

Temporal Response Function

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What you can describe with TRF analysis

- How the brain responds to **continuous stimuli**
- **Neural entrainment** to continuous signals

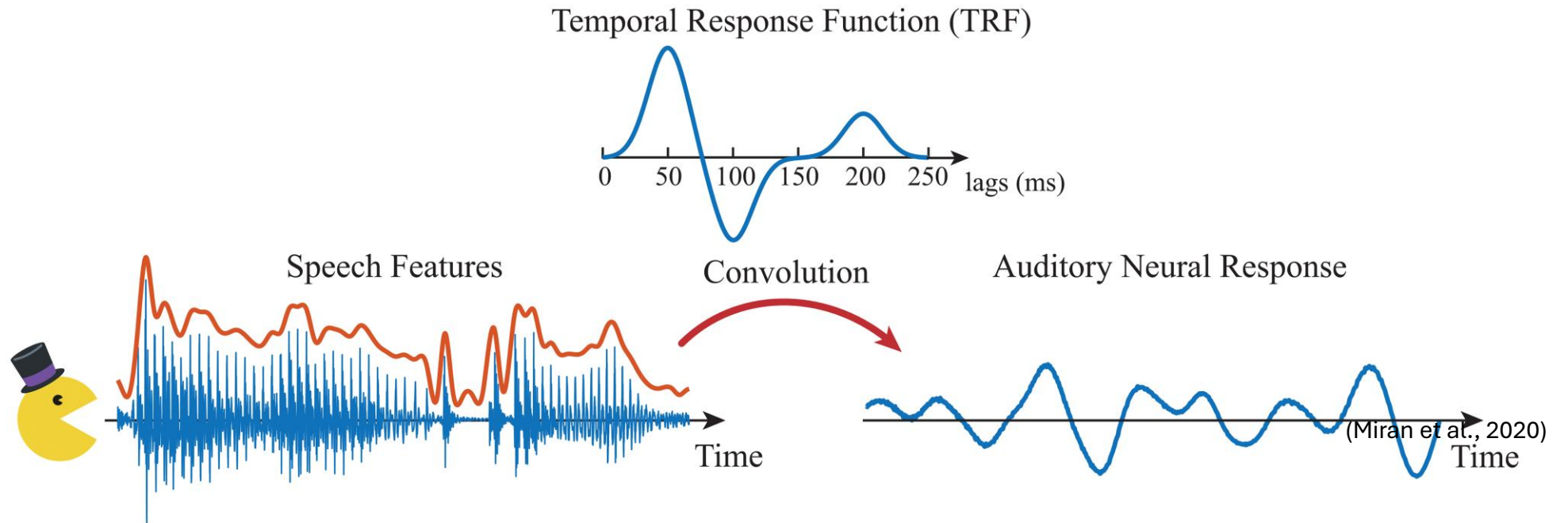


Can we decode at which talker a person's attention is?

How are rhythmic vs. tonal musical features encoded in the brain?

Where and when in the brain are expectations about upcoming stimuli processed?

Basic idea of TRF

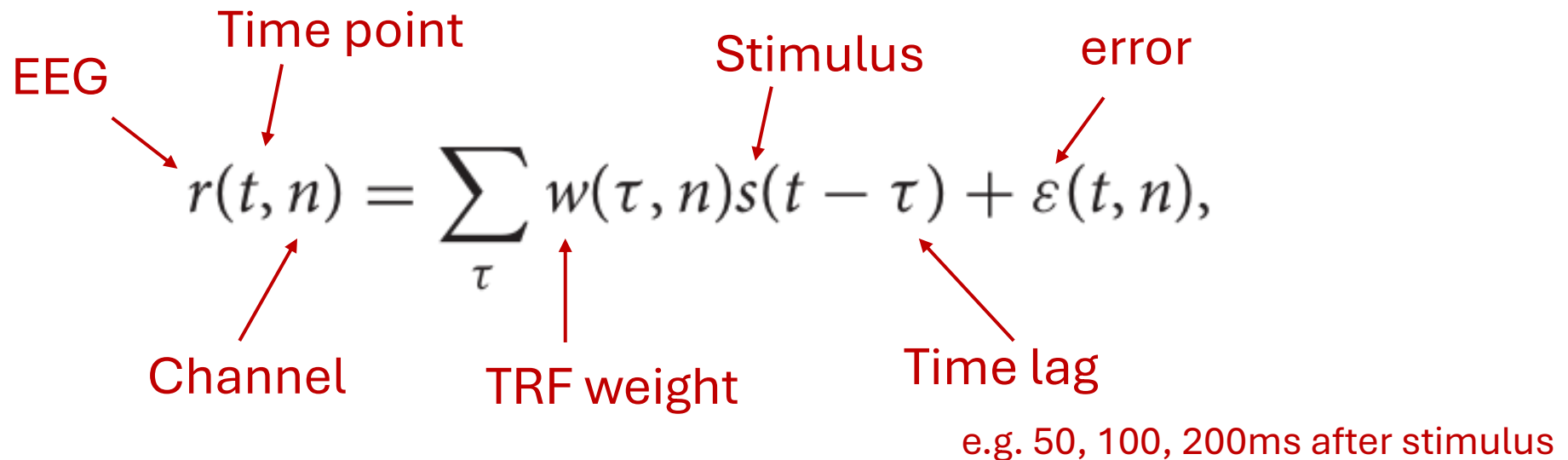


- filter describing the linear **transformation of the stimulus (e.g. audio) to the response (e.g. EEG)**

→ mathematically describing how the input relates to the output

Equations

- Basically a linear regression in which the stimulus predicts the response
- Weight of the stimulus → TRF



The diagram shows the equation $r(t, n) = \sum_{\tau} w(\tau, n) s(t - \tau) + \varepsilon(t, n)$ with red arrows pointing to various components and their meanings:

- EEG** points to $r(t, n)$.
- Time point** points to t in $r(t, n)$.
- Channel** points to n in $r(t, n)$.
- Stimulus** points to s in $s(t - \tau)$.
- TRF weight** points to w in $w(\tau, n)$.
- Time lag** points to τ in $s(t - \tau)$, with the example text "e.g. 50, 100, 200ms after stimulus" below it.
- error** points to ε in $\varepsilon(t, n)$.

Equations

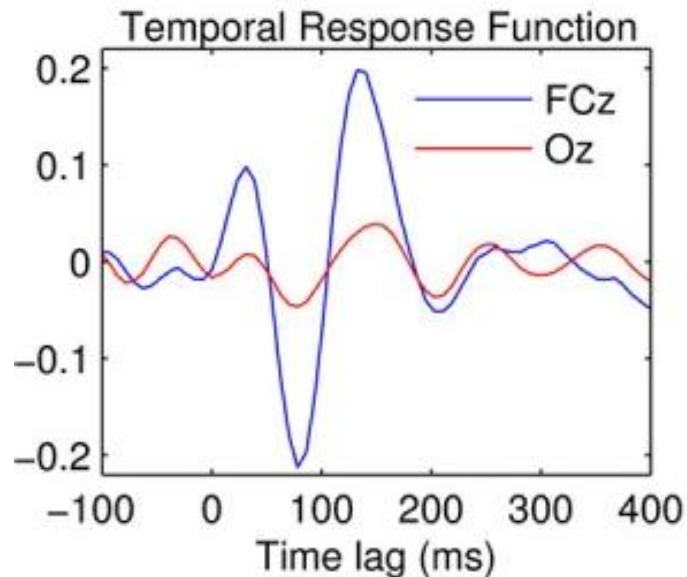
Regression weight (TRF) computed using this equation:

$$\mathbf{w} = \left(\mathbf{S}^T \mathbf{S} + \lambda \mathbf{I} \right)^{-1} \mathbf{S}^T \mathbf{r},$$

- You can think of it as a more complicated correlation between EEG signal \mathbf{r} and the stimulus at different time lags (\mathbf{S})
- Lambda: regularization parameter

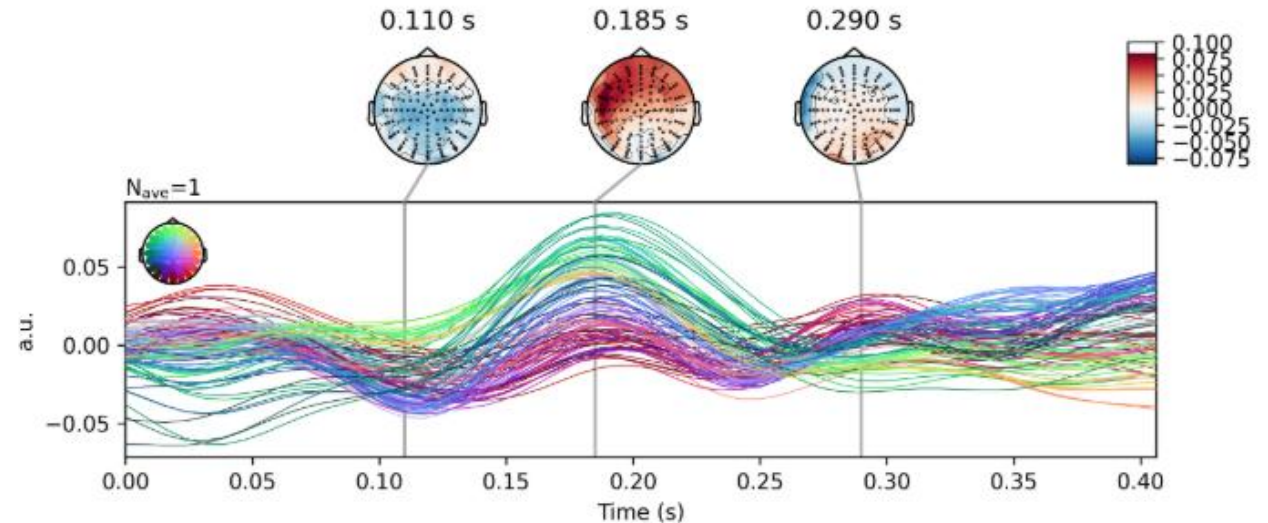
Measures: TRF

→ Weight for every time lag (= TRF) at every channel



→ Like continuous ERP!

Different channels + topography

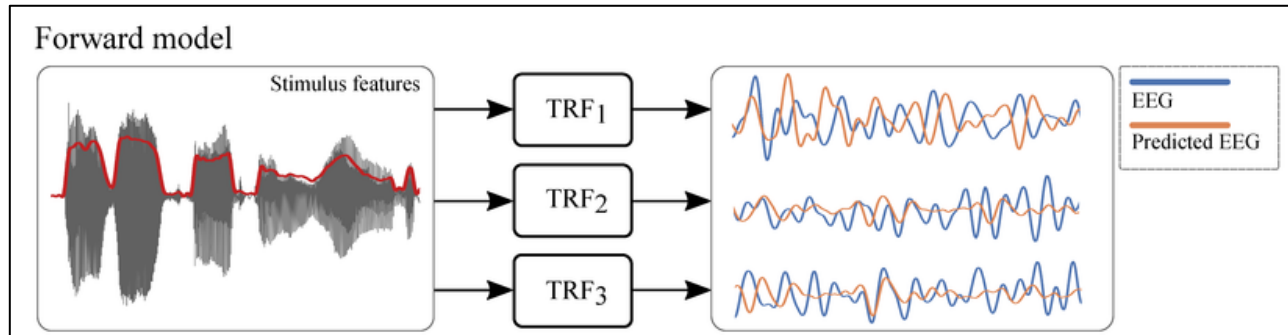


(Crosse et al., 2016)

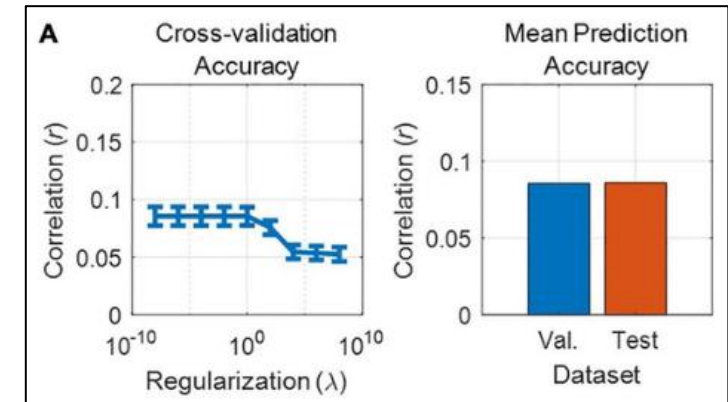
<https://mtrfpy.readthedocs.io/en/latest/basics.html>

Measures: Accuracy

- **Predict brain response** based on audio and TRF
- Correlate with actual brain response



(Deoisres et al., 2023)

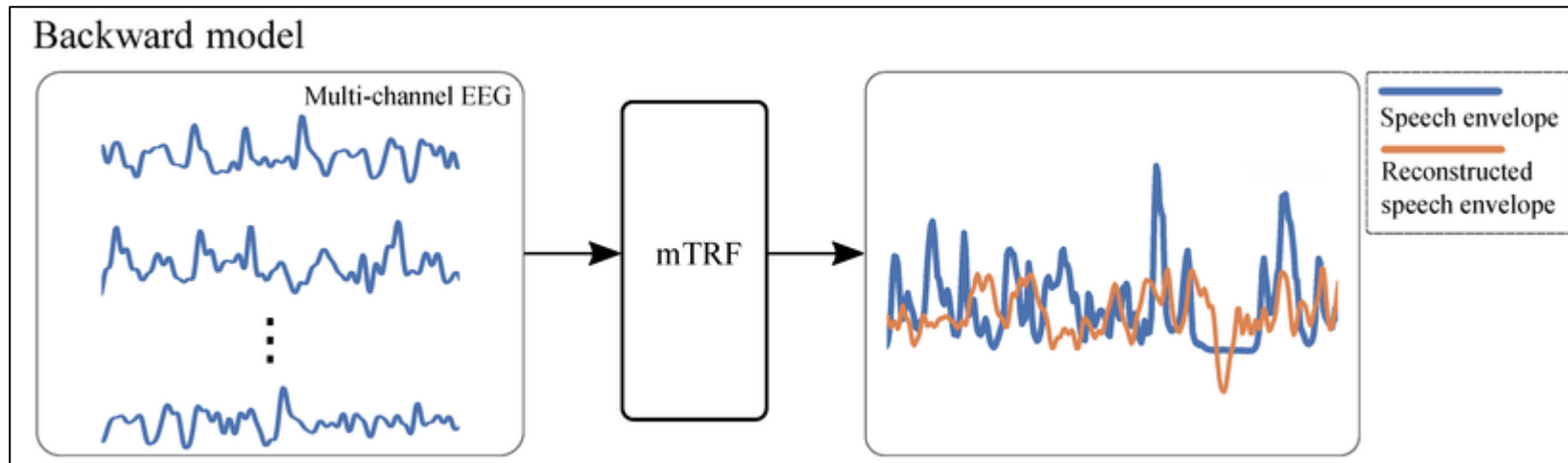


(Crosse et al., 2021)

→ Forward Model / Encoding

Measures: Accuracy

- **Predict stimulus** based on EEG and backward TRF
- Correlate with actual stimulus



(Deoisres et al., 2023)

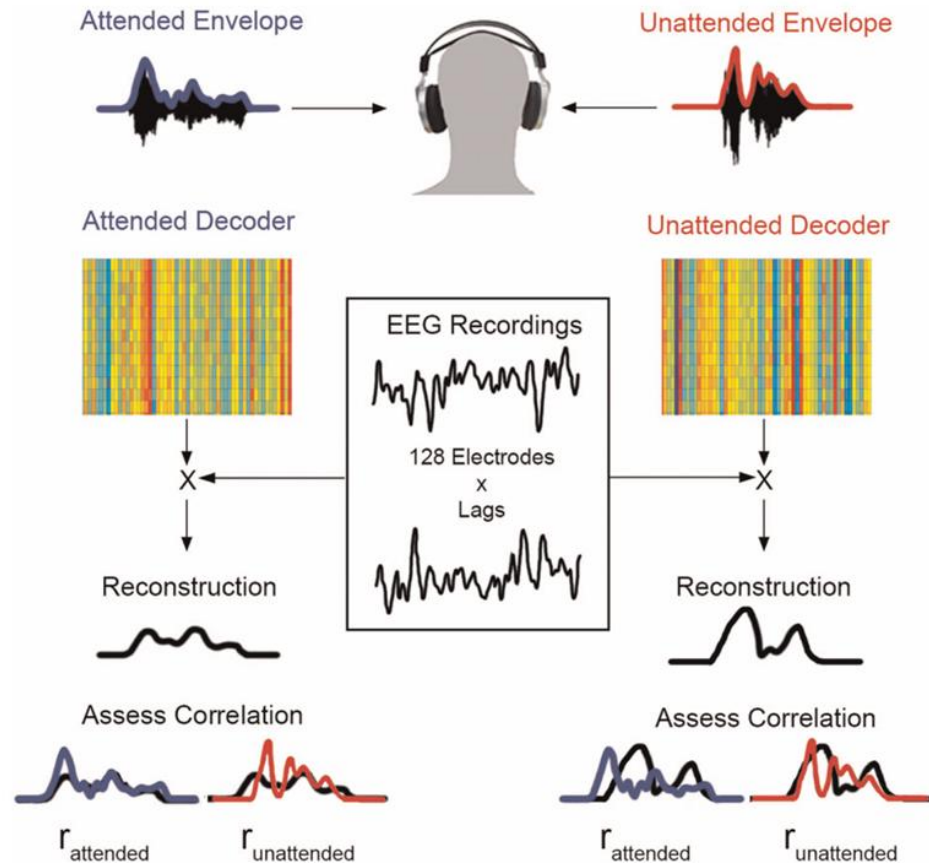
→ Backward Model / Decoding

Measures: Accuracy

- Always **cross-validate** your data to prevent overfitting
- Subset of your data for training the model
- Remaining data for computing accuracy



Measures: Accuracy

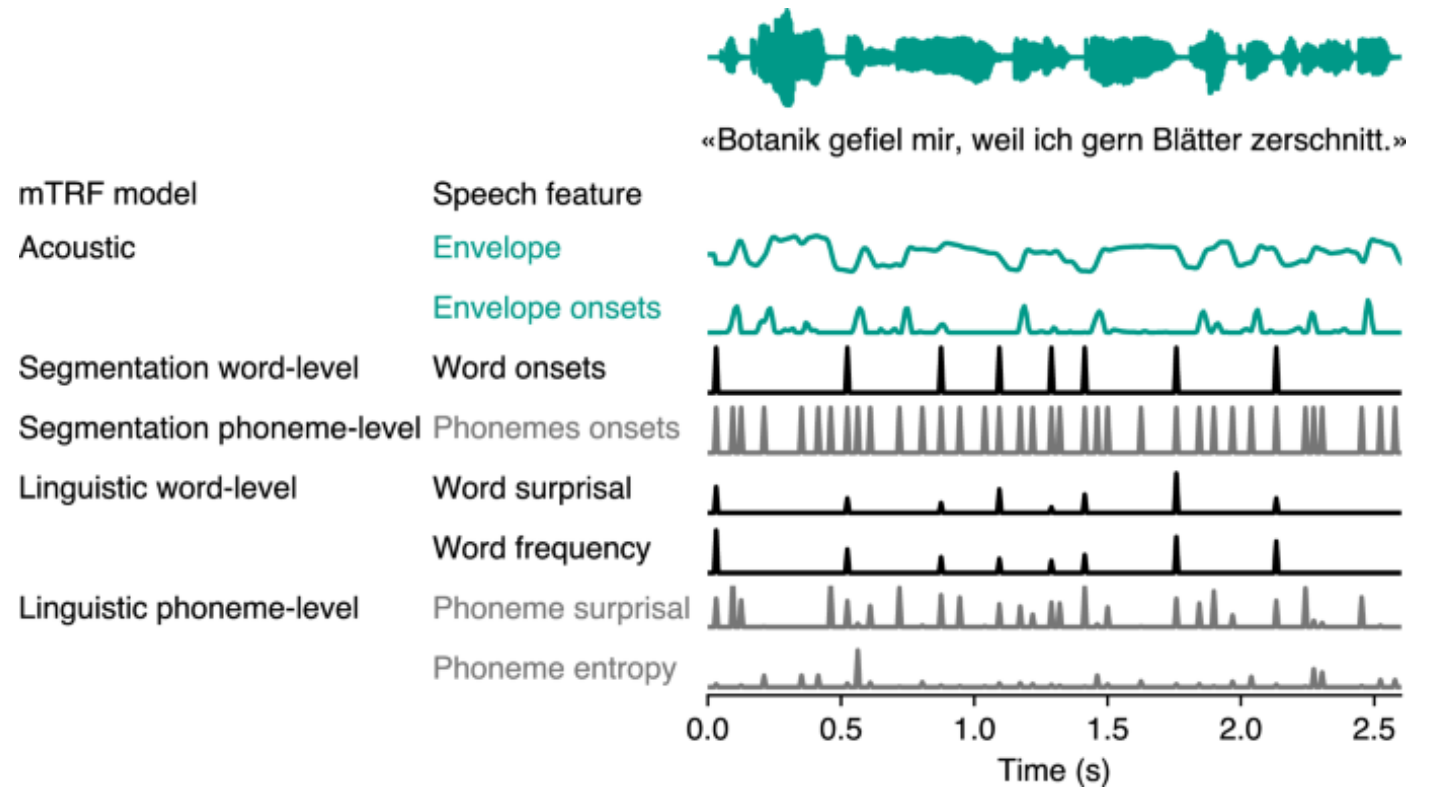


Attention at speaker 1 or 2?

- Decode both audios based on EEG
- Which accuracy is higher?
- Calculate classification accuracy

Multiple TRF

- So far, we've talked about one predictor (envelope of the audio)
- We can also use **multiple predictors** at the same time, e.g.
 - Different frequency bands of the audio
 - Additional information in the stimulus



(Bolt & Giroud, 2024)

What we've covered



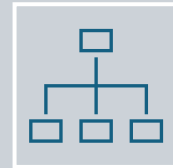
Potential Application of TRF Analysis



Math behind TRF



About TRF weights and accuracy



Multiple TRF

Any Questions?