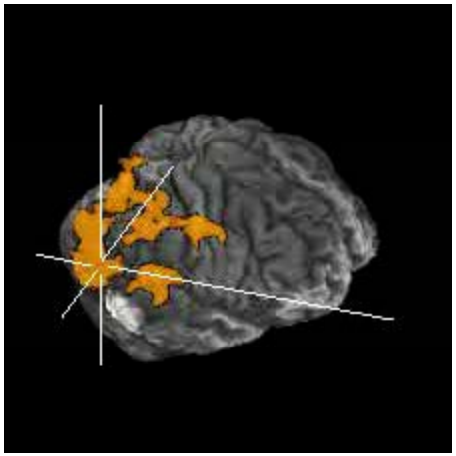
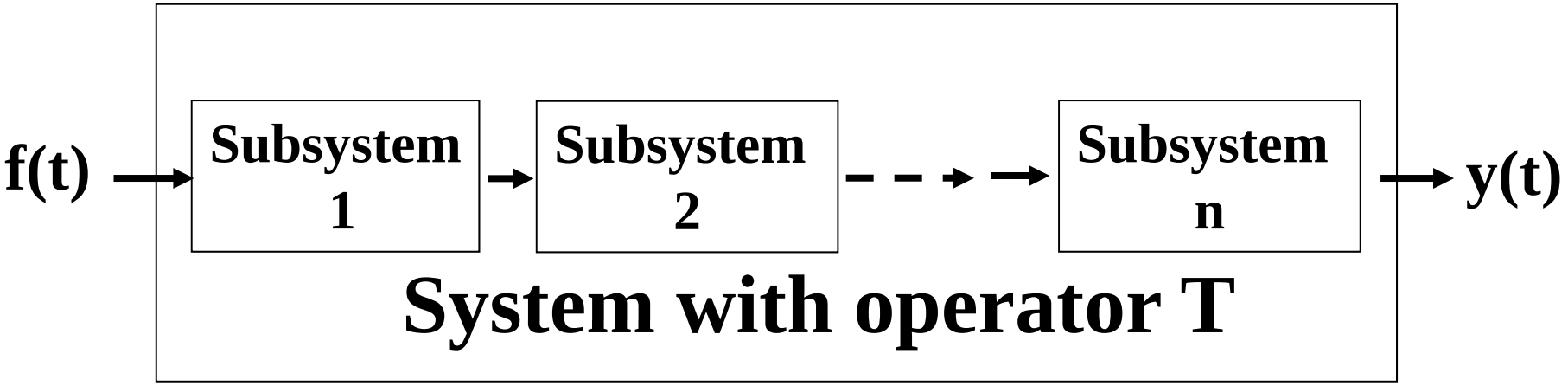
fMRI Block Design and Data Analysis

David C. Zhu, Ph.D.
Cognitive Imaging Research Center
Departments of Radiology and Psychology



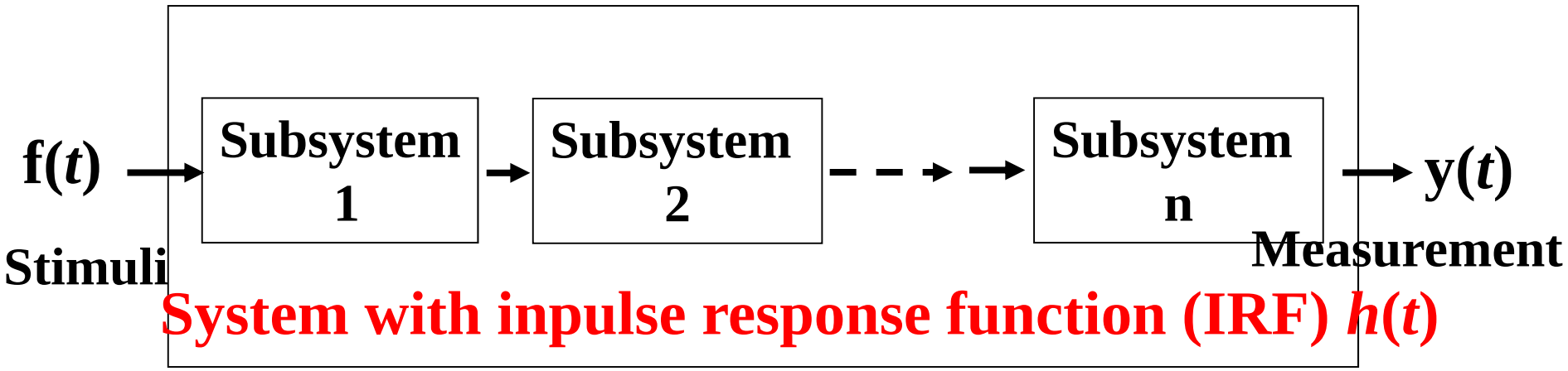


$$y(t) = T\{f(t)\}$$

(1) Find T => Event-related design

(2) Assume T' = T based on some model
Find expected y'(t) = T'{f(t)}
Compare y(t) and y'(t)
=> Block related design

Modeling of fMRI



$$y(t) = f(t) \otimes h(t)$$

$$= \int_0^t f(\tau) h(t-\tau) d\tau$$

deconvolution

$h(t)$

Continuous: $$y(t) = f(t) \otimes h(t) = \int_0^t f(\tau) h(t-\tau) d\tau$$

Discrete times: $$y(n\Delta t) = \sum_{m=0}^{n} f(m\Delta t) h(n\Delta t - m\Delta t) \Delta t$$

In short hand,

$$y_n = \sum_{m=0}^{n} f_m h_{n-m}$$

$$= \sum_{m=0}^{n} f_{n-m} h_m$$

Assume $h_m = 0$ for n ≥ p, then

$$y_n = \sum_{m=0}^{p} f_{n-m} h_m$$

Lathi BP. *Linear Systems and Signals*. Berkeley-Cambridge Press. 1992.

$$Z_n = k\sum_{m=0}^{p} f_{n-m} h_m + \varepsilon_n$$

measurement

y_n

Error

Including constant baseline + linear trend, the MR signal measured

$$Z_n = y_n + \beta_0 + \beta_1 n + \varepsilon_n$$

$$= \beta_0 + \beta_1 n + h_0 f_n + h_1 f_{n-1} + \cdots + h_p f_{n-p} + \varepsilon_n$$

For $n = p, p+1, \ldots, N\text{-}1$

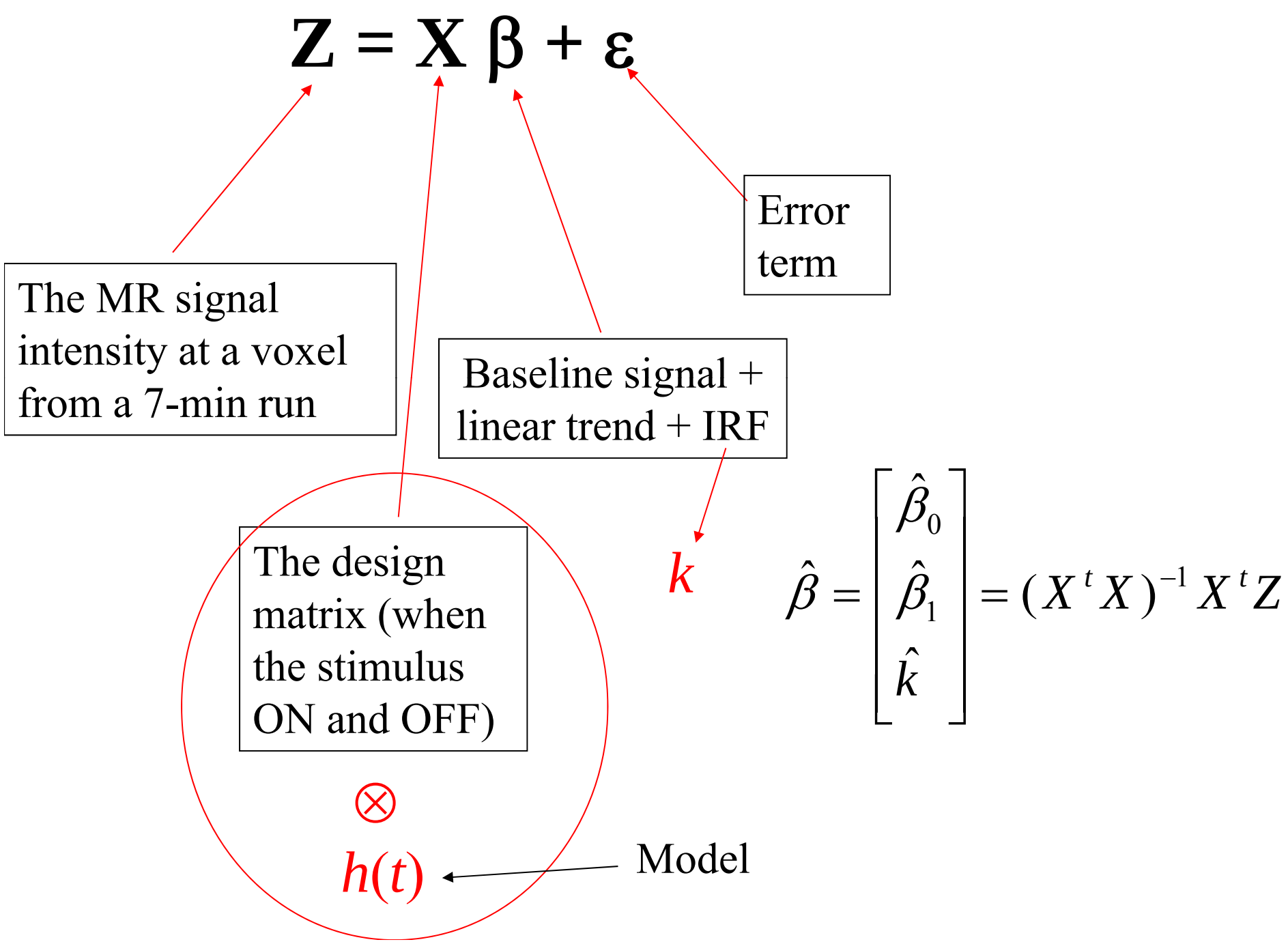
$$Z_n = \beta_0 + \beta_1 n + k y_n + \varepsilon_n$$

For $n = 0, 1, \ldots, N\text{-}1$

Using the matrix notation,

$$Z = \begin{bmatrix} Z_0 \\ Z_1 \\ . \\ . \\ . \\ Z_{N-1} \end{bmatrix}, \qquad X = \begin{bmatrix} 1 & 0 & y_0 \\ 1 & 1 & y_1 \\ . & . & . \\ . & . & . \\ . & . & . \\ 1 & N-1 & y_{N-p-1} \end{bmatrix},$$

$$\beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ k \end{bmatrix} \qquad \varepsilon = \begin{bmatrix} \varepsilon_0 \\ \varepsilon_1 \\ . \\ . \\ . \\ \varepsilon_{N-1} \end{bmatrix}$$


Z = X β + ε
The MR signal intensity at a voxel from a 7-min run
Error term
Baseline signal + linear trend + IRF
The design matrix (when the stimulus ON and OFF)
k
⊗
h(t)
Model
$\hat{\beta} = \begin{bmatrix} \hat{\beta}_0 \\ \hat{\beta}_1 \\ \hat{k} \end{bmatrix} = (X^t X)^{-1} X^t Z$

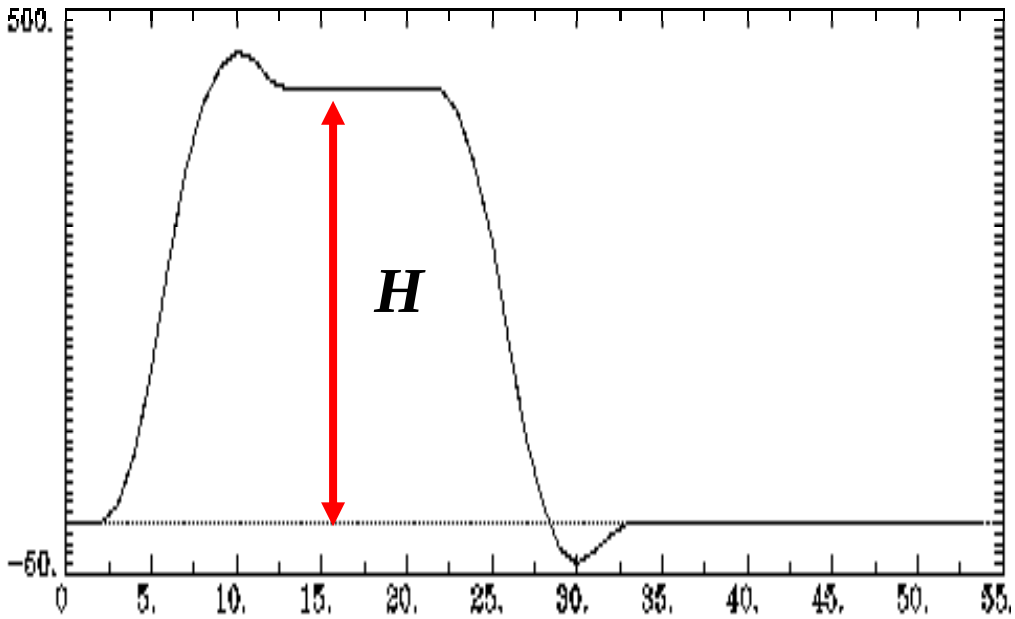
$$y(t) = f(t) \otimes h(t)$$

$$y'(t) = f(t) \otimes h'(t)$$ ← Model

In AFNI, gamma functions:
(1) Default: Cox special
(2) Mark Cohen

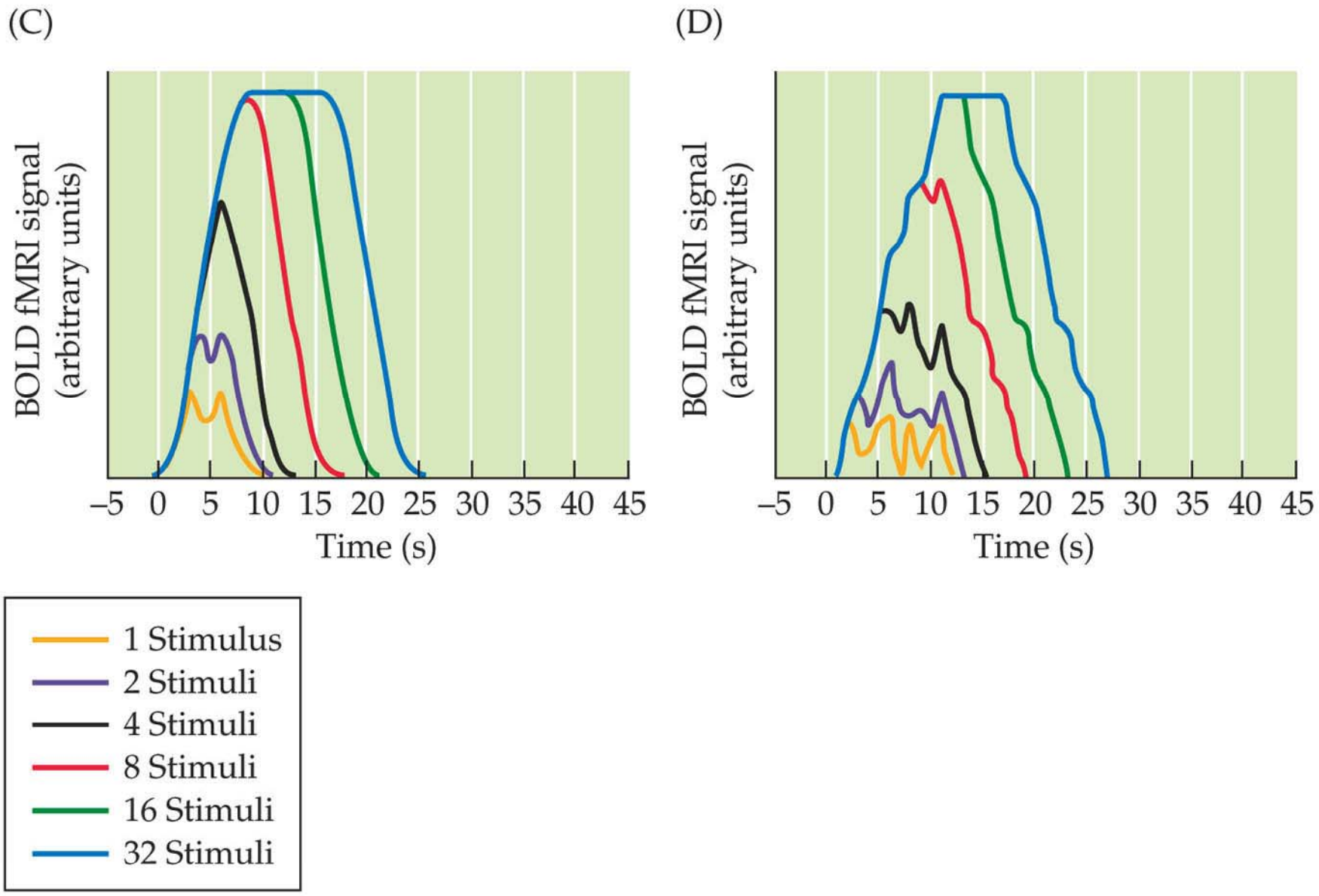
if $h(t) = kh'(t)$

then $y(t) = ky'(t)$



% signal change

$$= \frac{\hat{k}H}{\hat{\beta}_0}$$



***FUNCTIONAL MAGNETIC RESONANCE IMAGING,* Figure 11.11 (Part 2)**

Example

Henderson JM, Larson CL, Zhu DC. Cortical activation to indoor versus outdoor scenes: an fMRI study. Exp Brain Res. 2007;179:75-84.

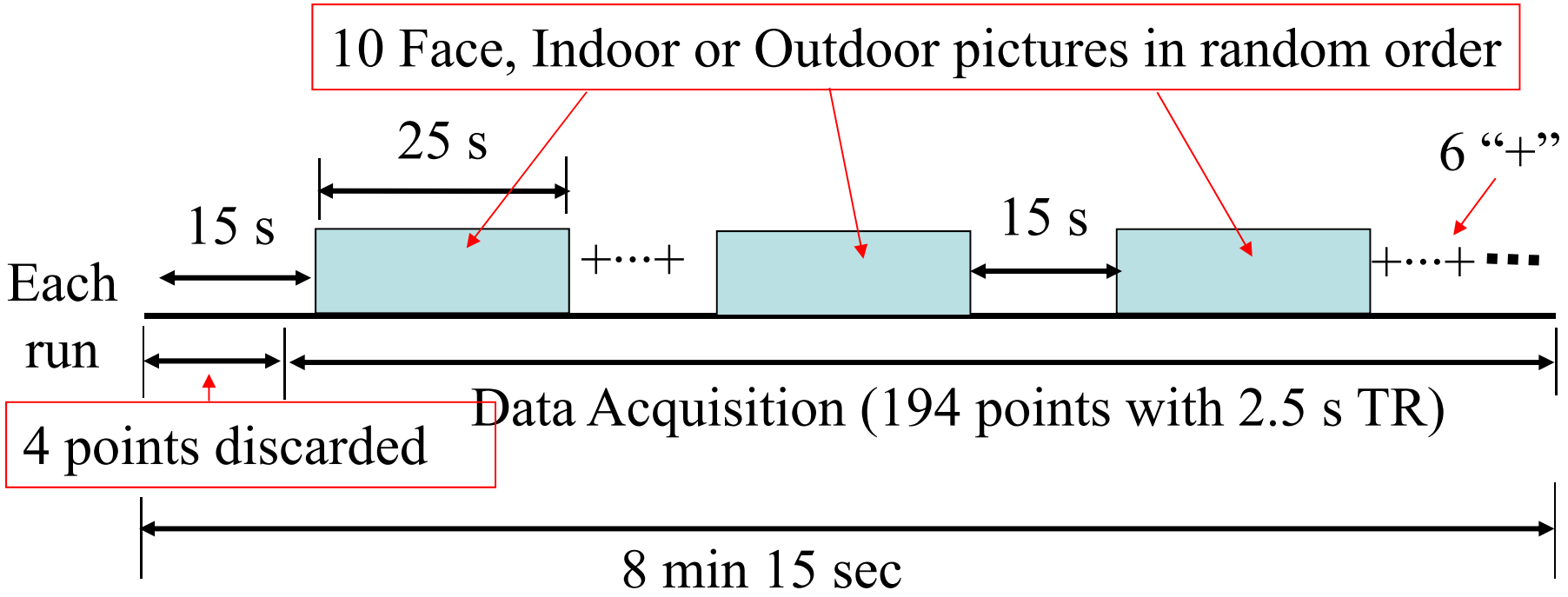
160 unique faces

160 unique indoor pictures

160 unique outdoor pictures

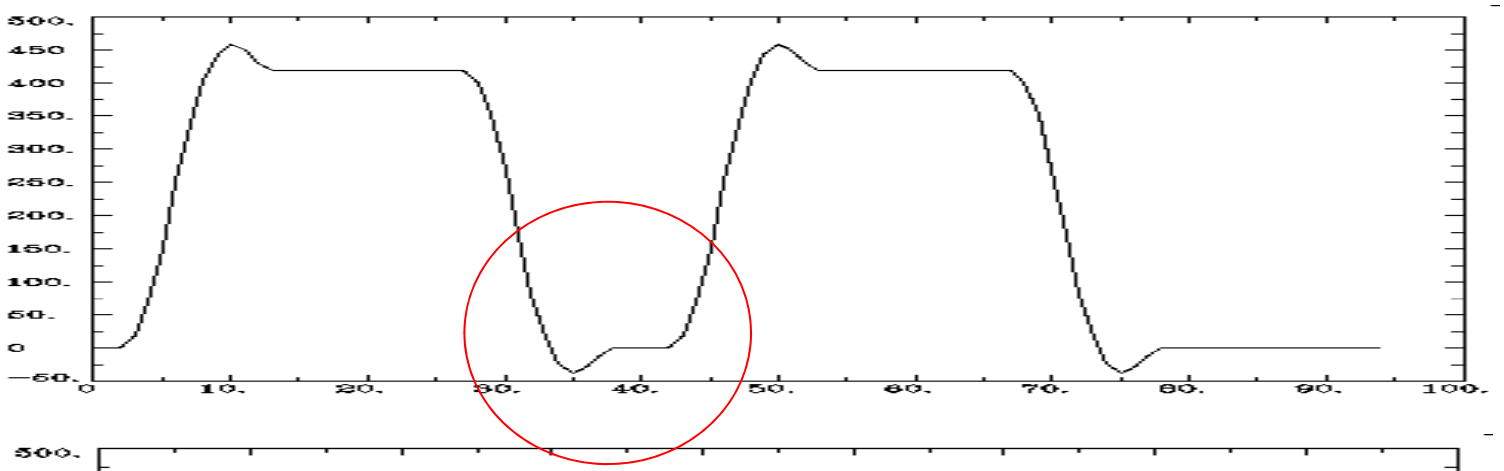
Detailed Design

160 neutral faces, 160 indoor pictures and 160 outdoor pictures.
No pictures will be repeated.
Block design.
4 runs.
Stimuli are randomized.
At each run, 6 "+" initial baseline + 12 blocks
At each block, 10 pictures + 6 "+".

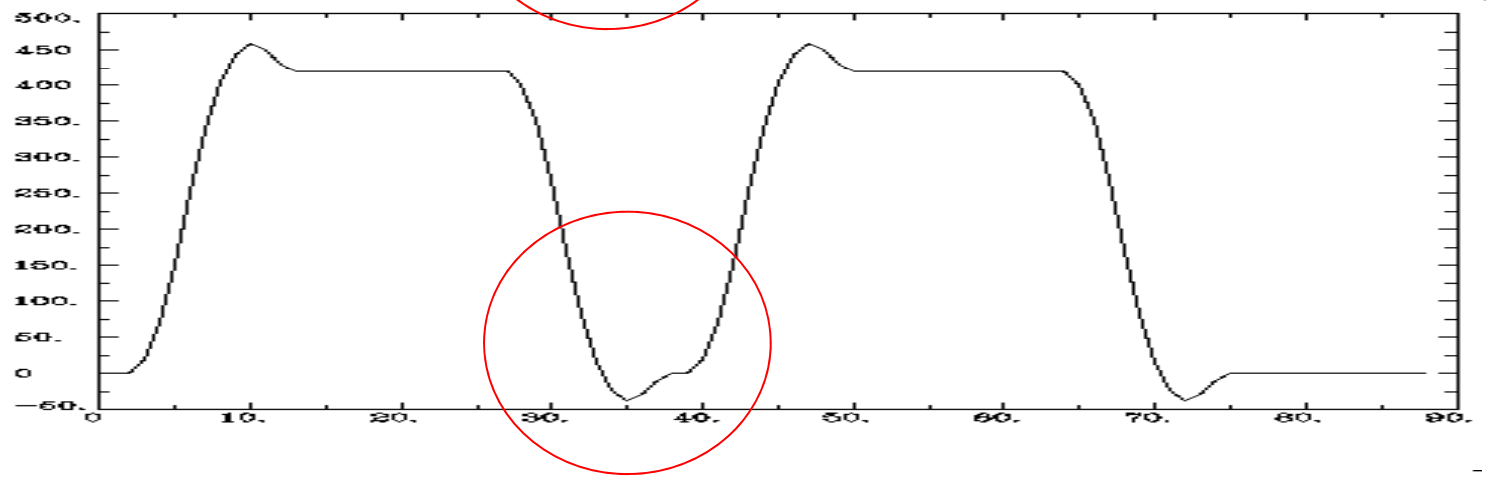


Why choose 15 sec of baseline?

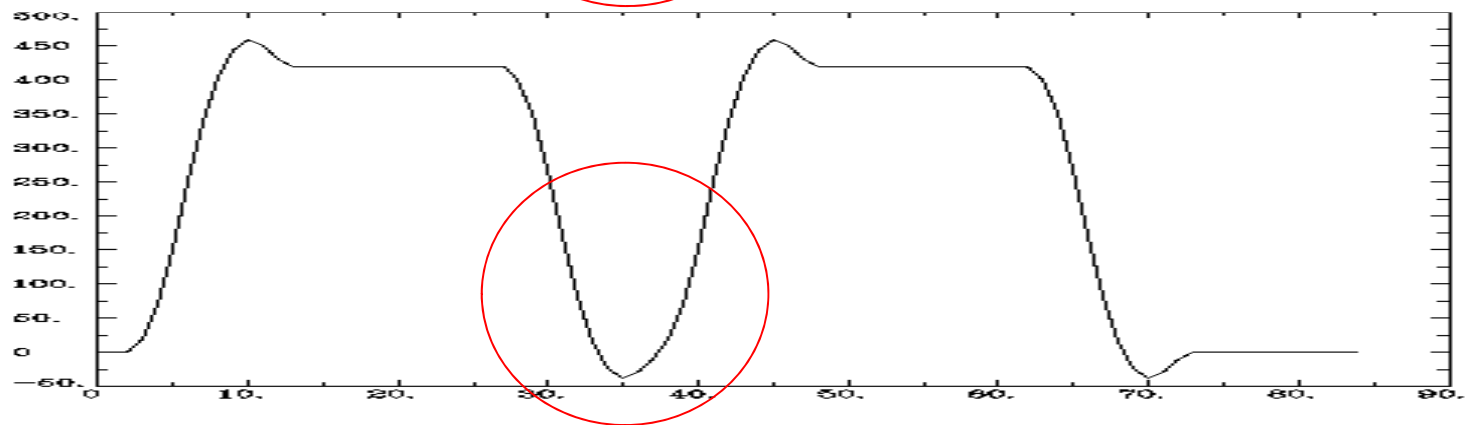
25 sec ON
15 sec OFF



25 sec ON
12 sec OFF



25 sec ON
10 sec OFF



Other considerations: Why choose 25 sec ON and 15 sec OFF?

1. Good duty cycle → shorten the scan time for same detection power.
2. Multiple of TR (2.5 sec).
3. We believe 25 sec is still good for maintaining the attention.

Generate stimulus files (1D files) and the expected BOLD response based on the model.

Data Analysis

1. Data Pre-processing:
   (1) Registration to AFNI
   (2) Slice timing adjustment
   (3) Motion correction
   (4) Spatial blurring
   (5) Mask generation

2. Data Processing:
   (1) Deconvolution analysis
   (2) Noise analysis
   (3) Overall significance level
   (4) Group analysis (ANOVA's)
   (5) ROI analysis

Live demo if possible

Group result in a standard template (Talairach, MNI …)