfort. Additionally, neutral word choice was used to prevent bias from differences in diction. Subjects were not given information regarding the hypotheses being tested. Following Intel International Science and Engineering Fair (ISEF) guidelines for ethical research with human subjects, all subjects gave consent to participate in the study with full awareness of risks and expectations.

Audacity audio software was used to create two additional clips for each gender, one 10 Hz higher and the other 10 Hz lower in pitch. The high-pitched male voice was 25 Hz lower than the low-pitched female voice; recordings between genders are therefore not comparable. Six separate listeners (three male, three female) were asked to rank each voice clip from lowest to highest pitch, and all listeners were able to correctly rank the voices. Because some of the original listeners commented that the high-pitched female voice sounded "unnatural," this pitch was lowered by 5 Hz to create a natural sounding voice. For each gender, clips were combined into a longer "playlist" composed of four clips of the following pitches: mid, high, low, and mid, with a fifteen second pause between each clip. The mid-pitched clip was repeated to reduce any "shock" caused by hearing the voice for the first time. Two versions of each playlist were created with counterbalancing order. One male and one female playlist was assigned to each subject, so that equal numbers of subjects listened to each playlist.

Data collection occurred in a quiet high school classroom. Subjects were high school volunteers aged 13 to 18. The Emotiv Insight EEG headset was used with EmotivPRO software. Electrodes were cleaned with ReNu general purpose eye contact solution and primed with electrode solution, as instructed by the Emotiv website, before each new subject. Subjects were situated at Computer A with the virtual questionnaire, the structure of which is displayed in **Figure 4**. The EEG was connected to EmotivPRO software on Computer B. Subjects wore the EEG, maintained at 90% or greater contact quality, throughout the experiment. Subjects listened to recordings of each advertisement clip and then filled out the questionnaire, rating each clip on a scale of 1 to 10 for the 3 effectiveness ratings (confidence, trustworthiness, and WTT) during the 15 seconds after each clip.

EEG Data was filtered in EEGLab (Matlab 2019). Recordings were bandpass filtered around 1 and 40 Hz using a FIR filter to remove noise related to lower or higher frequencies. The continuous data were automatically separated into 5 components in EEGLab using Independent Component Analysis (ICA). Artifacts caused by eye blinks, muscle movement, or noise were identified and removed using Independent Component Analysis (ICA). An example of each artifact type is shown in **Figure 5**. EEG data from 15 subjects were selected for further analysis. To avoid analyzing subjects with insufficient uncontaminated data, subjects were withdrawn if more than one independent component had to be removed. Fast Fourier Transform (FFT) was performed with the Darbeliai EEGLab plugin to calculate absolute power ($\mu V^2/Hz$) for theta, alpha, and beta frequency bands.

After data collection, male and female voices were analyzed separately using Microsoft Excel. All statistical tests were run with a significance level of $\alpha = 0.05$. For analysis of qualitative data, six initial ANOVA tests were run, one for each subjective rating. For each significant result, additional two-tailed t-tests were conducted to determine difference in ratings between pitches (high-low, high-mid, and mid-low), totaling in three t-tests for each significant ANOVA.

For qualitative data analysis, EEG absolute power values were log-transformed to normalize data, since untransformed power values tend to be positively skewed (9). A linear correlation and regression test was performed between the absolute power of each frequency band and each effectiveness rating. ANOVA tests were also performed for absolute power values of each frequency band between voice pitches. Frontal asymmetry was calculated by subtracting absolute power across the frontal electrodes ($\ln[AF4]-\ln[AF3]$). A linear correlation and regression test was performed between frontal asymmetry of each frequency band and each effectiveness rating. ANOVA tests were also performed for frontal asymmetry between voice pitches.

ACKNOWLEDGEMENTS

We would like to acknowledge the statistical advice given by our high school Algebra and Statistics teacher, Mrs. Karen Brown. We also acknowledge Jiaqi Su, a Ph.D. candidate at Princeton University, for her input on our EEG data analysis methods and support for this project.

Received: August 5, 2020
Accepted: February 8, 2021
Published: April 2, 2021

REFERENCES

1. Urbonavičius, Sigitas, and Vytautas Dikčius. "Importance of Marketing Activities in a Company: the Management Perspective." Ekonomika, vol. 83, 2008, pp. 41-50.
2. Brierley, Geraldene L. Subconscious Marketing Techniques: the Implications for Consumer Regulations and the Marketing Profession. 2017. Cardiff Metropolitan University, PhD dissertation. hdl.handle.net/10369/8781.
3. Sebastian, Vlăsceanu. "Neuromarketing and Evaluation of Cognitive and Emotional Responses of Consumers to Marketing Stimuli." Procedia - Social and Behavioral Sciences, vol. 127, 2014, pp. 753-757, doi.org/10.1016/j.sbspro.2014.03.349.
4. Babu, S. S., and Thalluri P. Vidyasagar. "Neuromarketing: Is Campbell in Soup?" IUP Journal of Marketing Management, vol. 11, no. 2, 2012, Questia. www.questia.com/.
5. Meyerding, Stephan G., and Clara M. Mehlhose. "Can neuromarketing add value to the traditional marketing research? An exemplary experiment with functional near-infrared spectroscopy (fNIRS)." Journal of Business Research, vol. 107, 2020, pp. 172-185.
6. Bhatia, Keshav. "Neuromarketing: Towards a better understanding of consumer behavior." Optimization, vol. 6, no. 1, 2014, ResearchGate. www.researchgate.net/. Accessed 6 Oct. 2020.
7. Khushaba, Rami N., *et al*. "Consumer Neuroscience: Assessing the Brain Response to Marketing Stimuli Using Electroencephalogram (EEG) and Eye Tracking." Expert Systems with Applications, vol. 40, no. 9, 2013, pp. 3803–3812., doi:10.1016/j.eswa.2012.12.095.
8. Abhang, Priyanka A., *et al*. Introduction to EEG- and Speech-Based Emotion Recognition. Academic Press, 2016.
9. Smith, E, *et al*. "Assessing and Conceptualizing Frontal EEG Asymmetry: An Updated Primer on Recording, Processing, Analyzing, and Interpreting Frontal Alpha Asymmetry." International Journal of Psychophysiology, vol. 111, 2016, pp. 98–114., doi: 10.1016/j.ijpsycho.2016.11.005.
10. Ohme, Rafal, *et al*. "Application of Frontal EEG Asymmetry to Advertising Research." Journal of Economic Psychology, vol. 31, no. 5, Oct. 2010, pp. 785–793., doi:10.1016/j.joep.2010.03.008.
11. Boksem, Maarten A.s., and Ale Smidts. "Brain Responses to Movie Trailers Predict Individual Preferences for Movies and Their Population-Wide Commercial Success." Journal of Marketing Research, vol. 52, no. 4, 2015, pp. 482–492., doi:10.1509/jmr.13.0572.
12. Paul L. Nunez and Ramesh Srinivasan (2007) Electroencephalogram. Scholarpedia, 2(2):1348.
13. Re, Daniel E., *et al*. "Preferences for Very Low and Very High Voice Pitch in Humans." PLoS ONE, vol. 7, no. 3, 2012, doi:10.1371/journal.pone.0032719.
14. Pisanski, Katarzyna, and David R Feinberg. "Vocal Attractiveness." The Oxford Handbook of Voice Perception, edited by S. Frühholz and P. Belin, Oxford University Press, 2018, pp. 607-676.
15. Sorokowski, Piotr, *et al*. "Voice of Authority: Professionals Lower Their Vocal Frequencies When Giving Expert Advice." Journal of Nonverbal Behavior, vol. 43, no. 2, 2019, pp. 257–269., doi:10.1007/s10919-019-00307-0.
16. Klofstad, Casey A., *et al*. "Sounds Like a Winner: Voice Pitch Influences Perception of Leadership Capacity." SSRN Electronic Journal, 4 Nov. 2011, doi:10.2139/ssrn.1954756.
17. Martín-Santana, J.D., *et al*. "Influence of radio spokesperson gender and vocal pitch on advertising effectiveness: The role of listener gender." Spanish Journal of Marketing - ESIC, vol. 21, no. 1, 2017, pp. 63-71, ScienceDirect. doi:10.1016/j.sjme.2017.02.001.
18. Junger, Jessica, *et al*. "Sex matters: Neural correlates of voice gender perception." NeuroImage, vol. 79, 2013, pp. 275-287, ScienceDirect. doi:10.1016/j.neuroimage.2013.04.105.
19. Tanner, Darren *et al*. "How inappropriate high-pass filters can produce artifactual effects and incorrect conclusions in ERP studies of language and cognition." Psychophysiology vol. 52,8 (2015): 997-1009. doi:10.1111/psyp.12437
20. Chatterjee, Rajdeep, *et al*. "Ensemble Learning Approach to Motor Imagery EEG Signal Classification." Machine Learning in Bio-Signal Analysis and Diagnostic Imaging, 2018, pp. 183-208, doi:10.1016/B978-0-12-816086-2.00008-4.
21. Yes Marketing. "A Marketer's Guide to Reaching the Generations." Yesmail Interactive, 2017.
22. Yuvaraj, Rajamanickam *et al*. "On the analysis of EEG power, frequency and asymmetry in Parkinson's disease during emotion processing." Behavioral and brain functions : BBF vol. 10 12. 9 Apr. 2014, doi:10.1186/1744-9081-10-12
23. Titze, I. R. (1994). Principles of voice production. Allyn & Bacon.