Tactile sensitivity of different oral tissues to punctate pressure

Kevin Berkowitz[1], Brittany Miles[1], and Dr. Christopher Simons[1]

College of Food, Agricultural, and Environmental Sciences / The Ohio State University / Department of Food Science and Technology[1]

Abstract

The tongue has been shown to be a highly sensitive area to tactile stimuli; however, little has been studied on the other tissues in the mouth, such as the gums and hard palate All three tissues play a role in the mastication process. The purpose of this study was to see which tissue has the greatest sensitivity to punctate stimuli. It was hypothesized that the tongue would be the most sensitive tissue compared to the hard palate (HP) and gums because of its greater deformability even at very low forces and active role in texture perception. To test this hypothesis a punctate pressure sensitivity just-noticeable difference (JND) threshold was determined for 30 individuals (aged 18-40, 17F/13M) via the forced-choice, up-down staircase method using Luneau Cochet-Bonnet Aesthesiometers to deliver a range of very-low forces (F=0.0044-0.010g). The tongue (0.00192±9.6e-5g) was found to be significantly more sensitive than both the HP (0.00252±0.000 21g) and the gums (0.00288±0.00023g) ($p=0.019$ and $p<0.001$, respectively). JNDs for the hard palate and gums, however, were not significantly different ($p=0.235$) This order of JNDs (tongue, hard palate, gums) was also the most common on an individual basis (n=12), and binomial probability indicated that this was a very significant effect ($p=0.0015$). These findings are in agreement with the hypothesis that the tongue would be the most sensitive tissue to punctate pressure. The tongue is a softer surface than the gums or the roof of the mouth. Future studies could use other types of texture stimuli to provide an improved overall understanding of what occurs with the various tissues.

Introduction

The oral cavity has been shown to be a highly sensitive area to tactile stimuli; however, most studies have focused on the tongue, as it is the structure involved in active touch. Little has been studied on the other tissues in the mouth. Previous work shows that both hard and soft tissues are used in the mastication process (Running 2016). Additionally, there are mechanoreceptors found in both the hard and soft tissues within the mouth that allow us to control the force at which we chew (Aktar et al 2015).

Unlike most previous studies on punctate-pressure sensitivity, this study used Luneau Cochet-Bonnet aesthesiometers (Figure 1). Compared to the Semmes-Weinstein filaments – which are typically used – aesthesiometers are able to produce a lower force threshold, and there is less inter-device variability due to the force adjustability of a single device (Miles et al 2018). The aesthesiometers are able to produce lower forces which enabled testing at levels not possible in past studies. This is why the aesthesiometers seem like an excellent choice because of the low forces that people are able to determine.

The purpose of this study was to determine which tissue has the greatest sensitivity to punctate-pressure stimuli. It is important to understand which tissues are highly tactile sensitive because this sensitivity directly relates to texture perception. Texture perception has a direct effect on consumers perception of quality (Strassburg 2009). By understanding which tissue is the most sensitive we will have a better understanding of which tissue has the most interaction with texture perception. It was hypothesized that the tongue would be the most sensitive tissue compared to the hard palate and gums because of its greater deformability even at very low forces and active role in texture perception.

Objective

The purpose of this study was to determine which tissues in the oral cavity that are involved in the mastication process were most sensitive to punctate-pressure stimuli testing.

Methods

Subject Criteria

30 subjects (17f/13m, ages 18-40) participated in the study were recruited from The Ohio State University Research Database. Subjects were excluded who had symptoms of xerostomia, were immunocompromised, smokers/ vape users, and anyone with scars or open wounds within the mouth.

Testing

Upon arrival, subjects were given a consent form (Protocol: 2013B0277). Subjects were informed of the purpose of the study and any related questions were answered. Each subject sat in a chair and the investigator would use the aesthesiometer to test punctate sensitivity on three different tissues (tongue, hard palate, and lower gums; Figure 2) in the mouth. One tissue was tested at a time using two aesthesiometers. The control and experimental stimuli were applied separately. Subjects were instructed to say which stimulus felt stronger. If a subject could not tell a difference between the forces, they were still asked to give a response. All three tissues were evaluated using a forced choice up-down staircase method. The length of the aesthesiometer could be adjusted to change the force. Subjects were blindfolded so that they could not see the length of the stimuli.

Figure 1: Luneau Cochet-Bonnet Aesthesiometers. The control was a length of 6 cm and a force of 0.0044 g and the smallest length used was 3.75 cm with a force of 0.010 g. Force and length were inversely proportional.

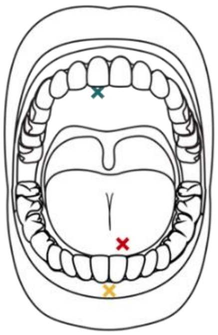

Figure 2: Representation of where stimuli would be applied. Blue X represents hard palate. Red X represents the tongue. Yellow X represents lower gums.

Forced Choice, Up-Down Staircase Method

Stimuli were presented in a randomized order to subjects on each tissue so that they did not know whether they were receiving the control or variable first. Subjects were told to identify either the first or second of each stimulus pair as being the strongest. The control always remained at 6 cm (F=0.0044 g), but the other forces ranged from 3.75-5.75 cm (F=0.010-0.0052g). The initial variable stimulus was always 4.75 cm (F=0.0071 g). If the correct force was chosen between the two stimuli, then the next variable stimulus would increase by a quarter of a centimeter which would decrease the administered force. This would decrease the differences between the forces. If the subject incorrectly answered, then the filament length would decrease by a quarter centimeter which would increase the force. This would increase the differences between the forces. After each trial, the answer provided by the subject was recorded (Figure 3). This was performed on one tissue until eight reversals were achieved. A reversal was signified by a correct response followed by an incorrect response, or an incorrect response followed by a correct response. This process was repeated for the remaining two tissues. Stimuli were applied to the lower gums just below the teeth, hard palate, and the tip of the tongue.

	I	2	3	4	5	6	7	8	9	10	11	12	13	14
5.75cm							✓	✗		✗				✓
5.50cm						✓			✓		✗		✓	
5.25cm			✗		✓							✓		
5.00cm		✓		✓										
4.75cm	✓													
4.50cm														
4.25cm														
4.00cm														
3.75cm														

Figure 3: Table of subject's responses for a single tissue. A check mark represents a correct response and an X represents an incorrect response. Highlighted boxes signify a reversal. The column to the left represents the forces in length.

Sanitization

The aesthesiometers were cleaned between subjects using CIDEX disinfectant. Each aesthesiometer was placed in the solution for twelve minutes and rinsed with water. Finally, they were dried using pressurized air.

Data Analysis

The Just Noticeable Difference (JND) was calculated by taking an average of the eight reversals for each tissue and subtracting the lowest force of 0.0044 g. A two-way ANOVA was run with a Tukey post-hoc test (α=0.05). Binomial probability analysis (1/6 chance probability) was also conducted to determine whether a given tissue sensitivity order (tongue>hard palate>gums) was observed in a significant majority of subjects.

Results and Discussion

Among the subjects, the Just Noticeable Difference (JND) threshold for the tongue was significantly better in detecting lower forces than the roof of the mouth and the gums (p=0.019 and p<0.001). The JNDs between the gums and palate did not show any statistical significance (p=0.235). The distribution of forces from least to most, as shown in figure 4 were the tongue with 0.00192±9.6e-5g, followed by the palate with 0.00252±0.000 21g , and finally the gums at 0.00288±0.00023g. Binomial probability indicated that a significant number of participants were best with their tongue, then the palate, and then then the gums (p=0.001). 17 subjects performed best with their tongue and 12 subjects performed best to worst in the order of tongue, hard palate, and lower gums. Based off of the ranges in figure 4 it can be clearly seen that most subjects perform the best with their tongue.

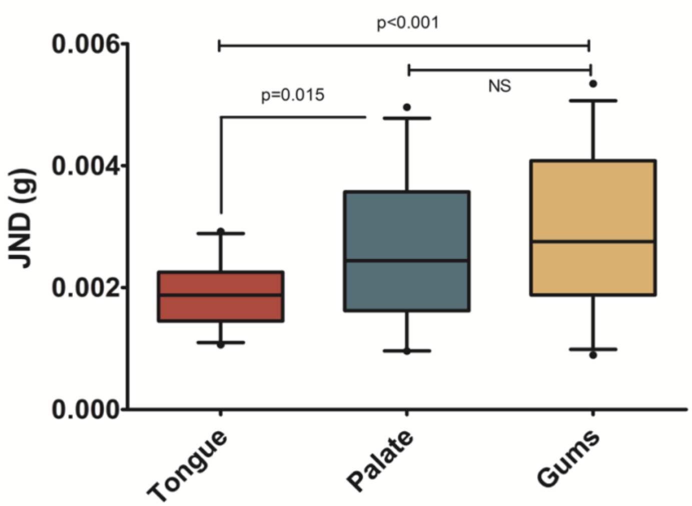

Figure 4: Box and whisker plots representing the ranges of JNDs for each tissue. Colored bars represent the interquartile range, the middle line represents the median, and lines extending vertically from the bars represent the JND range.

Conclusion

The results agree with the hypothesis that the tongue would be the most sensitive to punctate stimuli because of its greater deformability compared to the other tissues. It is important to understand that the tongue may have a greater influence on texture perception for the consumption of food so that producers can make food with the attributes that the customer is expecting. A higher density of the mechanoreceptors within the tongue may be the reason for its sensitivity to punctate stimuli compared to the other tissues. Future studies could look at other characteristics such as grittiness on texture sensitivity or use other types of texture stimuli to provide an improved overall understanding of what occurs with the various tissues.

Acknowledgments

Thank you to Dr. Simons, Brittany Miles, and everyone in the OSU Food Science & Technology Sensory Lab group for all of the support and help.

References

[1]Running CA (2016) Human Oral Sensory Systems and Swallowing. Perspectives of the ASHA Special Interest Groups 1:38–47. doi: 10.1044/persp1.sig13.38

[2]Aktar T, Chen J, Ettelaie R, Holmes M (2015) Tactile Sensitivity and Capability of Soft-Solid Texture Discrimination. Journal of Texture Studies 46:429–439. doi: 10.1111/jtxs.12142

[3]Boesveldt S, Bobowski N, Mccrickerd K, et al (2018) The changing role of the senses in food choice and food intake across the lifespan. Food Quality and Preference 68:80–89. doi: 10.1016/j.foodqual.2018.02.004

[4]Miles B, Simaeys KV, Whitecotton M, Simons CT (2018) Comparative tactile sensitivity of the fingertip and apical tongue using complex and pure tactile tasks. Physiology & Behavior 194:515–521. doi: 10.1016/j.physbeh.2018.07.002

[5]Shupe GE, Resmondo ZN, Luckett CR (2018) Characterization of oral tactile sensitivity and masticatory performance across adulthood. Journal of Texture Studies 49:560–568. doi:10.1111/jtxs.12364

[6] Strassburg J, Burbidge A, Hartmann C (2009) Identification of tactile mechanisms for the evaluation of object sizes during texture perception. Food Quality and Preference 20:329–334. doi: 10.1016/j.foodqual.2009.02.004