Needle Calculation Fix - Summary

Date: October 20, 2025

Issue Description

The gauge needle was displaying incorrectly due to baseline interpolation causing floating-point comparison failures in the reference resistance lookup.

Root Cause Analysis

Primary Issue: Baseline Interpolation

1. **Baseline was being interpolated linearly** between samples
   - When baseline changed from 5 to 4.95, intermediate values like 4.975 were calculated
   - These interpolated values didn't match any actual sample baselines

2. **Reference resistance lookup failed**
   - The `calculateGaugePosition` function searched for samples with matching baseline values
   - Interpolated baseline values (e.g., 4.975) never matched actual sample values (5 or 4.95)
   - This caused the reference resistance to be incorrect or undefined

3. **Result: Incorrect needle positioning**
   - Needle pointed to wrong positions
   - Didn't respond correctly to resistance changes
   - Could point to the opposite side of the gauge

Solutions Implemented

Fix 1: Baseline as Step Function

File: `frontend/src/components/SignalPreview.tsx` (Lines 107-108)

Change:

```
// BEFORE:
baseline: lower.baseline !== undefined && upper.baseline !== undefined
  ? lower.baseline + (upper.baseline - lower.baseline) * clampedRatio
  : lower.baseline ?? upper.baseline,

// AFTER:
// Baseline is a step function (changes only on normalize), so use lower sample's
baseline
baseline: lower.baseline,
```

Rationale:
- Baseline only changes when user presses "normalize" button
- It should jump to new values instantly, not transition smoothly
- This eliminates floating-point comparison issues

Fix 2: Improved Reference Resistance Lookup

File: `frontend/src/components/SignalPreview.tsx` (Lines 134-161)

Changes:
- Rewrote lookup logic with forward iteration (clearer than backward)
- Added explicit checks for undefined baseline/resistance values
- Handles baseline periods that oscillate (baseline changes back and forth)
- Finds the most recent baseline change point correctly

Key Logic:

```
// Look through samples up to current time
for (let i = 0; i < samples.length; i++) {
  const s = samples[i];

  // Only look at samples up to current time
  if (s.timeSec > sample.timeSec) break;

  // Check if this sample has valid baseline and resistance
  if (s.baseline === undefined || s.resistance === undefined) continue;

  // Check if this is the start of a baseline period
  if (s.baseline === sample.baseline) {
    if (i === 0 || samples[i - 1].baseline !== sample.baseline) {
      // Found baseline change point
      referenceResistance = s.resistance;
    }
  }
}
```

Fix 3: Explicit Clamping

File: `frontend/src/components/SignalPreview.tsx` (Lines 176, 181)

Change:

```
// Ensure needle stays within valid range
return clamp(position, DISPLAY_MIN, DISPLAY_MAX);
```

Rationale:
- Prevents needle from going outside 1-6.5 range
- Even if resistance changes dramatically, needle stays visible

Expected Behavior After Fix

✅ **Baseline as center position**
- When baseline = 5, needle centers at 5 on the gauge
- When baseline changes to 4.95, needle immediately moves to 4.95

✅ **Correct directional movement**
- Resistance DECREASES → needle moves RIGHT (higher gauge value)
- Resistance INCREASES → needle moves LEFT (lower gauge value)

✅ **Proper scaling**
- 1 kΩ resistance change ≈ 0.5 gauge units of needle movement
- Formula: `needlePosition = baseline + (currentResistance - referenceResistance) * (-0.5)`

✅ **Range enforcement**
- Needle stays within 1-6.5 range at all times
- Values are explicitly clamped

✅ **Stable reference tracking**
- Reference resistance correctly tracks baseline periods
- Handles baseline changes (user pressing “normalize”)
- Handles baseline oscillations (back and forth changes)

Testing Results

- ✅ TypeScript compilation successful
- ✅ Production build successful
- ✅ No errors or warnings
- 🔄 Ready for user testing with actual CSV data

How to Test

1. Upload a CSV file with baseline and resistance columns
2. Play the session
3. Verify needle behavior:
   - Needle should center at the baseline value
   - When resistance decreases, needle should move right
   - When resistance increases, needle should move left
   - When baseline changes (user presses normalize), needle should jump to new baseline
4. Check that the orange baseline marker aligns with expected position

Technical Details

Gauge Specifications

- **Range:** 1.0 to 6.5
- **Scale markers:** 2 rectangles = 0.15 units (as per original design)
- **Resistance scale factor:** -0.5 (1 kΩ change ≈ 0.5 gauge units)
- **Direction:** Negative scale ensures resistance decrease = rightward movement

Data Format

- **Time column:** Time in milliseconds or seconds
- **Baseline column:** Normalized gauge position (1-6.5 range)
- **Resistance column:** Absolute resistance measurements (kΩ)

Algorithm

1. Parse CSV to extract baseline and resistance values
2. For each time point, get current sample via interpolation
   - Baseline uses step function (no interpolation)
   - Resistance uses linear interpolation

3. Find reference resistance for current baseline period
   - Search forward through samples up to current time
   - Find most recent point where baseline changed to current value
   - Use resistance at that point as reference
4. Calculate needle position:
   - `needlePosition = baseline + (currentResistance - referenceResistance) * (-0.5)`
5. Clamp to valid range (1-6.5)

Files Modified

1. `frontend/src/components/SignalPreview.tsx`
   - Fixed `useInterpolatedSample` function (baseline interpolation)
   - Rewrote `calculateGaugePosition` function (reference resistance lookup)
   - Added explicit clamping

Commit Information

Commit: 26d395a
Branch: fix-gauge-needle-position
PR: #15
Status: ✅ Pushed to GitHub

Next Steps

1. User should test with actual CSV files
2. Verify needle displays correctly in all scenarios
3. If behavior is correct, PR can be merged to main branch

Additional Notes

Potential Future Improvements

- Add configurable resistance scale factor (currently hardcoded to -0.5)
- Add visual indicator for baseline changes
- Add tooltip showing resistance delta from baseline
- Support for multiple simultaneous baseline tracks

Known Limitations

- Scale factor (-0.5) is calibrated for typical GSR ranges (50-60 kΩ)
- May need adjustment for different sensor types or resistance ranges
- Assumes CSV data is pre-sorted by time

Support

For issues or questions:
- GitHub PR: https://github.com/patman77/NeuroNarrative/pull/15
- Repository: https://github.com/patman77/NeuroNarrative

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