# Tongue Piercings' Effects on Sensitivity to Salt and Sucrose

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Abstract

Little scientific research focuses on the effects tongue piercings have on taste sensitivity. People who have tongue piercings reported no noticeable changes; yet also reported not to have previously considered it. This study utilized two preliminary tests to find threshold sensitivities for saltiness and sweetness, and two signal detection tasks utilizing those thresholds. However, salt has a potential confound, which is a burn component. Therefore, pain, not taste, might have been tested. Sucrose does not have this confound. Participants' data showed a significant increase in salt sensitivity among pierced participants, but no significant change to sucrose.

Tongue Piercings' Effects of Sensitivity to Salt and Sucrose

Three nerves innervate the tongue: The chorda tympani nerve (seventh cranial nerve), the glossopharyngeal nerve (ninth cranial nerve) and the vagus nerve (tenth cranial nerve). These nerves are located in different areas of the tongue; with respect to the type of taste bud they innervate (McMahon, Shikata & Breslin, 2001). It is on either side of the tongue that the chorda tympani nerves reside. These nerves innervate the taste buds on the anterior two thirds of the tongue. This nerve has two branches, which run down either side of the tongue to form a "U" at the bottom (Zuniga, Chen, & Miller Jr., 1994 and Sun & Oakley, 2002). Both foliate and fungiform papillae are innervated by this nerves. The glossopharyngeal (or the chorda lingual) nerve innervates taste buds on the posterior part of the tongue; the circumvallate papillae are found in that area in the form of a "V" shape on the back of the tongue. And the vagus nerve is found innervating taste buds on the far posterior tongue, extending further down into the throat. The fourth type of papillae, the filiform papillae, does not have taste buds. These papillae are responsible to help the movement of food (Kazdin, 2000).

It is generally accepted that there are four major tastes (sweet, salt, bitter, and sour) and a fifth, more controversial taste, known as Umami (Japanese for "delicious") (Carlson, 2004). Everything we taste comes from a combination of those basic tastes (Kazdin, 2000). Taste is controlled by specialized receptor cells that are found in groups known as taste buds. Taste buds are pear-shaped structures that have an opening at one end known as a taste pore and are found arranged within the pore similar to the segments of an orange (Kazdin, 2000). Certain chemicals, known as tastants, encounter the taste pore and produce a sensation of taste. Taste buds in mammals develop in unspecified regions and in random assortment on the tongue and soft palate (Sun & Oakley, 2002) and are found in clusters within pores known as papillae.

Figure 1 shows the positions of the different types of papillae and, in theory, where in the tongue the nerves are located. The different groups of taste buds have been found to be more sensitive to certain tastes than others. Foliate papillae are especially sensitive to sour tastes, circumvallate papillae to sweet and fungiform papillae to salt (Carlson, 2004). Most people have approximately 200 fungiform papillae on the anterior two thirds of the tongue; fungiform papillae on super tasters, anatomically speaking, are found in the most abundance (Bartoshuk, 2000). Research has shown these taste buds have a higher affinity for certain tastes, but that the buds do react to all four tastants. The buds are different when groups are compared to each other, but similar within the group itself (Kazdin, 2000). There are two major theories on how taste buds react: the labeled-line theory and the pattern theory. The labeled-line theory states that each taste bud within a group is responsible for one taste quality. The pattern theory says that all cells contribute to tasting equally, but that the rate of response to stimuli is what puts the stimuli into the different categories. It has been found that both theories are correct when they work together. Neither is fully correct alone, but in cooperation, both account for almost all of the data (McBurney & Gent, 1979).

One of the most common causes for taste deficits is damage to the nerves. Zuniga et al. (1994) found that if the chorda tympani nerves are severed, taste sensitivity decreases. Ogden's (1989) study (as cited in Zuniga et al., 1994), reported an absence of fungiform papillae in patients with chorda lingual nerve transsections. In studies done by Chilla et al. (1982), Grant et al. (1989), and Abrahams et al. (1993) (as cited in Zuniga et al., 1994), a permanent alteration of taste sensitivity was found in patients with chorda tympani or glossopharyngeal nerve transsections. Some patients even reported taste phantoms. In the case of localized loss of taste sensitivity, some patients have reported a chronic taste when there was nothing there

(Yanagisawa, Bartoshuk, Catalanotto, Karrer, & Kveton, 1998). Previous research found that for taste sensations to diminish, an injury must come from the nerves of the tongue, not necessarily just superficial damage to the tongue itself. The major inference from this is that if the area known as the midline of the tongue has a wound, theoretically participants should not lose the sense of taste, as little damage has occurred to either of the nerves. The midline has been found to have a decreased number of papillae when compared with the rest of the tongue.

A study done by McMahon, Shikata, and Breslin (2001) confirmed the findings of the non-uniformity of sensitivity on both the anterior and posterior tongue and palate. In concordance with Carlson and Kazdin, research has found that taste buds are sensitive to all tastes, but may have a slightly increased sensitivity to a certain taste. Taste buds are found all over the tongue and soft palate, although they are mostly found in groups: circumvallate papillae on the posterior tongue, fungiform and foliate on the anterior two thirds of the tongue, and filiform extending into the back of the throat. The midline, an area in the center of the tongue that has a significantly reduced number of taste buds compared to such regions as the tip and outer edges of the tongue, is an exception. This reduced number of taste buds is accompanied by a lack of direct nerve innervation (Shikata, McMahon, & Breslin, 2000). A web of axons innervates the midline; taste sensation here occurs due to an increased concentration of axons firing to the nerves on either side of the tongue or the nerve located in the back. This is the most popular and "correct" place to have the tongue pierced; it is ideal due to the reduced number of papillae. It is believed that pain and swelling occur the least in this area (M. Macon, personal communication, December 31, 2001), perhaps due to the lack of blood vessels and direct nerve innervation found there. In an article about the potential risks of body modification, a doctor by the name of C. Meltzer has reported that the midline is the safest place to pierce. This is due to

the blood vessels being on the sides of the tongue, and not directly in the middle, so blood loss is theoretically reduced (Jordan, 2003).

In 2003, Fahey tested the effects of tongue piercings on salt sensitivity. The data from the pierced participants were statistically significant; pierced participants tasted salt at lower concentrations than non-pierced participants. A potential confound of the study was brought forth: salt may cause a burning sensation that is in collaboration with the flavor component. It was possible that the experiment tested the burn sensation and participants incorrectly interpreted the sensation as taste. A follow-up study was presented: repeat the experiment using a sucrose solution to find if there was an actual change in sensitivity to taste.

There is very little research on how tongue piercing affects different taste sensitivities. When informally asked, a piercing artist has revealed he is not one hundred percent sure that a piercing will change taste sensitivity in any way (M. Macon, personal communication, December 31, 2001). Tongue piercings are considered "open wounds" or puncture wounds. Puncture wounds are unique in that once whatever has punctured the skin is taken out; the wound should close and heal. A potential confound of testing salty sensitivity with people who have open wounds in their mouth is presented with the idea that salt may cause the sensation of burning in conjunction with the flavor component (L. Bartoshuk, personal communication, April 12, 2003). This may explain why getting salt into an open wound can cause a pain, or stinging, sensation. Should this be accurate, the sensation that was actually studied may have been the pain sensation and not the actual taste may have been tested. In order to more fully understand whether a change in taste sensitivity has occurred, one would have to test another substance, one that does not have a potential burn confound, alongside the salt study. Sucrose does not have a burn

component to it; because of this, it is hypothesized that taste sensitivity to sucrose will not significantly change due to a piercing.

## Preliminary Test: Method of Limits

### *Participants*

Experiment 1's preliminary test analyzed the salt sensitivity of students at a college in north central Pennsylvania. The sample consisted of 14 female participants, divided into two groups of seven each: with tongue piercings and without tongue piercings. Participants consisted of psychology students and other volunteers who responded to a campus wide posting.

Experiment 2's preliminary test analyzed the sucrose sensitivity of students from the same college. There were 11 participants: five with tongue piercings and six without tongue piercings. Participants were recruited in the same way.

### *Stimuli*

The stimuli for Experiment 1 consisted of distilled water and sodium chloride (salt) solutions ranging from 0.0M to 1.0M. These increments helped the experimenter narrow down the solutions to a final common threshold.

The stimuli for Experiment 2 consisted of distilled water and sucrose solutions in the same concentration range and even distribution.

### *Common Apparatus*

Both preliminary tests utilized cotton swabs to eliminate olfactory cues and to restrict the solution to the midline of the tongue. Each trial used a new cotton swab.

### *Common Design*

The preliminary tests used the same design. The experimenter requested that all participants refrain from eating and drinking within one hour prior to testing. When the

participant arrived at the room, she closed the door, sat at a table, and completed the release form. Participants then rinsed with distilled water and spit it out three times. The experimenter asked the participant to hold her tongue out while the experiment proceeded. Rows of identical cups containing either salt solution or deionized water were set out for Experiment 1. Experiment 2's cups contained sucrose solution or deionized water.

The experimenter made use of the distinct features of the tongue by asking the participants to stick out their tongues and finding the "V" created by the circumvallate papillae and the "U" created by the fungiform papillae. The participants with tongue piercings could not remove the piercing during testing due to the rapid closing of the piercing. Owing to this, the experimenter asked the participants with tongue piercings to pull their tongue ring up and back, so the experimenter could swab around the piercing without wiping the extraneous papillae (see Figure 2). The experimenter utilized the same anatomy to attempt to stimulate the same area as the pierced participants.

*Common Procedure*

The preliminary tests consisted of an ascending series Method of Limits for both solutions. The purpose of this test was to find the approximated threshold for tasting salty and sweet solutions. The experimenter dipped a cotton swab into the first cup and wiped the solution around the piercing or on the midline. Each participant was asked to nod affirmatively or shake her head negatively to the question "Did you taste anything?" The experimenter then wrote down the answer on a piece of paper. After each trial, each participant rinsed and spit with distilled water to eliminate any potential contamination. Each participant was asked to come in once every day for four consecutive days; 25 trials were presented to each participant each day. The first two days of trials tested solutions ranging from 0.0M to 1.0M in increments of 0.1M

concentrations. The cups were lined up, ten in a row, each containing a different solution. There were two rows of ten and one row of five per day. The last two days of testing used smaller solutions, ranging from 0.0M to 0.1M in increments of 0.01M concentrations. Each set of trails, or row of cups, was ended after three affirmations of tasting something.

## Signal Detection Task Methods

### *Participants*

The salt study utilized the same participants as the Method of Limits experiment. The sucrose study added three participants to the original number to make the groups even at seven participants each. Participants consisted of psychology students and other volunteers who responded to a campus wide posting.

### *Stimuli*

Experiment 1's signal detection task stimuli consisted of distilled water and a threshold sodium chloride (salt) solution of 0.05M.

Experiment 2's signal detection task stimuli consisted of distilled water and a threshold sucrose solution of 0.04M.

### *Common Apparatus*

Both signal detection tasks utilized cotton swabs to eliminate olfactory cues and restrict the solution to the midline of the tongue. Each trial used a new cotton swab.

### *Common Design*

Both signal detection tasks used the same design. The experimenter requested that all participants refrain from eating and drinking within one hour prior to testing. When the participant arrived at the room, she closed the door and sat at a table. Participants then rinsed with it distilled water and spit it out three times. The experimenter asked the participant to hold

her tongue out while the experiment proceeded. Rows of identical cups containing either salt solution or deionized water were set out for Experiment 1. Experiment 2's cups contained sucrose solution or deionized water.

The experimenter made use of the distinct features of the tongue by asking the participants to stick out their tongues and finding the "V" created by the circumvallate papillae and the "U" created by the fungiform papillae. The participants with tongue piercings could not remove the piercing during testing due to the rapid closing of the piercing. Owing to this, the experimenter asked the participants with tongue piercings to pull their tongue ring up and back, so the experimenter could swab around the piercing without wiping the extraneous papillae (see Figure 2). The experimenter utilized the same anatomy to attempt to stimulate the same area as the pierced participants.

*Common Procedure*

Signal detection theory was used to differentiate sensory sensitivity from possible criterion differences. In Experiment 1, each participant completed 100 trials, 50 0.05M sodium chloride (salt) solution and 50 distilled water. Experiment 2 had the same signal detection task as Experiment 1, with a solution and a ratio change. The test used a 0.04M threshold for sucrose sensitivity with 30 presentations of the sucrose and 20 with distilled water. Experiment 2 utilized 50 trials instead of 100 due to testing at three different concentrations: 0.03M, 0.04M, and 0.05M instead of just one during the signal detection phase. The data from the 0.03M and 0.05M solutions were found to be too far away from the threshold to produce meaningful comparisons (see Figures 3a and 3b).

## Results

### Experiment 1: Salt

The mean number of hits for pierced participants ($X_P = 46.86 \pm 3.13$) was significantly higher than the mean number of hits for non-pierced participants ($X_{NP} = 27.14 \pm 13.18$) ($t\,(12) = 3.85, p \leq .01$) and the mean number of false alarms for pierced participants ($X_{PFA} = 7.00 \pm 6.03$) was significantly lower than the mean number of false alarms for non-pierced participants ($X_{NPFA} = 14.00 \pm 2.887$) ($t\,(12) = -2.77, p \leq .05$). Sensitivity curves for the groups were also calculated: $d'_{XP} = 2.75$ and $d'_{XNP} = 0.45$ and found to be statistically significant ($t\,(12) = 4.06, p \leq .05$) (See Figures 4a and 4b). Table 1 shows the sensitivity (d') for each individual participant for Experiment 1.

### Experiment 2: Sucrose

The mean number of hits for pierced participants ($X_P = 16.29 \pm 8.43$) was not statistically significantly when compared to the mean number of hits for non-pierced participants ($X_{NP} = 19.86 \pm 5.74$) ($t\,(12) = 0.86, p > .05$). Neither was the mean number of false alarms for pierced participants ($X_P = 4.29 \pm 2.43$) when compared to the mean number of false alarms for non-pierced participants ($X_{NP} = 6.43 \pm 6.53$) ($t\,(12) = 0.75, p > .05$). The sensitivity curves for the groups were calculated: $d'_{XP} = 0.93$ and $d'_{XNP} = 1.45$ but no statistical significance was found ($t\,(12) = 0.98, p > .05$) (See Figures 5a and 5b). Table 2 shows the sensitivity (d') for each individual participant for Experiment 2. Table 3 shows individual hits, false alarms, sensitivity (d'), and t-values for Experiments 1 and 2. Table 4 shows individual hits, false alarms and sensitivity (d') for the .03M and .05M concentrations. No further analyses were done of these data because they were not close enough to the threshold to make meaningful comparisons.

## Discussion

The signal detection task showed that significant changes in salty taste perception had occurred in pierced participants. The differences in both the number of hits and false alarms between groups were significant. The significance in the number of hits can be explained in two ways: either the participants changed their criteria, meaning they just answered "yes" to complete the study more quickly or there was an actual change in sensitivity. Signal detection task analyses established which alternative was true in the form of ROC curves. A ROC curve shows the actual sensitivity, free of criterion. The curves of each participant and the groups as a whole, show that it was not the criterion, but the sensitivity that had changed for salty stimuli (see Figures 4a and 4b). Based on the data, it may be safe to assume that the salt experiment tested the burn component of salt, and not the taste. The data in this study supports the theory that no permanent taste decrement happens due to a piercing because of a lack of significant nerve injury (Zuniga et al., 1994; Sun & Oakley, 2002). When individually questioned, pierced participants reported no formal noticeable changes in taste perception. However, they also reported never having considered it.

The experience of tasting salt may have two components that are connected: the actual salty flavor and a burn sensation. The pierced participants might have been responding to the onset of pain rather than the taste of salt. Thus, the experimenter then performed the sucrose experiment to determine whether an actual change in taste sensitivity occurred or if the results from the salt experiment might be due to the potential pain confound. The sucrose experiment yielded no statistically significant results. The data showed the sensitivity to sucrose in pierced participants had similar effects as the salt experiment, but nowhere near as strong. The pierced

participants had a slightly increased sensitivity to sucrose, but again, the finding was not statistically significant (see Figures 4a and 4b).

A statistically significant difference in sucrose sensitivity might be found if a larger sample were used. Although a larger sample may show statistical significance, the practical significance might be questioned. The individual sensitivities (d') of pierced participants to salt suggest that piercing is likely to cause an increase in salt sensitivity in every pierced person. However, the effect found in individual sensitivities (d') of pierced participants to sucrose was much smaller. A larger population of pierced participants may show a statistically significant increase in sensitivity, but the smaller effect implies that the tongue piercing would not produce a detectable effect in an individual's perception to sweetness.

The rate of diffusion may have affected the data. The type of innervation needed for sucrose takes longer than passive diffusion, which is the way salt is absorbed into a cell. Salt flows into a cell via ion channels while sucrose must use membrane receptor proteins (Bartoshuk & Beauchamp, 1994). Salt diffusion is quick and requires no extra help when entering a cell. The depolarization of salt causes neurotransmitters to be rapidly released and sent to depolarize other nerves. The pain might have caused a more rapid reaction than the sucrose. Sucrose, however, binds to the membrane and causes the cyclic AMP 2$^{nd}$ messenger pathway to act (Carlson, 2004).

Some areas for future research into this topic might include an increased number of trials to sucrose. The second part of Experiment 2 had three participants added to equalize the groups. Due to the inconsistent results of the initial 11 participants, the three participants that were added were only tested on the 0.04M solution and not on the 0.03M and 0.05M solutions. Moreover, they had not participated in the salt study or the preliminary Method of Limits test. Although

there is no reason to suspect that getting rid of the unnecessary trials or previous testing experience might change the results, their data were not entirely consistent with the previous participants, especially the pierced participants. This data might have thrown off any conclusive evidence of significance.

Although age of piercing was not taken into consideration for this study, another area of future interest might be aimed at any potential differences between younger or "newer" piercings as opposed to older piercings. Some participants had informed the experimenter that they could take out the ring/barbell and not have the hole close up. This implies that scar tissue has formed around the piercing and may cause differences in sensitivities to specific stimuli. It might have been that there was enough stimulation from the direct diffusion of salt to increase sensitivity, yet the scar tissue caused a decrease in sensitivity to sucrose.

A final area for future research should concentrate on what happens once a person takes the piercing out. Based on previous research, taste sensitivity should go back to the way it was prior to the piercing. Due to tongue physiology and typical piercing location, the nerves in the tongue should retain no negative effects.

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Table 1.

*Sensitivity Values for Experiment 1*

| P | d' | NP | d' |
|---|---|---|---|
| 1 | 1.72 | 8 | 1.05 |
| 2 | 1.52 | 9 | 1.05 |
| 3 | 2.82 | 10 | -2.73 |
| 4 | 4.84 | 11 | 0.68 |
| 5 | 2.73 | 12 | 0.71 |
| 6 | 3.61 | 13 | 1.38 |
| 7 | 2.05 | 14 | 1.06 |
| Group | 2.75 | Group | 0.45 |

The sensitivity (d') values for each participant. The first column, P#1 – 7 indicates pierced participants, while the third column, P#8 – 14 indicates non-pierced participants. The last row in each column represents the groups' average sensitivity.

Table 2.

*Sensitivity Values for Experiment 2*

| P | d' | NP | d' |
|---|---|---|---|
| 1 | 1.12 | 8 | 0.43 |
| 2 | 1.30 | 9 | 0.00 |
| 3 | 0.24 | 10 | 4.05 |
| 4 | 0.00 | 11 | 2.84 |
| 5 | 0.78 | 12 | 0.00 |
| 6 | 1.45 | 13 | 2.77 |
| 7 | 1.65 | 14 | 1.58 |
| Group | 0.93 | Group | 1.58 |

The sensitivity (d') values for each participant. The first column, P#1 – 7 indicates pierced participants, while the third column, P#8 – 14 indicates non-pierced participants. The last row in each column represents the groups' average sensitivity.

Table 3.

*Data for Experiment 1 and Experiment 2*

Experiment 1 (Salt)

| Pierced | Hits | False Alarms | d' |
|---|---|---|---|
| 1 | 43 | 13 | 1.72 |
| 2 | 42 | 15 | 1.52 |
| 3 | 49 | 11 | 2.82 |
| 4 | 48 | 0 | 4.84 |
| 5 | 47 | 6 | 2.73 |
| 6 | 49 | 3 | 3.61 |
| 7 | 50 | 1 | 2.05 |
| Non-Peirced | | | |
| 8 | 35 | 15 | 1.25 |
| 9 | 34 | 14 | 1.16 |
| 10 | 0 | 18 | 1.29 |
| 11 | 27 | 14 | 1.93 |
| 12 | 25 | 12 | 1.77 |
| 13 | 41 | 16 | 0.78 |
| 14 | 28 | 9 | 0.86 |

Experiment 2 (Sucrose)

| Pierced | Hits | False Alarms | d' |
|---|---|---|---|
| 1 | 13 | 2 | 1.12 |
| 2 | 22 | 5 | 1.3 |
| 3 | 10 | 5 | 0.24 |
| 4 | 0 | 0 | 0.00 |
| 5 | 21 | 8 | 0.78 |
| 6 | 22 | 4 | 1.45 |
| 7 | 26 | 6 | 1.65 |
| Non-Peirced | | | |
| 8 | 20 | 10 | 0.43 |
| 9 | 25 | 20 | 0.00 |
| 10 | 25 | 0 | 4.05 |
| 11 | 12 | 0 | 2.84 |
| 12 | 11 | 8 | 0.00 |
| 13 | 26 | 1 | 2.77 |
| 14 | 20 | 6 | 0.96 |

Experiment 1 t-values:
Hits: $t\,(12) = 3.849, p \leq .01$
False Alarms: $t\,(12) = -2.771, p \leq .05$
d': $t\,(12) = t\,(12) = -2.771, p \leq .01$

Experiment 2 t-values:
Hits: $t\,(12) = 0.86, p > .05$
False Alarms: $t\,(12) = 0.75, p > .05$
d': $t\,(12) = t\,(12) = 0.98, p > .05$

The individual hits, false alarms, sensitivity (d') values, and t-values for both experiments. Experiment 1 (salt sensitivity) data is shown in the top table, while Experiment 2 (sucrose sensitivity) data is shown in the bottom table. T-values are listed. In Experiment 1, both Hits and False Alarms were out of 50. In Experiment2, the Hits were out of 30 and the False Alarms out of 20.

Table 4.

*Data for Experiment 2 (Sucrose) at 0.03M and 0.05M concentrations*

0.03M

| NP | H | FA | d' |
|---|---|---|---|
| 1 | 15 | 10 | 0.00 |
| 2 | 25 | 15 | 0.28 |
| 3 | 15 | 0 | 3.09 |
| 4 | 5 | 10 | 0.00 |
| 5 | 24 | 8 | 0.59 |
| 6 | 18 | 11 | 0.12 |
| P | H | FA | d' |
| 7 | 14 | 0 | 3.00 |
| 8 | 17 | 2 | 1.45 |
| 9 | 1 | 4 | 0.00 |
| 10 | 0 | 0 | 0.00 |
| 11 | 12 | 6 | 0.27 |

0.05M

| NP | H | FA | d' |
|---|---|---|---|
| 1 | 25 | 12 | 0.71 |
| 2 | 25 | 8 | 1.22 |
| 3 | 25 | 0 | 4.05 |
| 4 | 18 | 0 | 3.34 |
| 5 | 27 | 1 | 2.92 |
| 6 | 30 | 9 | 0.13 |
| P | H | FA | d' |
| 7 | 27 | 2 | 2.57 |
| 8 | 24 | 2 | 2.22 |
| 9 | 17 | 1 | 1.81 |
| 10 | 28 | 0 | 2.16 |
| 11 | 25 | 7 | 1.35 |

The individual hits, false alarms and sensitivity (d') for the .03M and .05M concentrations. No further analyses were done of these data because they were not close enough to threshold to make meaningful comparisons. These data were taken before the addition of three participants in the second half of the study.

## Figure Captions

*Figure 1.* Map of the tongue showing the locations of the circumvallate papillae (A) on the dorsal posterior portion of the tongue. Also, note the filiform papillae (C), which form the "U" between the foliate papillae (D) and the blank area directly above it (B). The blank area is the midline.

*Figure 2.* The midline was stimulated. This is one participant's tongue piercing. Notice the location of the piercing and how when the tongue is placed in this position, how the ring is brought up and back, exposing the midline.

*Figure 3.* ROC curves for the (a) 0.03M and (b) 0.05M data.

*Figure 4.* ROC curves for both pierced and non-pierced groups (a) and individual participants (b) for salt. Notice there is no overlap in sensitivity at all. The lack of any overlap indicates that sensitivity, not criterion, changed.

*Figure5.* ROC curves for both pierced and non-pierced groups (a) and individual participants (b) for sucrose.

Figure 1.

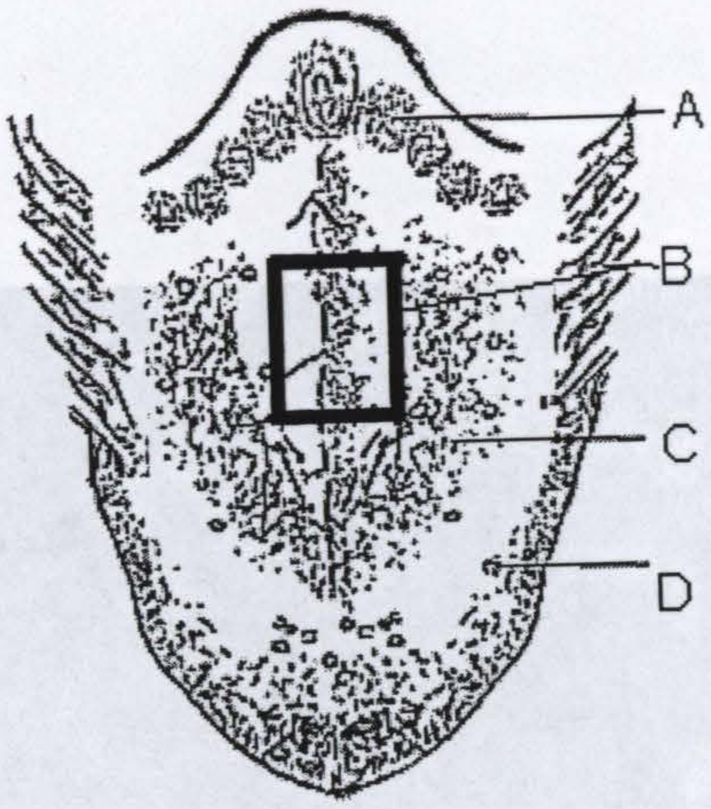


Figure 2.

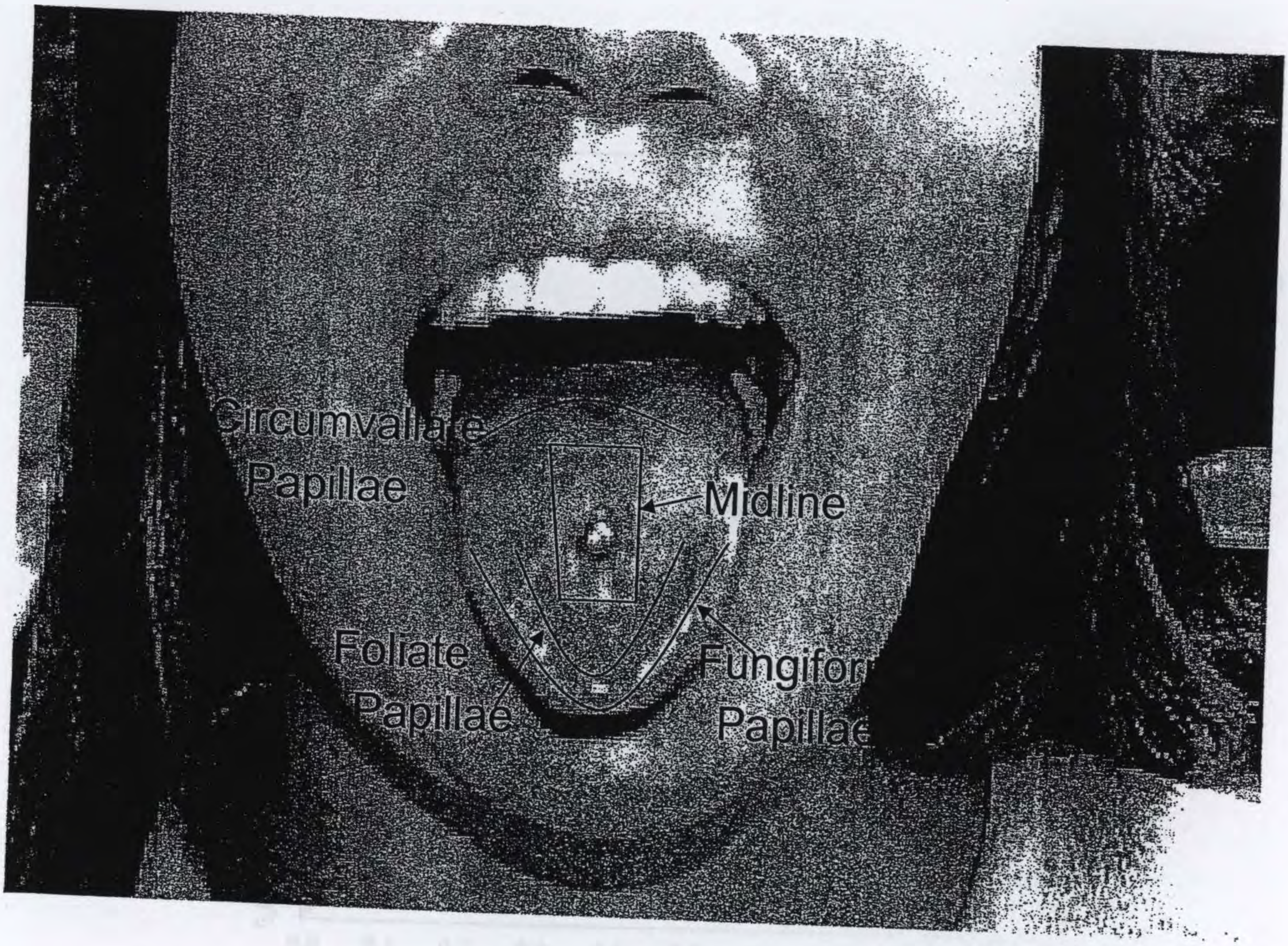

Circumvallate
Papillae
Midline
Foliate
Papillae
Fungiform
Papillae

Figure 3a.

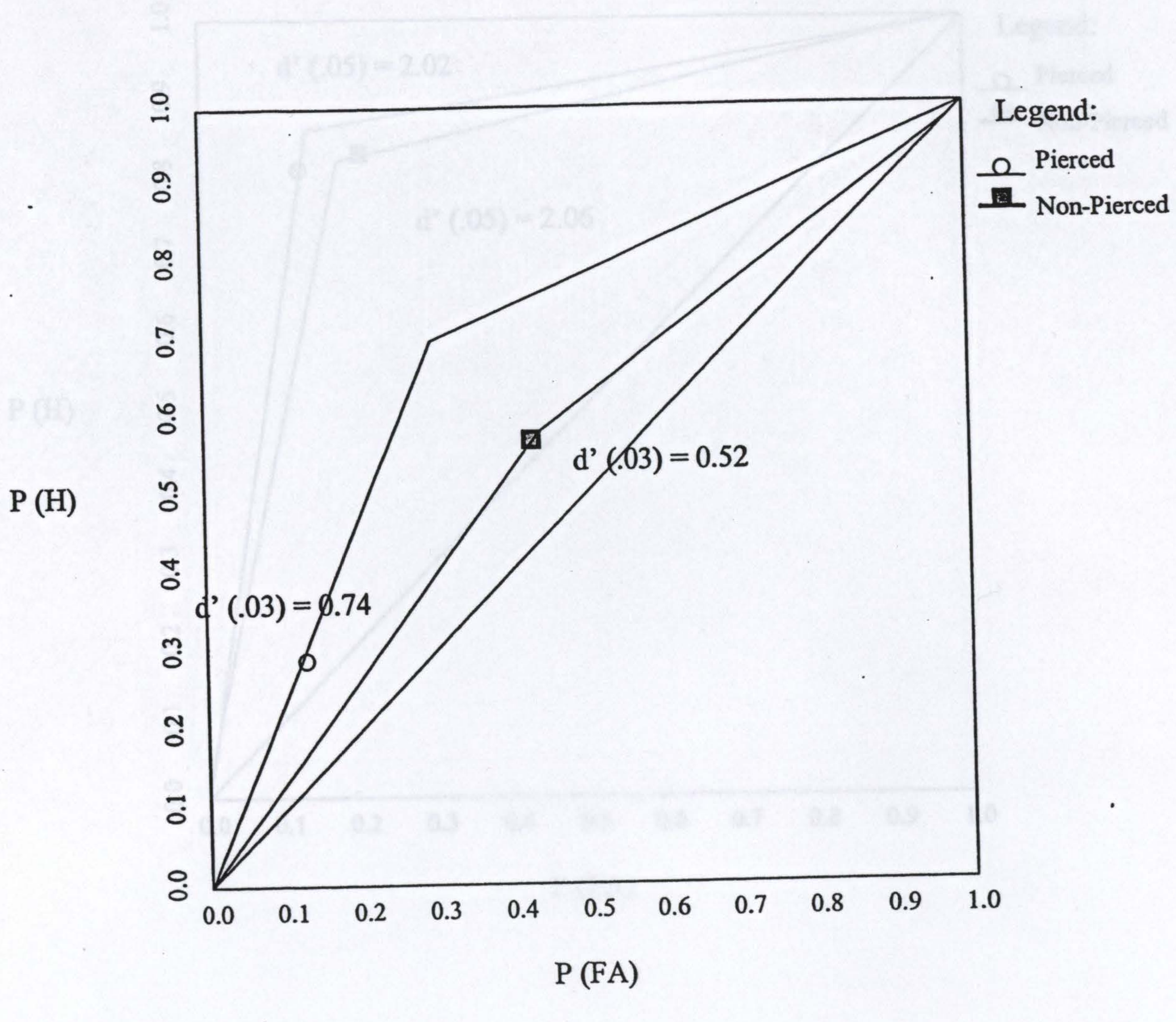

Legend:
Pierced
Non-Pierced
d' (.03) = 0.52
d' (.03) = 0.74
P (H)
P (FA)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Figure 3b.

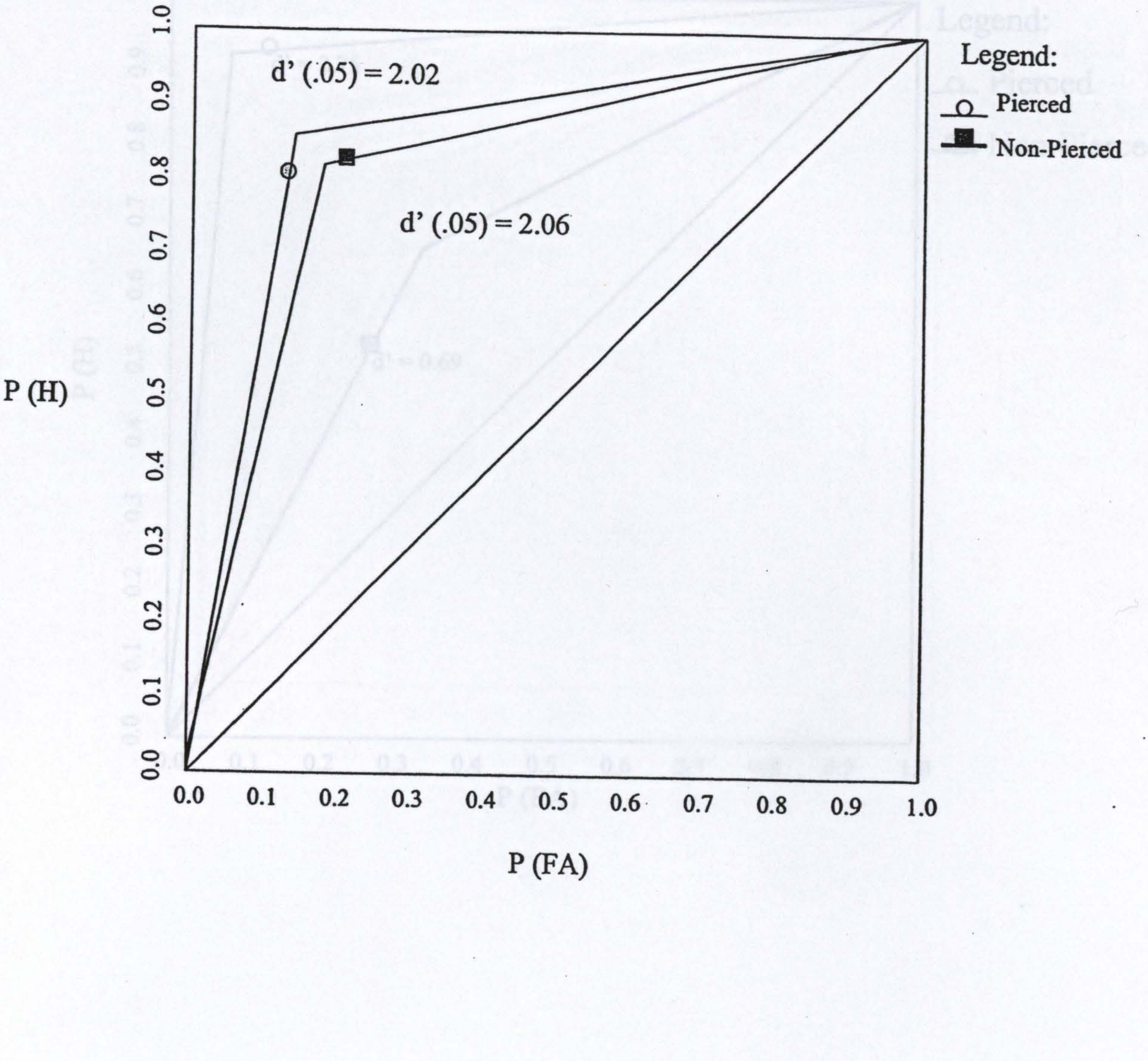

d' (.05) = 2.02
d' (.05) = 2.06
Legend:
Pierced
Non-Pierced
P (H)
P (FA)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Figure 4a.

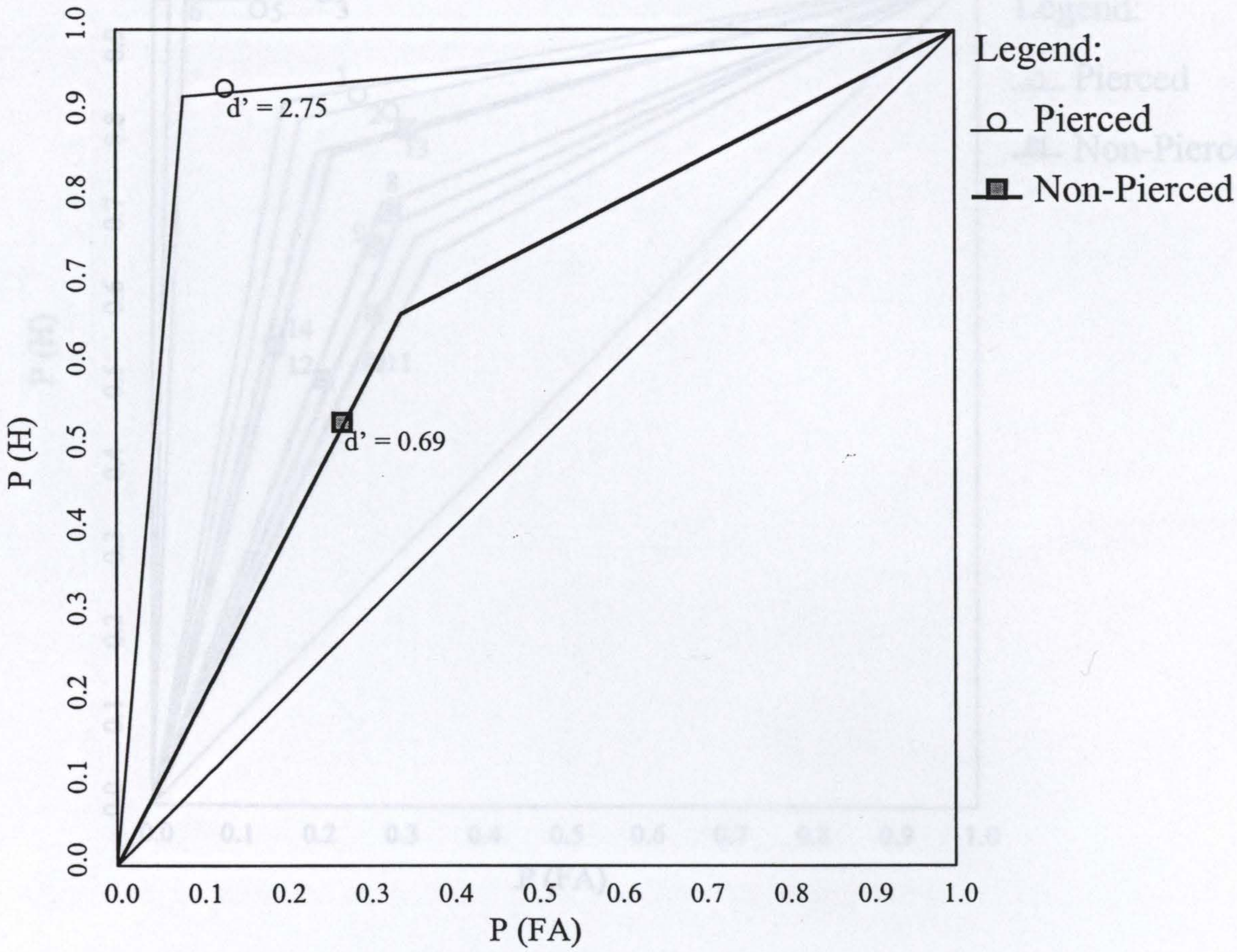
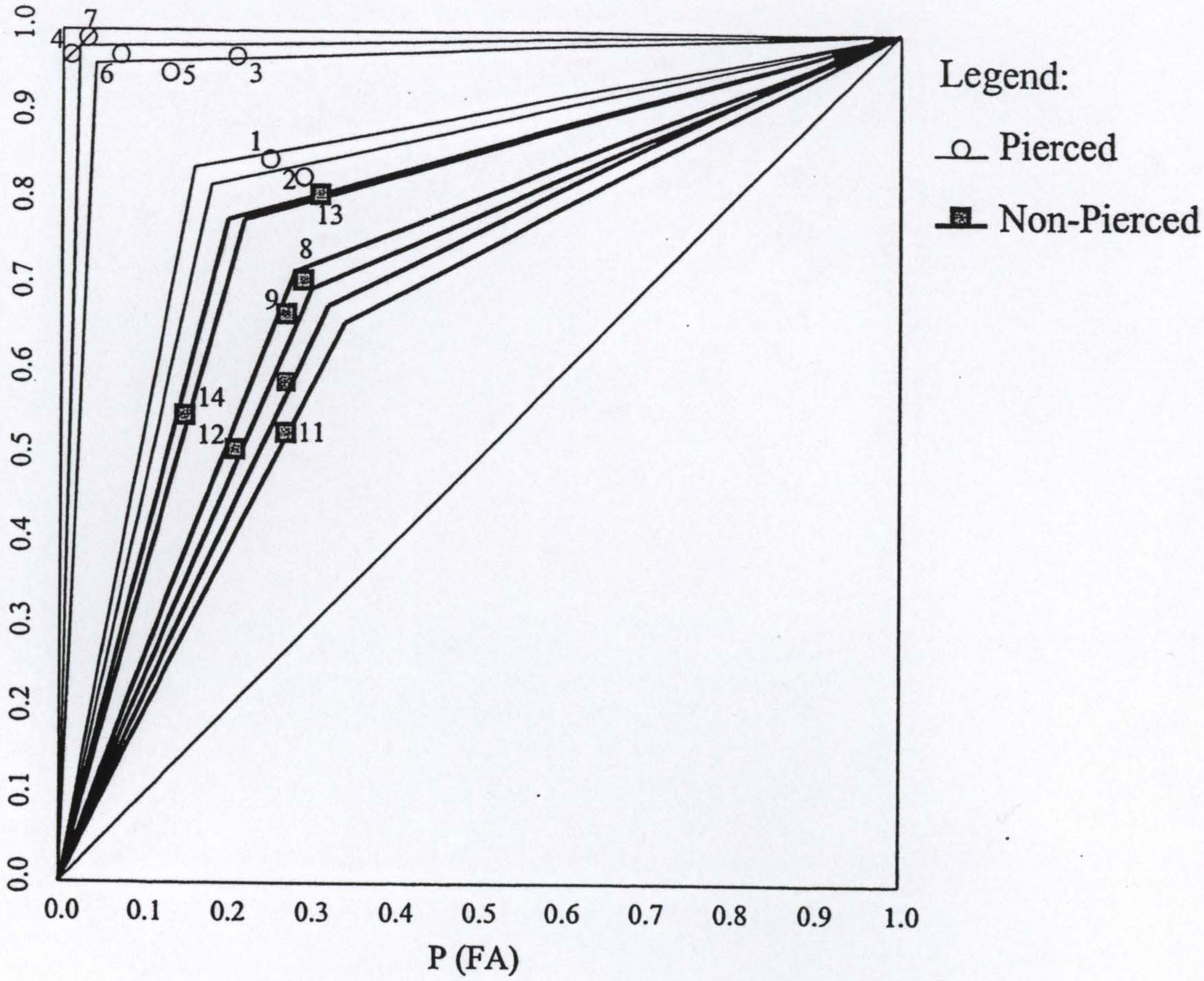

Legend:
Pierced
Non-Pierced
d' = 2.75
d' = 0.69
P (H)
P (FA)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Figure 4b.


Legend:
Pierced
Non-Pierced
P (H)
P (FA)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
7
4
6
5
3
1
2
13
8
9
14
12
11