Assessing Human Perceptual Acuity for Detecting Thyroid Nodules Through Palpation

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Background

Patients living in rural areas can face some challenges when accessing healthcare resources due to the lack of public transportation, urgent care & clinic facilities, and healthcare practitioners. About 20% of the total U.S. population lives in rural areas, but only 10% of all physicians practice in rural areas. Telemedicine has become an important topic as a promising solution that can fill the healthcare resource gap between urban and rural areas.

## Remote Physical Examination Research

The "Remote Physical Examination" research done at INVENT Lab is aimed at developing a tactile-sensing glove that facilitates cooperation between a nurse and a physician during the palpation exam of the thyroid. In this model, the nurse would wear a haptic tactile sensing glove and perform the examination on the patient. The physician who is remote would sit at a cockpit at which they receive audio, video, and haptic feedback of the exam through the perspective of the nurse.
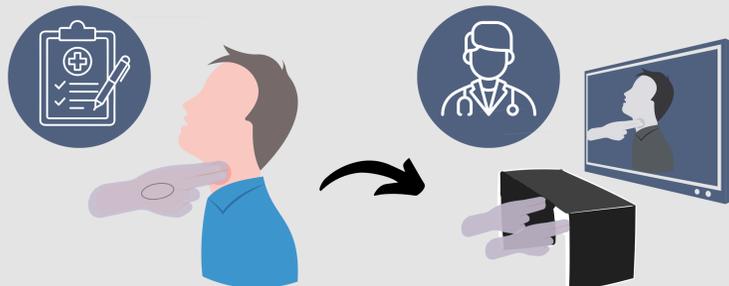
Research Goals & Setup

Two questions must be answered:

✓ (1) What forces are involved in palpation?

✓ (2) How well can humans detect lumps?
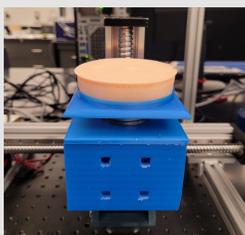
The Palpation Exam

1. **Poke:** A vertical press into the skin in the normal direction
2. **Push & Pull:** A combination of poking and rubbing
3. **Symmetrical:** A motion that palpates using both hands and covers more surface area.
4. **Asymmetrical:** A motion that uses one hand as a counterweight against the pressure of the other hand which is performing a palpation motion.
5. **Finger Crawl:** The transition from one area of the neck to another where the physician moves the fingers in a crawling motion.
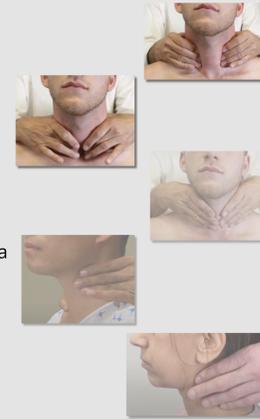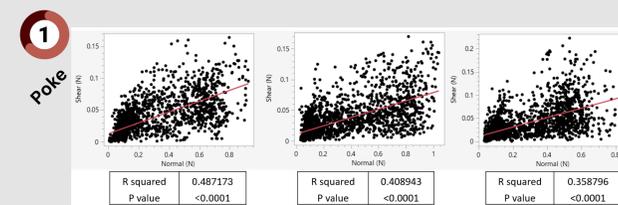
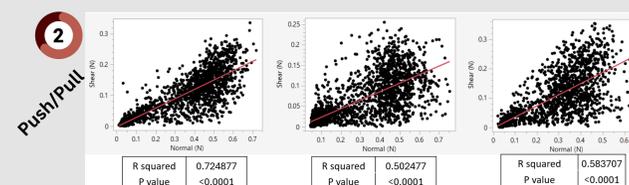## Study 1: Characterizing Palpation Forces

- Measured normal (pressing down) and shear (lateral) forces during palpation using an ATI Nano force sensor
- Phantom skin samples made from Ecoflex silicone with embedded lumps mimicked thyroid tissue

- Key Finding: Normal and shear forces must be measured independently — their relationship is not consistent across motions
  - Push & Pull: Strong correlation ($R^2 = 0.72$)
  - Poke: Moderate correlation ($R^2 = 0.49$)
  - Other motions: Low correlation

Study 1: Results

Linear Regression Analysis of Forces in Three Groups (N=1):
(1) No Skin, (2) Skin without Lump, (3) Skin with Lump
All data samples showed statistically significant correlations with *p*-values < 0.0001

(1) Poke

R squared	0.487173		R squared	0.408943		R squared	0.358796
P value	<0.0001		P value	<0.0001		P value	<0.0001

Positively correlated. Moderate R-squared value.

(2) Push/Pull

R squared	0.724877		R squared	0.502477		R squared	0.583707
P value	<0.0001		P value	<0.0001		P value	<0.0001

Strongly positively correlated. The Push/Pull motion has more forces in the shear direction than other motions.

Study 2: How Well Can Humans Detect Lumps?

Experiment 1 — Detection Accuracy
- 12 participants, 60 trials each
- Felt two phantom skin samples (one with a lump, one without) and identified which had the lump
- Lump sizes: 5–30 mm at shallow (11 mm) and deep (20 mm) depths
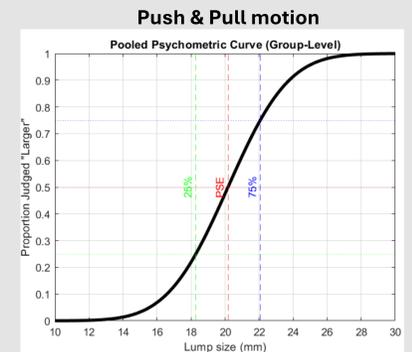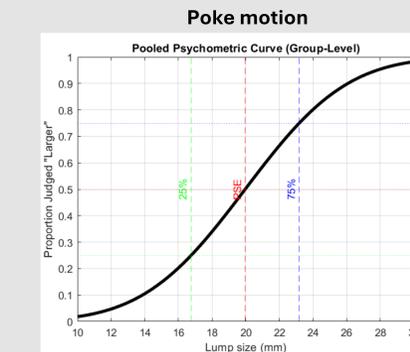
Experiment 2 — Size Discrimination
- 10 participants, 180 trials each
- Compared lumps against a 20 mm reference to measure smallest detectable size difference

Detection accuracy of Poke vs Push across lump sizes
Mean accuracy of Poke and mean accuracy of Push
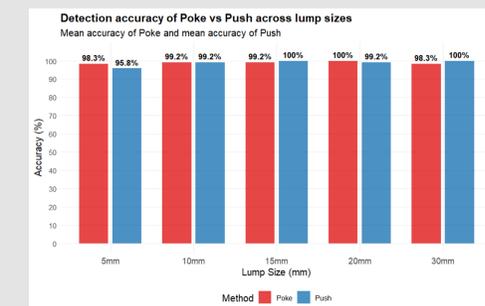
Detection accuracy: 95–100% across all lump sizes.

Push & Pull outperformed Poke for 5 mm deep lumps.

Size discrimination: JND of 1.64 mm (Push & Pull) vs. 3.10 mm (Poke), $p = 0.040$.

Poke motion

Pooled Psychometric Curve (Group-Level)

Push & Pull motion

Pooled Psychometric Curve (Group-Level)

Conclusion & What's Next

- Study 1: Normal and shear forces must be measured independently — the glove must capture both
- Study 2: Humans detect lumps as small as 5 mm, and Push & Pull enables finer discrimination — the glove must deliver lateral force feedback too
- Together, these set the design requirements for a remote palpation system
- This work contributed to two publications and taught me to design experiments, run human-subjects studies, and connect engineering to real healthcare needs
- Future work: Design and test tactile sensing gloves that meet these perceptual benchmarks

Acknowledgements & Publications

Publications

1. Chan, A., Kawazoe, A., Kim, N., et al. (2025). Characterization of medical neck palpation. Sensors, 25, 2159.
2. Kawazoe, A., Kim, N., et al. (2026). Effects of palpation motion on human perceptual acuity. IEEE Haptic Symposium.