Comparison of The Tactile Sensitivity of Tongue and Fingertip Using a Pure-Tactile Task

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Abstract

The human tongue perceives various textures through the sensitivity to tactile stimuli. Previously, studies attempting to assess point-and-edge (P&E) sensitivity in both the fingers and tongue relied on stereognostic tasks, which involve a shape recognition component, and were thus inherently cognitive. Consequently, it was unclear if differences between individuals' ability on these tasks were due to differences in tactile acuity or differences in cognitive processing ability. The objective of this research was to utilize novel stimuli to assess the relative P&E sensitivity of the fingertip and tongue in a pure-tactile task, independent from a cognitive component. We hypothesized the tongue would be better than fingertip at assessing point-and-edge stimuli as previous work has found the tongue to be more sensitive to other "pure-tactile" stimuli. Thirty participants' (aged 18-30), oral and lingual sensitivity to point-and-edge stimuli was assessed using the forced-choice, up-down staircase method. Stimuli consisted of 3-D printed tiles. The height of the step was consistent across all tiles, but the angle of the step perpendicular to the tile surface varied from 45-90°. A two-tailed t-test ($\alpha=0.05$) found that the JND for the tongue (12.75±1.21) was significantly smaller ($p=0.0002$) than the JND for the fingertip (19.81±1.75). A significant majority of subjects were more sensitive with their tongues compared to their fingertips (22/30; $p=0.016$). Delta JND (ΔJND) was calculated by comparing the relative differences in JNDs between individuals who were better with their tongues ($n=22$; 10.57±1.21) and individuals who were better with their fingers ($n=8$; 2.95±1.75). Individuals who were better with their tongues had significantly ($p=0.000633$) larger ΔJND's compared to individuals who were better with their finger.

Introduction

Humans interact with food daily, and other than taste, sight and hearing, the perception of food can be affected by touch (Nishinari, Kohyama, Kumagai, Funami, & Bourne, 2013; Szczesniak, 2002). During consumption, food texture can be perceived by the tongue and sometimes the finger, and food acceptance is dependent on this perception (Shupe, Resmondo and Luckett 2018). Touch, pressure, vibration, pain and stretching can be detected by finger and tongue, which then convey the message to the brain and inform one's food acceptance. Tactile perception plays a role in a variety of functions including chewing and swallowing. The stimulation of the sensory receptors due to the shapes, sizes and surface textures of the oral mucosa affects voluntary swallowing with the activation of the swallowing central pattern generator (Yahagi, Okuda-Akabane, Fukami, Matsumoto and Kitada 2008). With that said, sensory inputs are important to steadily perform voluntary swallowing and help to compensate the difficulty in performing swallowing generated by the central mechanism.

The purpose of this study was to assess the relative P&E sensitivity of fingertip and tongue in a pure-tactile task, independent from a cognitive component, utilizing novel stimuli. Previous work has shown that the sensitivity of fingertips was better than tongue in a P&E letter recognition task. During P&E letter recognition task using fingertips, the brain has that ability to imagine the stimuli when oral evaluation does not have the ability to do so (Zeki 1993). Other pure-tactile tasks run showed the tongue was better than the fingertips, but only the P&E recognition task varied from the rest (Miles, Van Simaeys, Whitecotton and Simons 2018). It was hypothesized that the cognitive component was the factor that led to higher sensitivity in fingertips than tongue in the P&E condition. Therefore, this study has removed the cognitive component by changing from the letter stimuli into angle stimuli to evaluate P&E sensitivity as pure-tactile task, and therefore it was hypothesized that the tongue would have the lower JND for angle recognition.

Objective

The objective of this study was to utilize novel stimuli to assess the relative P&E sensitivity of the fingertip and tongue in a pure-tactile task, independent from a cognitive component.

Methods

Subjects

Thirty healthy participants aged 18-30 were recruited from the Ohio State Sensory Database. Individuals with any visible injuries such as wounds, wrinkles, or scars around the mouth, tongue, or fingers were excluded. Individual with finger-tip calluses were also excluded. For the fingertip conditions, participants selected an index finger that they used throughout the test for consistency. Before touching the stimuli, participants were required to put on a pair of goggles covered with parafilm to prevent discrimination based on visual information.

Psychophysical Task

The P&E test was run using the forced-choice, up-down staircase method (Miles, Van Simaeys, Whitecotton and Simons 2018; Linne and Simons 2017), using size 1cm x 1cm 3-D printed tiles as the stimuli to be tested. The height of the raised portion of the tile was consistent, but the angle on the stimuli varied from 45-90° (Figure 1). Participants were presented with pairs of stimuli. The 90° control was always presented while the other stimulus was variable starting at 65°. If the correct stimulus was chosen, the angle of the variable stimulus was increased by 5°, making the task more difficult. On the other hand, if the incorrect stimulus was chosen, the angle of the variable stimulus was decreased by 5°, making the task easier.

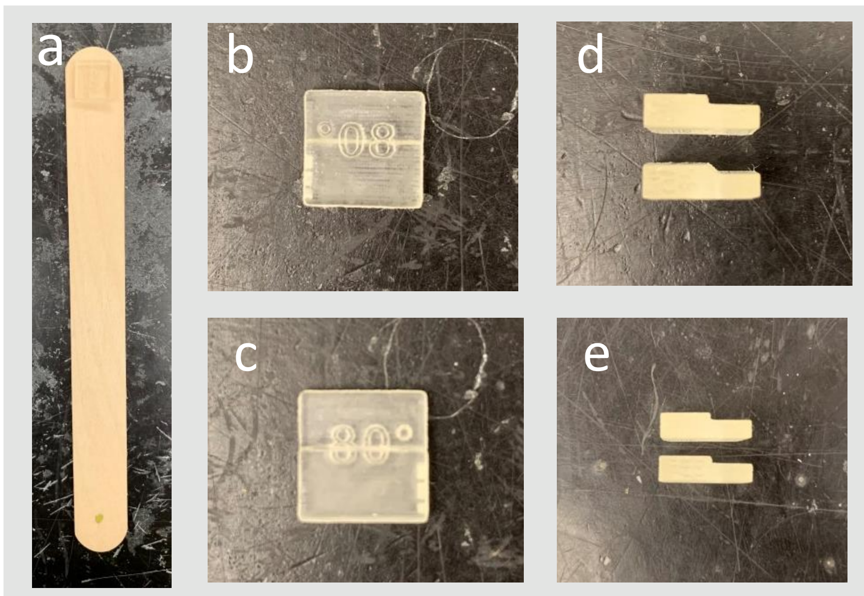

Figure 1 a-e. Example of stimuli presented to participant (Figure 1a). Front of stimuli (Figure 1b) and back of stimuli (Figure 1c). Side view of least challenging pair, 90°(top) and 45° (bottom) (*Figure 1d). Side view of most challenging pair, 90°(top) and 85°* (bottom) (*Figure 1e).*

Data Analysis

The task was completed when eight reversals were achieved (Figure 2). A reversal was obtained when there was a correct response followed by an incorrect one or vice versa. Reversals could also be obtained when the participant correctly identified the most similar pair of stimuli, or incorrectly identified the least similar pair of stimuli. Lastly, the average Just Noticeable Difference (JND) for each condition, tongue and fingertip, was determined by taking an average of the eight reversals. To find out if participants were significantly more sensitive with their tongue than their fingertips and to determine if the tongue had a higher ability detecting points and edges, binomial statistics (p=1/2, α=0.05) were used.

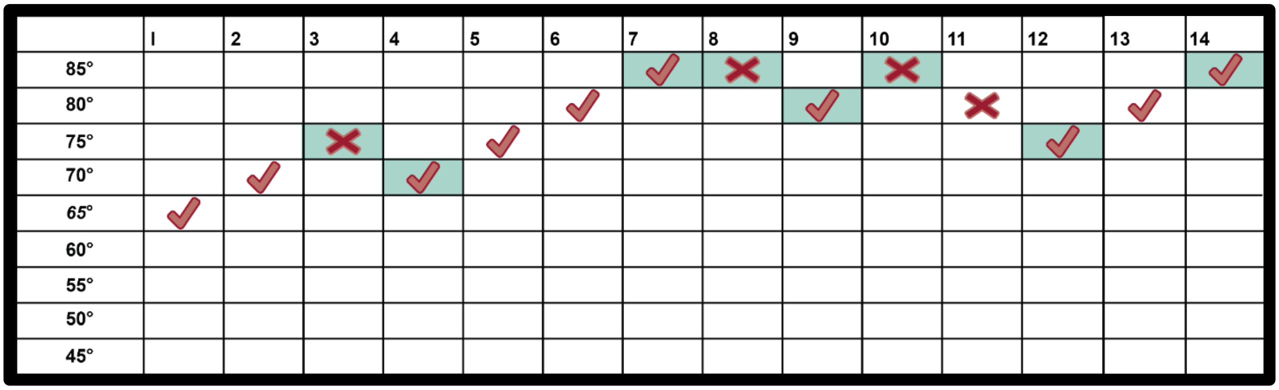

Figure 2. Example of eight reversals (highlighted boxes) in a forced-choice, up-down staircase method.

Results and Discussion

Comparison of average JND showed individuals could discriminate significantly better ($p<0.001$) with their tongue (JND = 12.75° ± 1.21°) than with their fingers (JND = 19.81° ± 1.75°) (Figure 3). Binomial probability indicated majority of the participants (n=22) showed higher sensitivity with their tongue (p=0.00545). These findings agree with the hypothesis stated that the cognitive component affected the results of sensitivity of tongue and fingertips in the original stereognostic P&E condition.

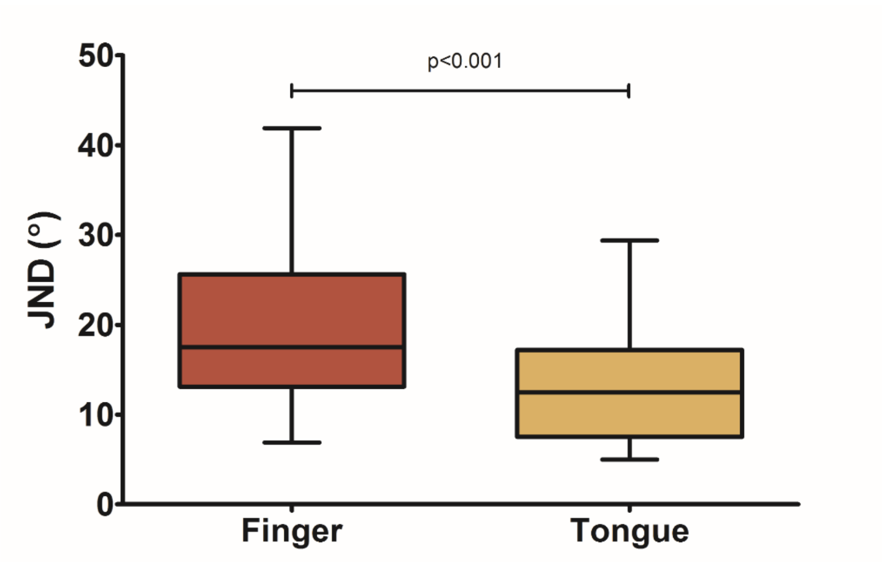

Figure 3. Average JND threshold for finger and tongue. The average JND threshold for finger and tongue were calculated by taking the average of the difference between the angle of each reversal and the angle of control stimulus (90°). The middle line represents the median of the average JND. Error bars represent standard error.

Difference in JND (ΔJND) was significantly higher ($p<0.001$) for individuals who were better with their tongue (ΔJND = 10.57°±1.21°) than individuals who were better with their finger (ΔJND = 2.95°±1.75°) (Figure 4). This indicates individuals who were better with their tongue were generally much better, while individuals who were better with their finger, were only marginally so. According to Figure 4, the acuity of the tongue was much higher than fingertip due, in part, to the large variability in sensitivity for the fingertips.

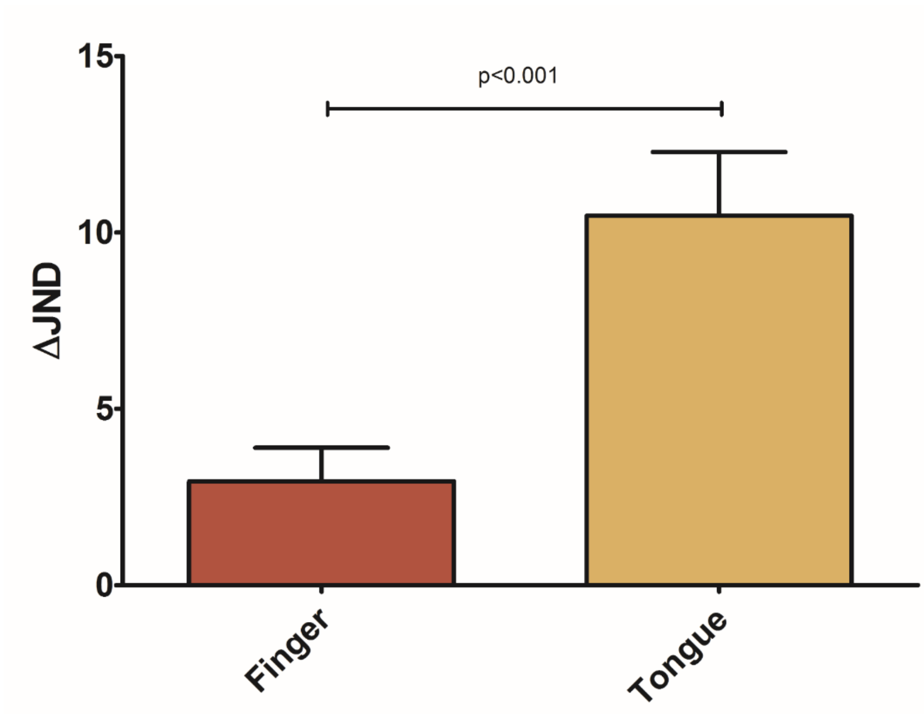

Figure 4. Average ΔJND threshold of relative sensitivity for fingertip and tongue. The relative sensitivity was calculated by taking the difference between the highest JND and the lowest JND for each tongue and fingertip. Error bars indicate standard error.

Conclusion

The goal of this experiment was to determine if tongue or fingertip is better at evaluating P&E differences in a pure-tactile task. Though sensitivity of fingertips was shown to be better than tongue in a P&E letter recognition task previously, research was done to further explore and understand the sensitivity of tongue and fingertip without cognitive component. This study excluded cognitive component in order to learn how the cognitive component can affect evaluation of P&E. By doing so, this information helps future studies to be aware of utilizing non-cognitively loaded tasks when evaluating oral tactile sensitivity.

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