Measuring Specific, Rather than Generalized, Cognitive Deficits, and Maximizing Discriminating Power in Studies of Cognition and Cognitive Change

Steven M. Silverstein, Ph.D.

University of Medicine and Dentistry of New Jersey:

University Behavioral HealthCare and Robert Wood Johnson Medical School, Piscataway, New Jersey, U.S.A.

silvers1@umdnj.edu

Overview

- Specific versus generalized deficit
- Strategies for avoiding confounds resulting from a generalized deficit
- Optimizing effect size in between-groups comparisons: reliability, within-group variation and between-group variation
- Summary: Tradeoffs

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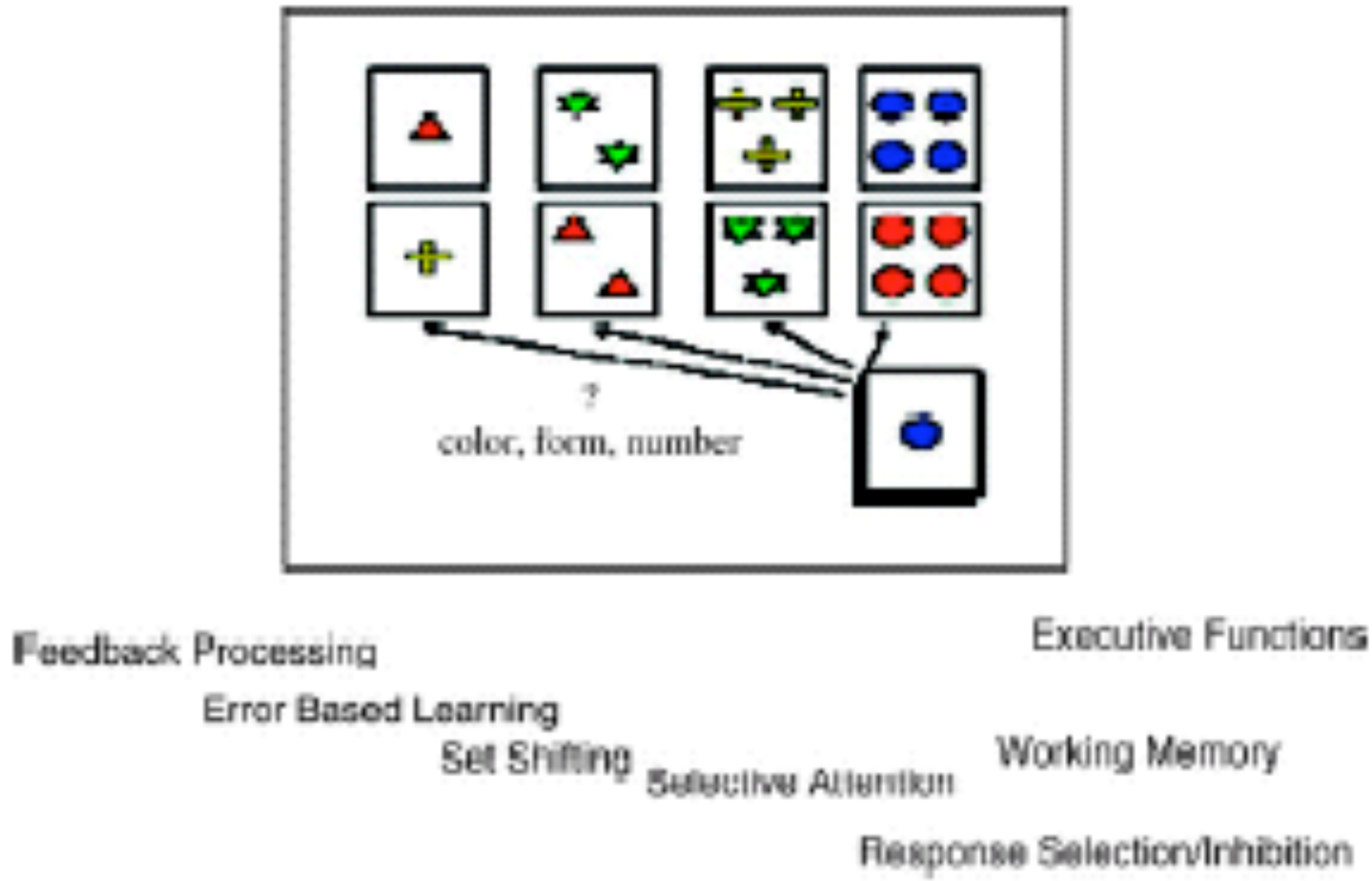
Obstacles to Isolating Specific Impairments

- Neuropsychological tests are generally confounded by multiple cognitive processes.
- Poor performance can be due to a variety of cognitive and non-cognitive factors.
- Differences in psychometric properties of tests can affect our interpretation of cognitive abilities.

Example of Multifactorial Nature of Neuropsychological Test

(from C. Carter, 2005, Scz. Bull)



- Multifactorial tests can be represented as:
  - $z_j = a_{j1}s_1 + a_{j2}s_2 + \ldots a_{jp}s_p + \ldots a_{jm}s_m + e_jE_j$

  - z_j = individual's standardized score on test j
  - s_p = true score for source of variance p
  - a_{jp} = influence of variance source p on test j
  - E_j = sources of measurement error on z_j
  - e_j = influence of E_j on z_j (Neufeld, 1984)

- We want: $z_j = a_{jp} s_p + e_j E_j$
- We need to either:
  – eliminate all ‘non-specific’ sources of true score variance (s), or
  – minimize effects of these sources (a) on test scores

Strategies to Isolate Cognitive Deficits

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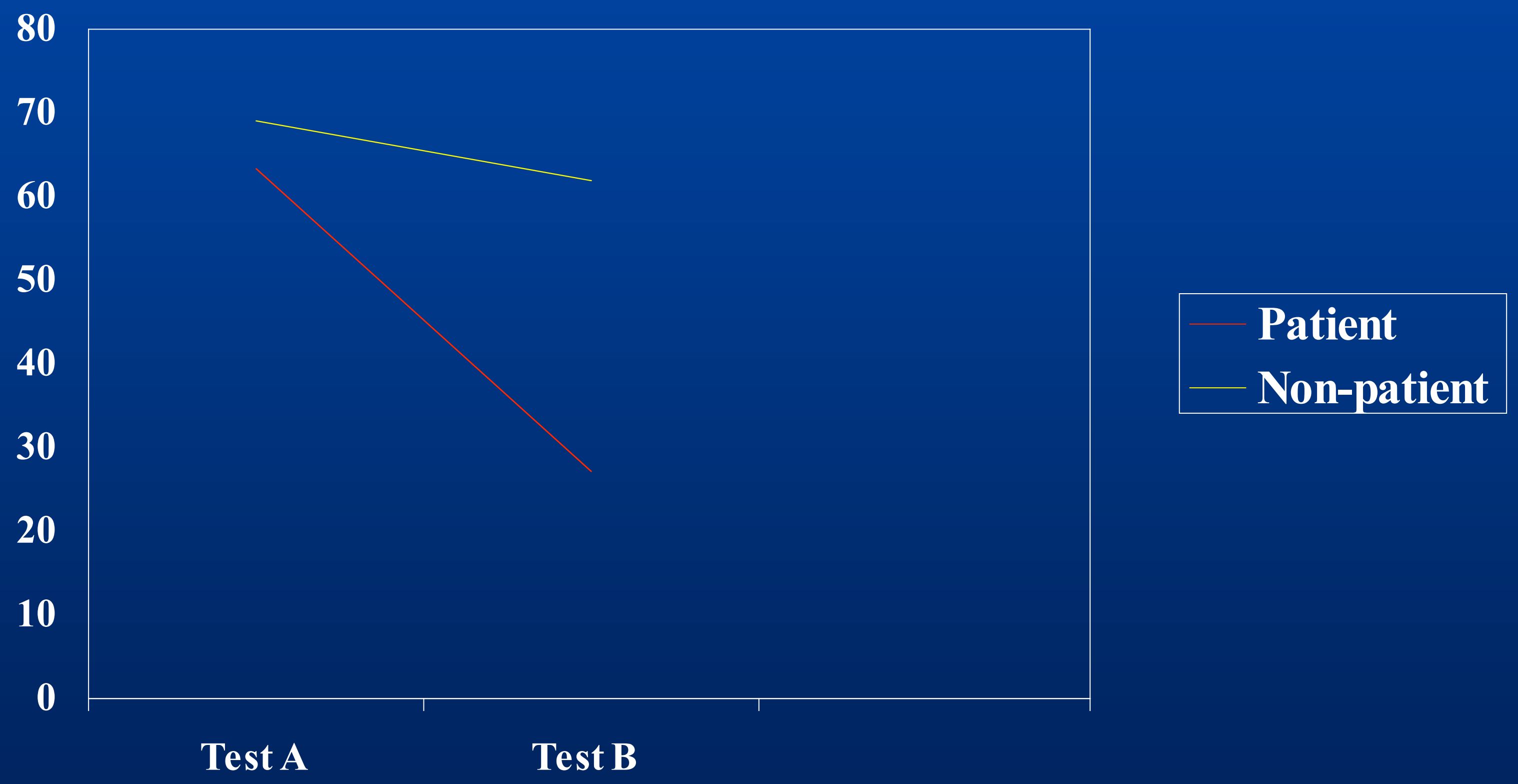
Differential Deficit



But….

- A differential deficit could be due to greater discriminating power of 1 of the tests.
- A test that is more reliable, and/or more difficult will discriminate between subjects better than a less reliable or less difficult test.

A differential deficit is only meaningful if:

- the patient group achieves <u>superior</u> performance on 1 of the tests.
- differences between groups are greater on the less discriminating task, and/or
- both tests have equivalent reliability and difficulty levels (Chapman & Chapman, 1978; Strauss, 2001)

Problems with Task Matching

- Matching on reliability and difficulty does not ensure construct validity (process specificity)
- Matching on difficulty level is a problem for cognitive neuroscience tasks where parameter manipulations change difficulty levels
- Matching does not maximize between-groups discriminating power (Knight & Silverstein, 2001)

Reliability and Discriminating Power

- Reliability: $r_{xx} = \sigma_t^2/\sigma_o^2$ or (=) $\sigma_t^2 / [\sigma_t^2 + \sigma_{me}^2]$
- Reliability of a test can be increased by:
  - reducing measurement error (σ_{me}^2)
  - increasing true score variance (σ_t^2)
- Reducing σ_{me}^2 will reduce within-group variance, and increase sensitivity to <u>between-groups</u> sources of variance.

- Increasing σ_t^2 will increase within-group variance/discrimination, but if it does not also increase between-groups discrimination, power will decrease (Neufeld, 1984).
- It has been shown that, for 2 tests of the same construct that differ by as much as 3x in σ_t^2, the test with higher σ_t^2 was associated with a lower between-group effect size, due to σ_t^2 being increased by mainly focusing on processes that increase within group variation but that are not related to between group discrimination.

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- Magnitude of between-group difference can be expressed as $(c\tau+\beta)/(\tau+e)$, where
  - β is the effect of a variable unique to group membership
  - τ represents effects of other variables that generate variance within-groups,
  - c represents overlap between τ and β (Neufeld, 2007)
- In standardization sample, c and β are irrelevant, within group discrimination = $\tau/(\tau+e)$, and we want to maximize τ.
- But, "a measure becomes less group-discriminating as its standardization-group psychometric precision goes up" (Neufeld, 2007; also Cohen, 1988).

$(c\tau+\beta)/(\tau+e)$

- Where group separation is a function primarily of β, power goes up as τ goes down.
- As τ increases, power goes up as c goes up.
- But, increasing τ is only beneficial to between-group discrimination when $\beta<c*e$.
- Less reliable tests with higher c values can be <u>more</u> (between-group) discriminating than more reliable tests with low c values.

Similar Issue With Increasing Task Length

- Adding trials to a task may increase test-retest reliability, but can reduce between-group discrimination if new items are associated with sources of within-group variance that are independent of β.
- Increasing task length is OK <u>only</u> if the test is unifactorial, or covariance structure of the task does not change with added items.
- However, this can add significant time and cost to clinical trials.

- Neither matching on reliability and difficulty, nor maximizing within-groups true score variance (i.e., individual differences) ensures either that a specific process is being measured, or that between-groups discriminating power is maximized.

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Alternative Strategies - I

- ANCOVA
  - typically not appropriate as a control for another cognitive process as represented by a second task score.
  - assumes independence of covariate and IV (group)
  - most appropriate when there is random assignment to groups. It was designed to reduce within-groups variance rather than between-groups variance.
- IRT
  - requires large samples to construct measures
  - cannot resolve the issue that a focus on τ and e cannot ensure a match on group discriminating power.
  - Assumes that item parameters do not differ across groups.

Alternative Strategies - II

- Profile analysis
  - this vulnerable to same psychometric artifacts as differential deficit strategy
- Aggregation of scores into cognitive subdomains
  - exacerbates effects of σ_{me}^2 and τ
- PCA, Factor analysis, and cluster analysis
  - Tests with the same confound may load on the same factor/cluster, confounding interpretation
  - Can be useful for understanding factor structure of single tests

Alternative Strategies - III

- Partially ordered classification models* (Jaeger, et al., 2006, *Schizophrenia Bulletin*)
  - Useful with neuropsychological battery data
  - Assumes that tests are multifactorial and accommodates this by organizing test scores into a conceptual network, based on the cognitive functions that are shared between tests, and functions that are unique to tests. Patients are then classified as belonging to 1 functional state in this network, based on their test scores, and Bayesian analysis techniques are used to determine the likelihood that these assignments are correct.
  - Would not be necessary with unifactorial tests

Simplest Poset: 2 States

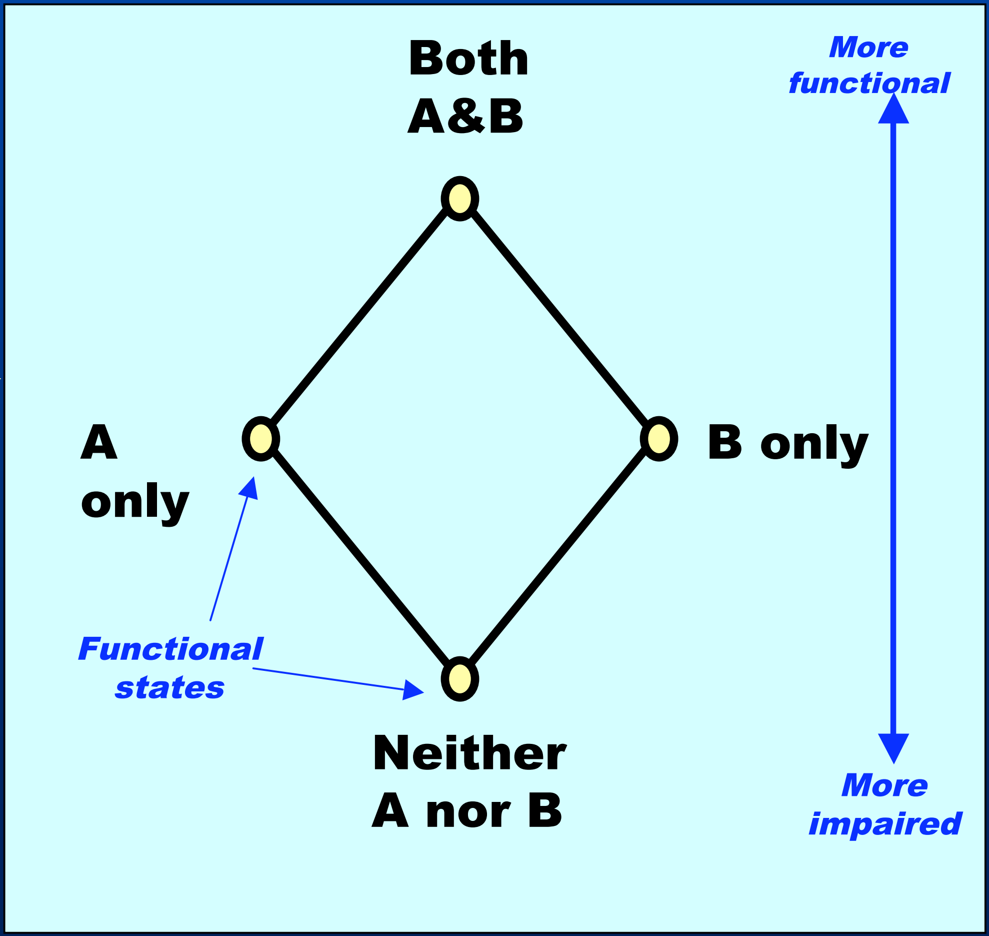
(this slide contributed by Judith Jaeger)

- These states can be viewed as belonging to a partially ordered set (i.e. poset)
- Some states have higher (cognitive) functionality than others. Others are not directly comparable.
- In typical application, more tests are used and more network states are present.

Example: A & B are attributes

Let A=Memory

Let B=Attention



Process-Oriented Strategies

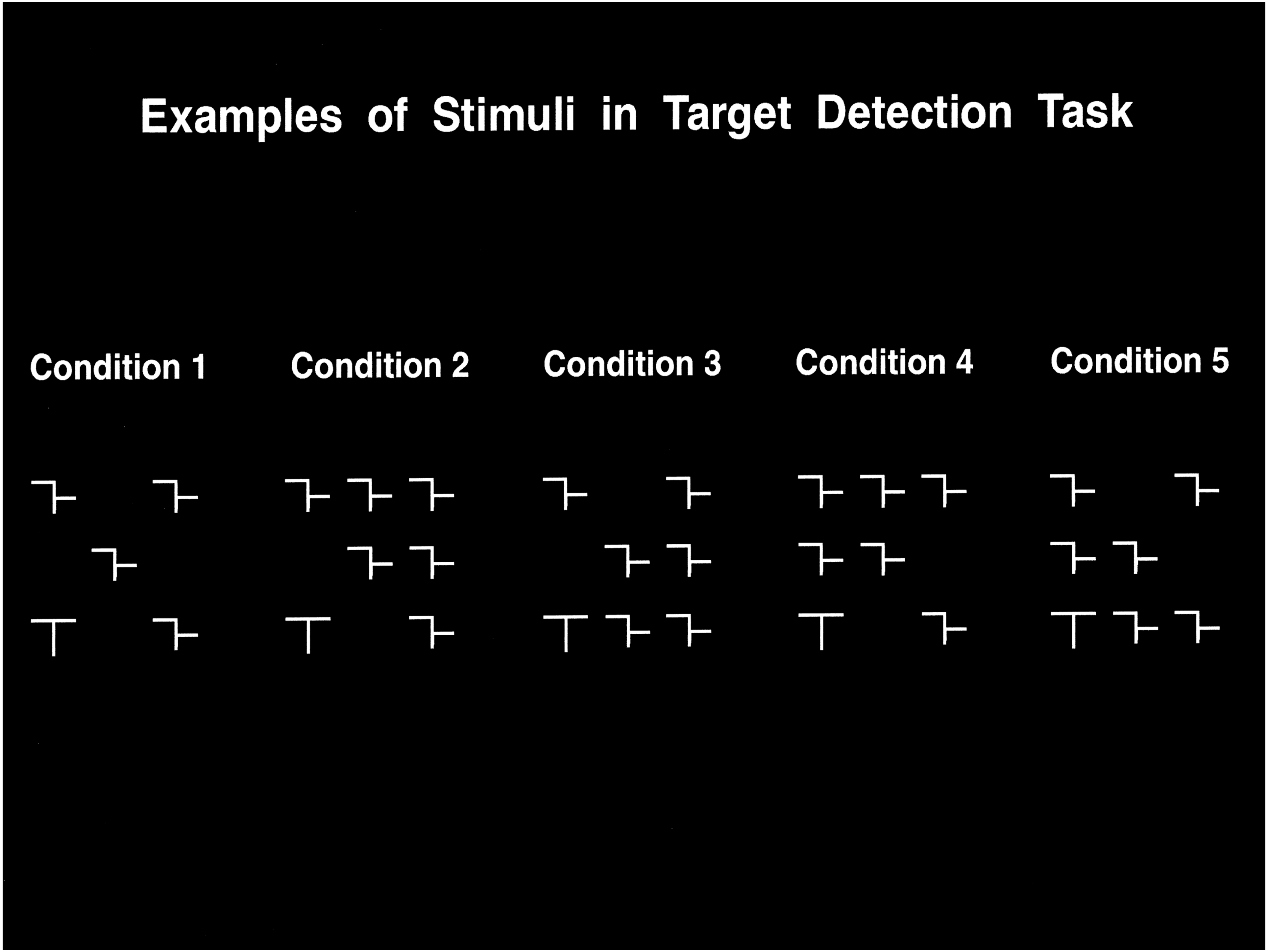
(Knight, 1984, 1992; Knight & Silverstein, 1998, 2001 *J. Abnormal Psychology*)

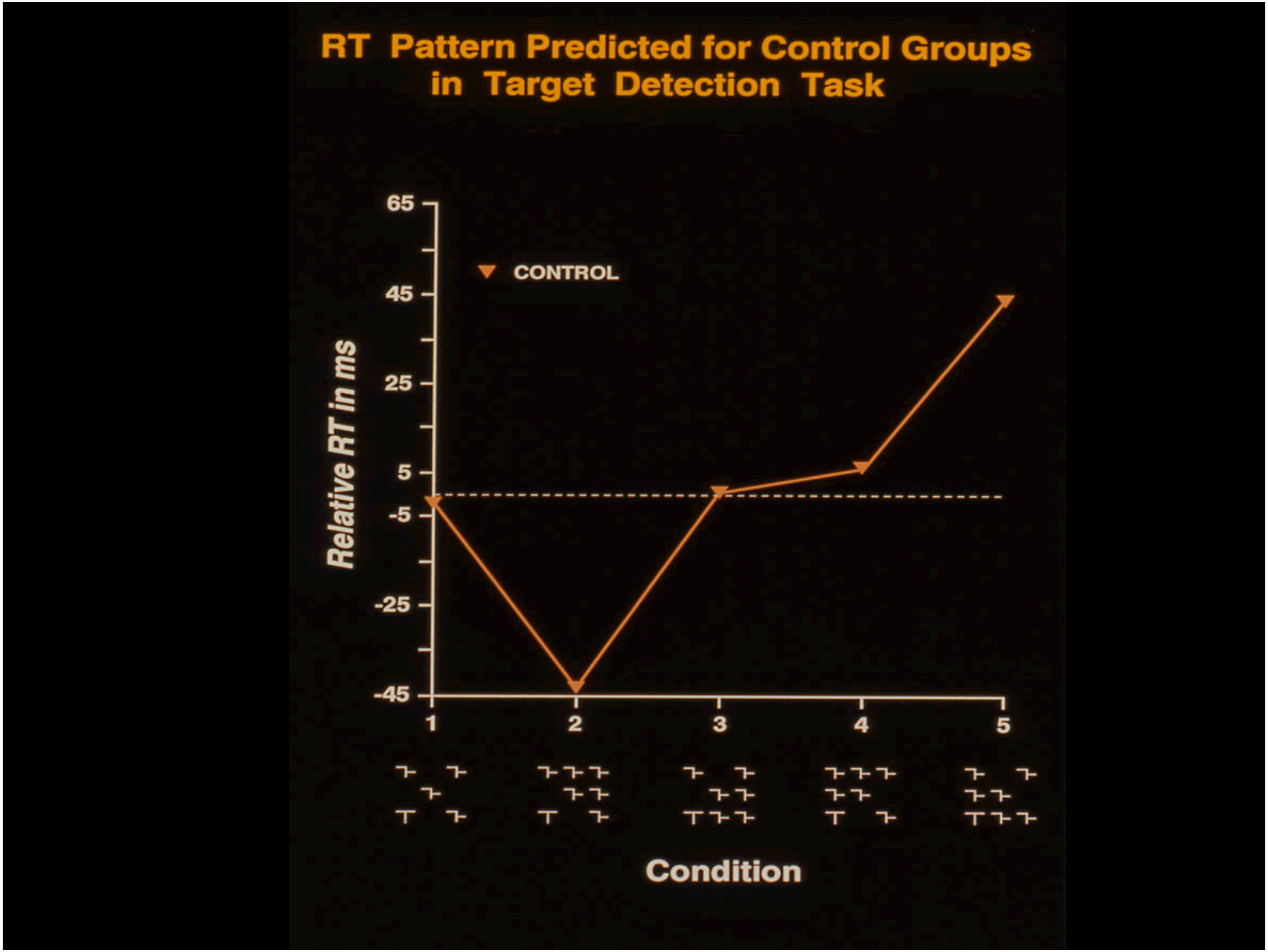
- Guided by theoretical models that make specific, falsifiable predictions, that can be tested against other hypothesis.
- Tasks typically include multiple conditions where specific parameters are varied to probe the integrity of an underlying process.
- Adequacy of the target process is understood in terms of the <u>pattern</u> of scores across conditions, or the pattern of psychophysiological correlates.
- Superiority and relative superiority are strongest findings.

Example of a Process-Oriented Task Involving a Relative Superiority Prediction

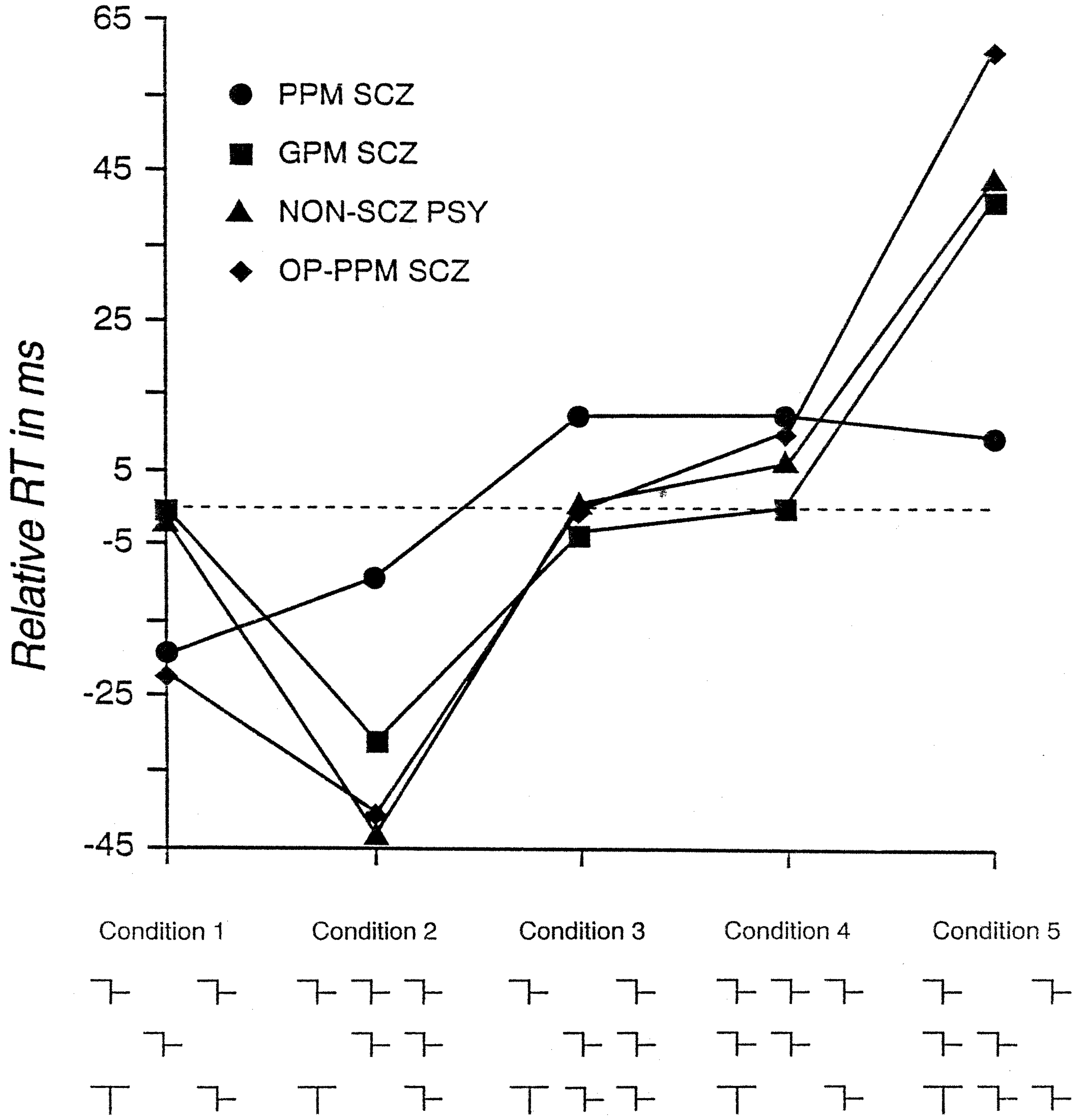
(Silverstein et al., 1996 *J of Abnormal Psychology*)

- Different patterns of RT predicted for schizophrenia inpatients with poor premorbid functioning compared to other patients
- Example of relative insensitivity to perceptual organization reflected in a display size effect, in contrast to other groups.


Examples of Stimuli in Target Detection Task
Condition 1
Condition 2
Condition 3
Condition 4
Condition 5



RT Pattern Predicted for Control Groups in Target Detection Task
CONTROL
65
45
25
5
-5
-25
-45
Relative RT in ms
1
2
3
4
5
Condition



Relative RT in ms
65
45
25
5
-5
-25
-45
PPM SCZ
GPM SCZ
NON-SCZ PSY
OP-PPM SCZ
Condition 1
Condition 2
Condition 3
Condition 4
Condition 5

- Examples of superiority or relative superiority are found in multiple cognitive domains [e.g., latent inhibition, working memory (AX-CPT), language (increased semantic priming, reduced negative priming, greater disambiguation for low-probability sentence endings), auditory and visual perception (reduced flanker interference effects, reduced perceptual grouping leading to more accurate judgements about features, etc.]
- Development of more process-oriented tasks, in more cognitive domains, will allow for greater process specificity, and stronger cognition-neurobiology links.

An Issue in Multiple Condition Comparisons: The Use of Difference Scores

- Reliability of gain scores: $\rho_{gg'} = \rho_{xx'} - \rho_{12} / 1 - \rho_{12}$
  - $\rho_{xx'}$ = average reliability of pretest and posttest measures
  - ρ_{12} = correlation between the pre- and post-tests (Lohrman, 1999).
- It was assumed that adequate validity required high ρ_{12} (trait stability), so low ρ_{gg}.
- When there is little change among people, or if all people change to a similar degree, the reliability of difference scores will be low.

- However, when there is heterogeneity in true change:
  - » There is low or moderate ρ_{12}
  - » Reliability of difference scores can be high

$$\rho_{gg'} = \rho_{xx'} - \rho_{12} / 1 - \rho_{12}$$

High → $.75 = (.8 - .2) / (1 - .2)$

Low → $.33 = (.8 - .7) / (1 - .7)$

Issues With Reliability of Change Scores

(Willett, 1989, 1994, 1997)

- Differences between conditions may be heterogeneous across people, even when a test is perfectly construct valid
- Under these conditions, the reliability of a difference score can be higher than the reliabilities of the individual scores that make up the index.
- The critical issue is whether we can understand/model the change in terms of relevant processes.

Increasing Sensitivity to Change

- Characterization of change across more than 2 conditions, via slope, non-linear functions, or other multivariate methods (e.g., slope, mean, variability around trend line*), will increase sensitivity
- Standard errors are reduced
- Reliability of change measurement is increased as measurement points are added (Willett, 1989, 1994, 1997)
- Appropriate modeling of covariance structure further increases sensitivity
- Cluster analysis can be useful to identify subgroups of subjects in 3-D space*, to identify factors responsible for heterogeneity in degree of change (either across conditions within a task, or across time with multiple testing points).

Summary: Tradeoffs

- Increased measurement sensitivity via increasing number of test conditions vs. ensuring adequate numbers of trials for within-condition measurement
- Measurement of full range of construct vs. optimizing discriminating power in each condition
- Individual difference discrimination vs. between-group discrimination
- Test-retest reliability/stability vs. sensitivity to change
- Construct validity vs. test-retest reliability
- Process-oriented designs vs. task/condition-matching
- Staircase procedures vs. standardized trial presentation