Psychology 205: Research Methods in Psychology
Personality and Arousal
An example of a research problem

William Revelle

Department of Psychology
Northwestern University
Evanston, Illinois USA

May, 2021

Outline

1. Background to Experiment 2
2. Testing personality theory by examining the interaction of subject variables and situational variables
3. Personality differences as subject variables
4. Types of relationships between Independent Variables and Dependent Variables
5. Prior work on personality and performance
6. Simulation study

Types of relationships and research designs

All statistics are just **Data = Model + Residual**.
What is the model?

1. Univariate
   - Linear (a typical assumption, rarely met) $Y \sim \beta X + \epsilon$ linear regression
   - Monotonic (More typical, rarely examined) $Y \alpha\ f(X) + \epsilon$
   - Non-monotonic (Unusual and rarely examined) $Y \sim \beta X^2 + \epsilon$
2. Multivariate (at least two variables)
   - Additive $Y \sim X_1 + X_2 + \epsilon$
   - Interactive $Y \sim X_1 * X_2 + \epsilon$ (The relationship of Y with X_1 depends upon X_2
   - Additive and interactive $Y \sim X_1 + X_2 + X_1 * X_2 + \epsilon$

   Statistics ask how well the model fits, design asks are the conclusion justified.

Subject variables: Nuisances or Useful?

1. For many experimentalists, subject variables are just sources of noise to be controlled.
   - Interest, boredom, fear, ability
2. But to Personality and Developmental psychologists, that people differ from each other is our field of study.
   - Stable between subject differences
   - Within subject differences over time
3. The measurement of individual differences is fundamental to the study of personality
   - How do people differ?
   - When do people differ?
   - Why do they differ?

Personality and Arousal as an example of research program

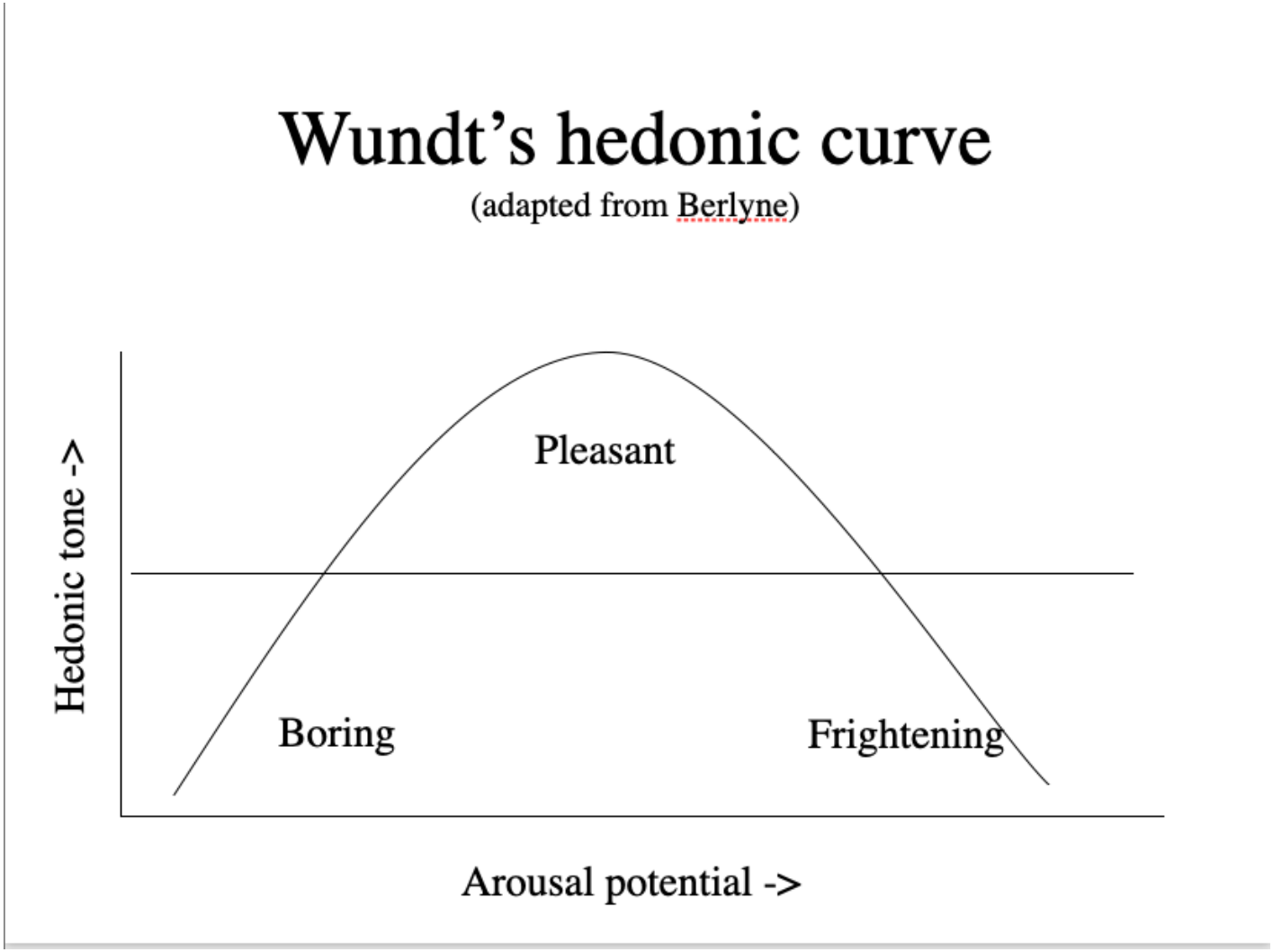
1. Motivation and Performance: The Yerkes-Dodson "law" (Yerkes & Dodson, 1908)
   - Explorations in arousal and performance (Broadhurst, 1957, 1959; Anderson, 1990)
2. Arousal and arousal preferences
   - Wundt, Berlyne and Goldilocks
3. Personality and Performance
   - Two dimensions of personality related to arousal theories
     - Introversion-Extraversion
     - Emotional Stability vs. Neuroticism

Behavioral consequences of arousal differences

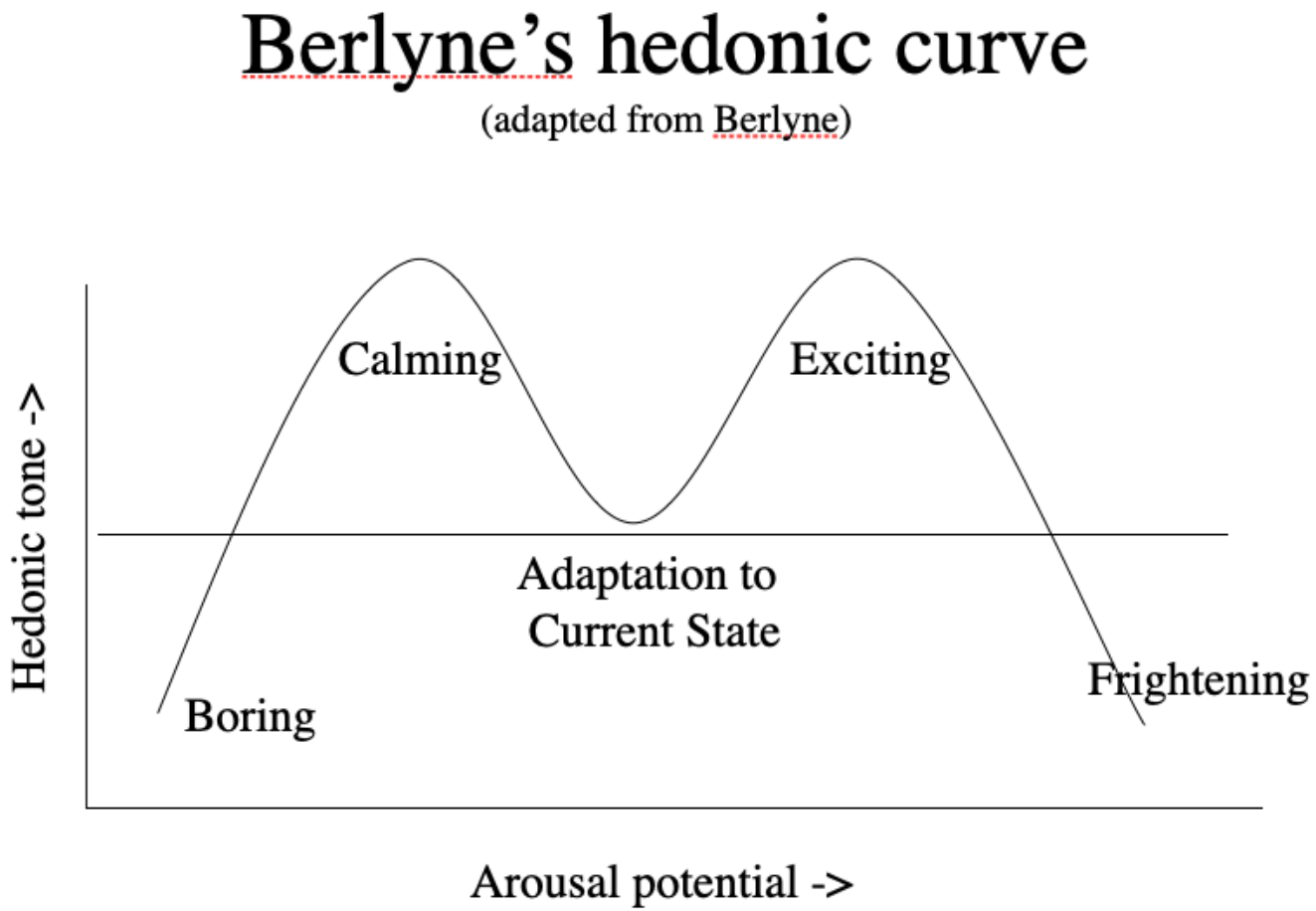
Differences in Arousal preference

1. Wundt's curvilinear hypotheses
2. Moderate levels of arousal are more pleasing than extreme levels
3. ("the Goldilocks hypothesis")
4. Berlyne
5. Changes in arousal are more pleasing than a steady state
6. Increases or decreases are pleasant

Wundt and hedonic tone: the "Goldilocks effect"



Berlyne and adaptation



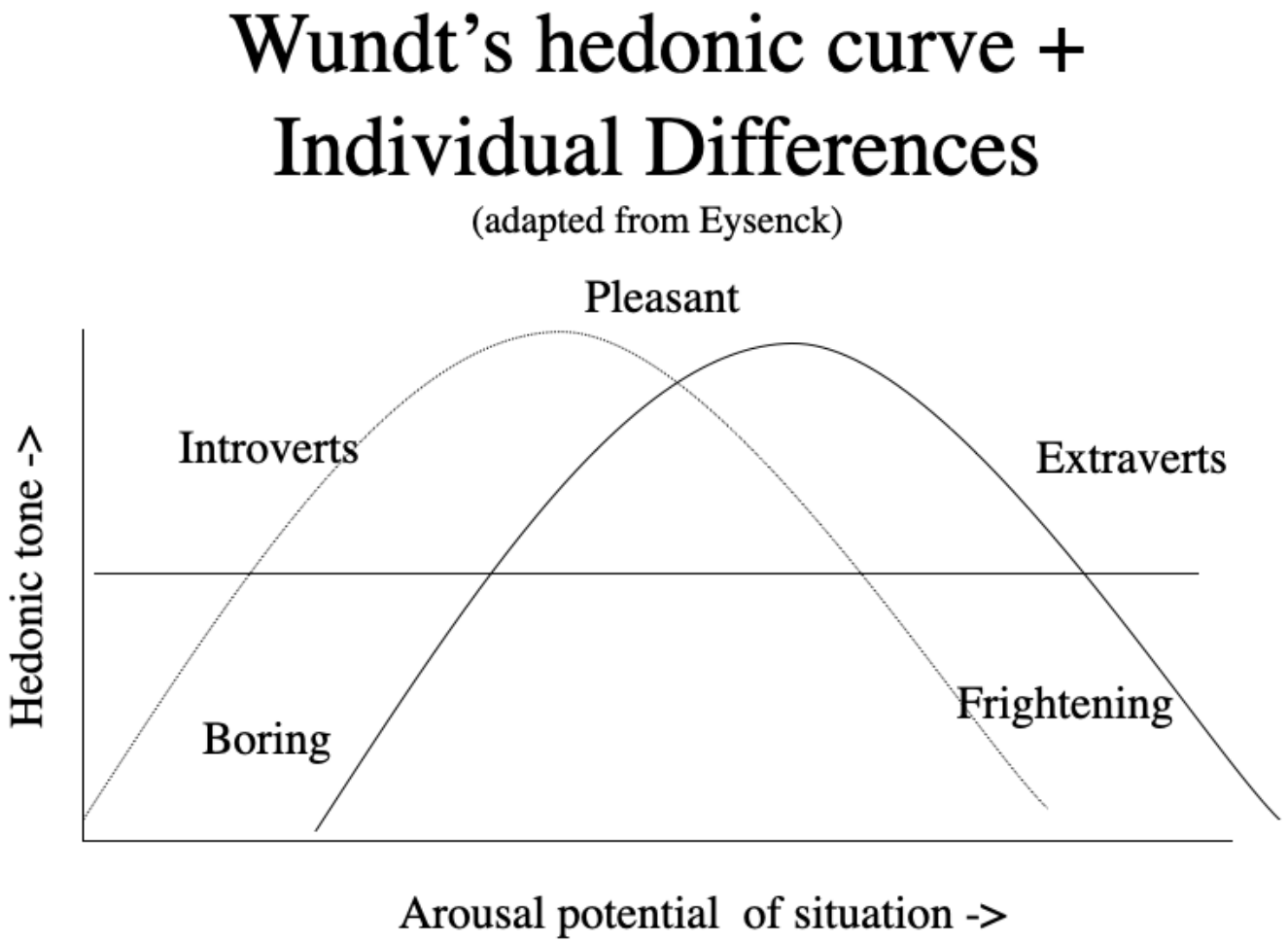
Arousal theories and experimental psychology

1. Arousal as a general, diffuse, and non-specific state of activation (Duffy, 1951, 1962; Malmo, 1959) and emotion.
2. Duffy (1951) distinguished between the directional and the energy mobilization functions of emotions.
3. The construct of arousal was used in experimental psychology to unify the disparate effects of noise, sleep deprivation, time on task, diurnal rhythms, and alcohol Broadbent (1971).
4. In terms of self report, arousal turned out to be at least two dimensional, with the alertness-sleepy dimension independent from a tension-calm dimension (Thayer, 1970, 1978, 2000).

Hans Eysenck and Arousal theory of extraversion

1. H.J. Eysenck wanted to combine experimental and correlational approaches to psychology. (Revelle, 2016)
2. Wanted to integrate best (at the time) biological and behavioral descriptions with theories of individual differences.
3. Some evidence suggested the introverts were more aroused, alert and vigorous than extraverts (Eysenck, 1967)
4. Combined this with the Wundt hypothesis of hedonic preference and proposed that under-aroused extraverts were always seeking stimulation while over-aroused introverts were avoiding stimulation.

Introversion-Extraversion and hedonic tone



Yerkes Dodson"Law"

1. Electric shock as drive inducer
2. 4-5 levels of shock
3. Discrimination Learning
4. 3 levels of difficulty
5. Performance as interactive effect of difficulty and drive
6. Interpreted as inverted U relationship between arousal and performance.
7. But the subjects were 40 "dancing" mice. (Perhaps the most famous mice ever!)

Discrimination learning and electric shock

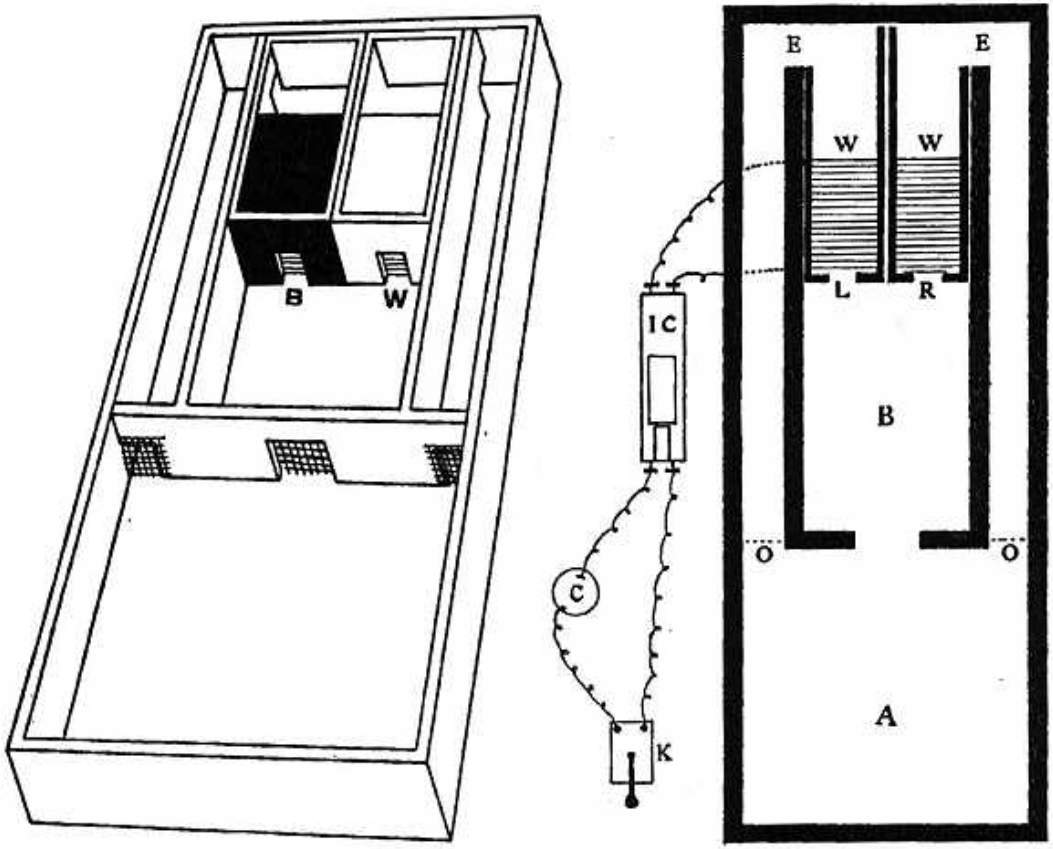


Fig. 1. Fig. 2.

Fig. 1. Discrimination box. *W*, electric box with white cardboards; *B*, electric box with black cardboards.

Fig. 2. Ground plan of discrimination box. *A*, nest-box; *B*, entrance chamber; *W W*, electric boxes; *L*, doorway of left electric box; *R*, doorway of right electric box; *E*, exit from electric box to alley; *O*, swinging door between alley and *A*; *IC*, induction apparatus; *C*, electric battery; *K*, key in circuit.

Yerkes & Dodson (1908)

Errors vary with trials and footshock

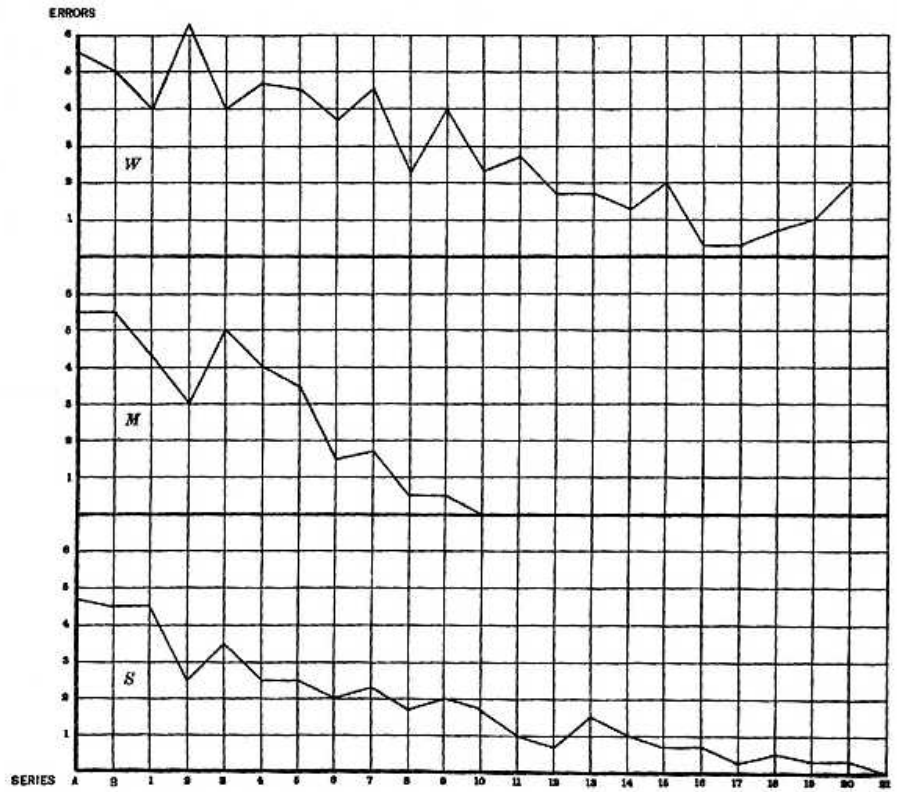


FIG. 4. Curves of learning. Ordinates represent series of ten tests each, and abscissæ represent the average number of errors for four mice in each series. *W*, designates the error curve for the individuals which were trained under the condition of *weak* electrical stimulation; *M*, designates the corresponding curve for the *medium* strength of stimulation; and *S*, that for the *strong* stimulus.

Yerkes & Dodson (1908)

Rapidity of learning and footshock

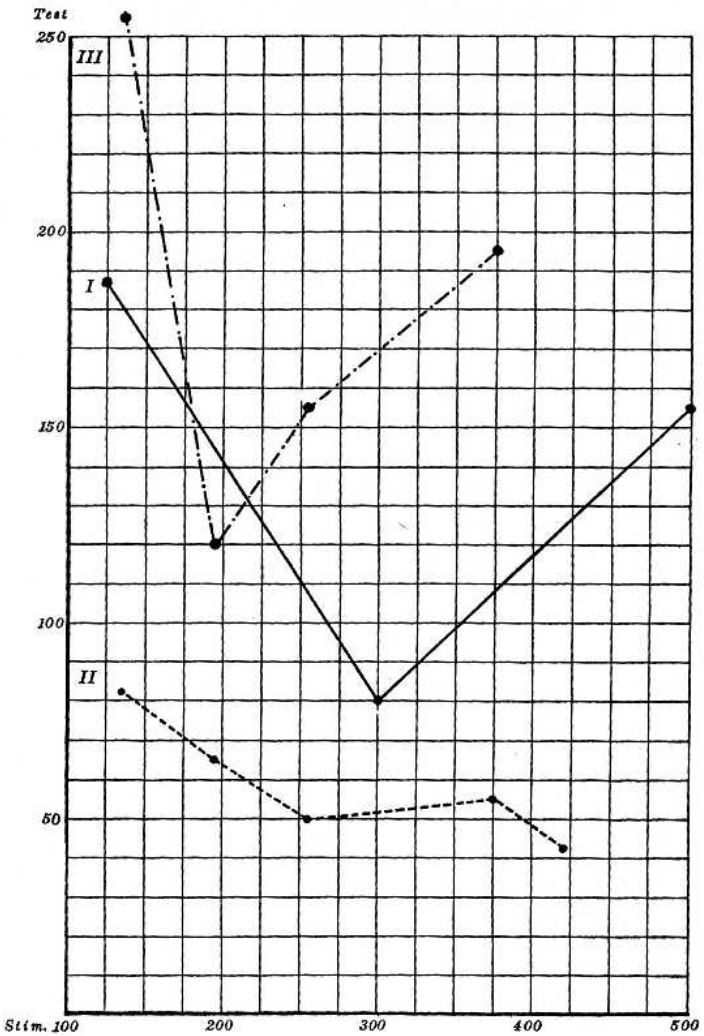
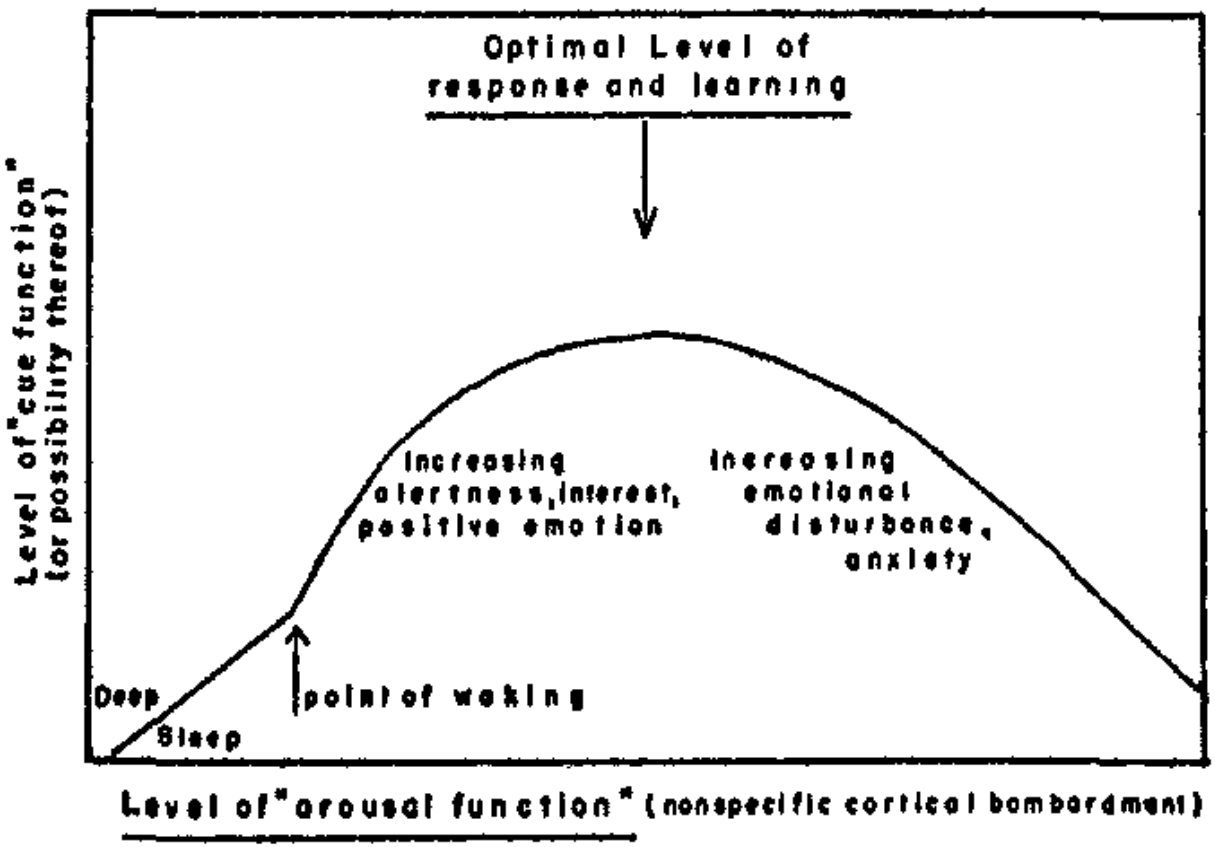


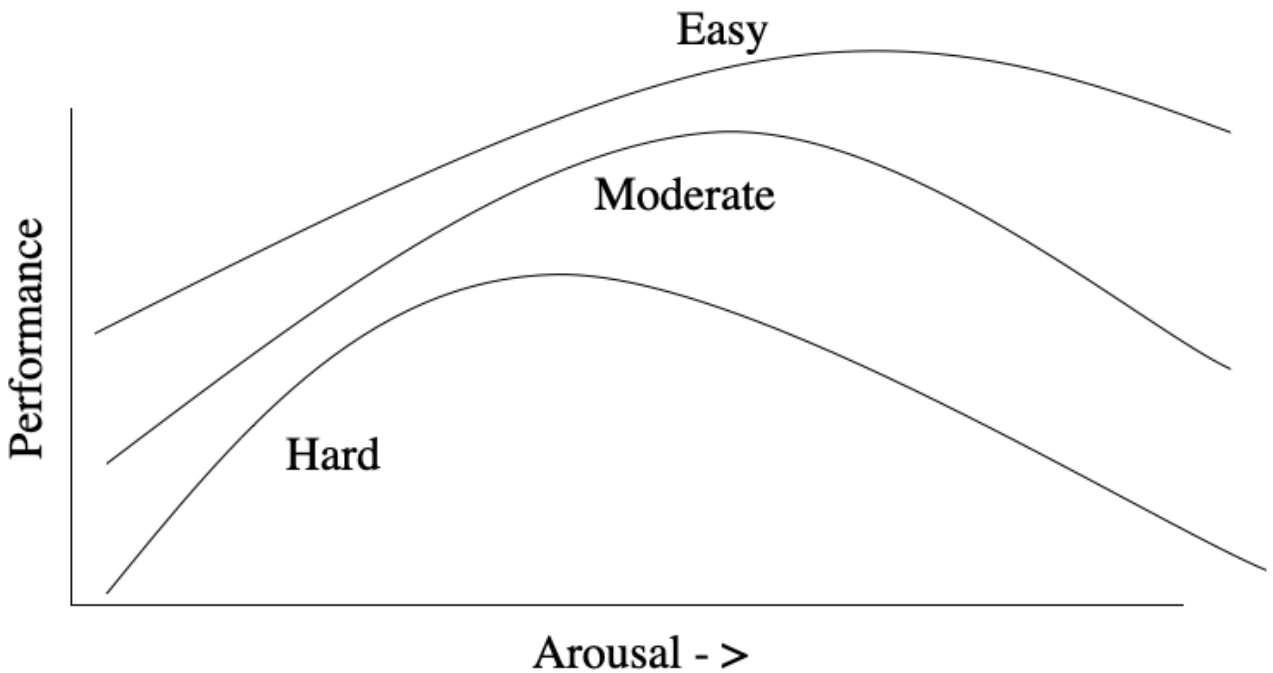
Fig. 5. A graphic representation of the relation of strength of electrical stimulus to condition of visual discrimination and rapidity of learning. Ordinates represent value of electric stimulus in units of stimulation; abscissæ represent the number of tests given. Curve *I* represents the results of the experiments of Set ⁻. Each dot indicates a value of stimulus which was used in the experiments. For example, the first dot to the left in curve *I* signifies that the stimulus whose value was 125 units gave a perfect habit, in the case of the four individuals trained, with 187 tests; the second dot, that for the stimulus value of 300 units 80 tests were necessary; and the third that for the stimulus value of 500, 155 tests. Curves II and III similarly represent the results of the experiments of sets II and III, respectively.

Hebb and the inverted U



Hebb (1955)

Interpretation of Yerkes-Dodson Law



Arousal and Performance

1. Broadbent and the Applied Psychology Unit
   - Sleep deprivation
   - Noise
   - Stress
2. Common theme of arousal
   - Problems with arousal:
   - Is it a unified construct?
   - Arousal of the hand, the heart, the head
3. Is there an inverted U (Anderson, 1994)

1. Introvert-extravert differences map into levels of arousal
   - Introverts perform as if more aroused
   - Extraverts perform as if less arousal
2. Eysenck and Arousal theory of I-E
   - Introversion-extraversion and arousal
   - Optimal arousal theory
   - Extraverts seeking to increase stimulation, introverts to reduce it

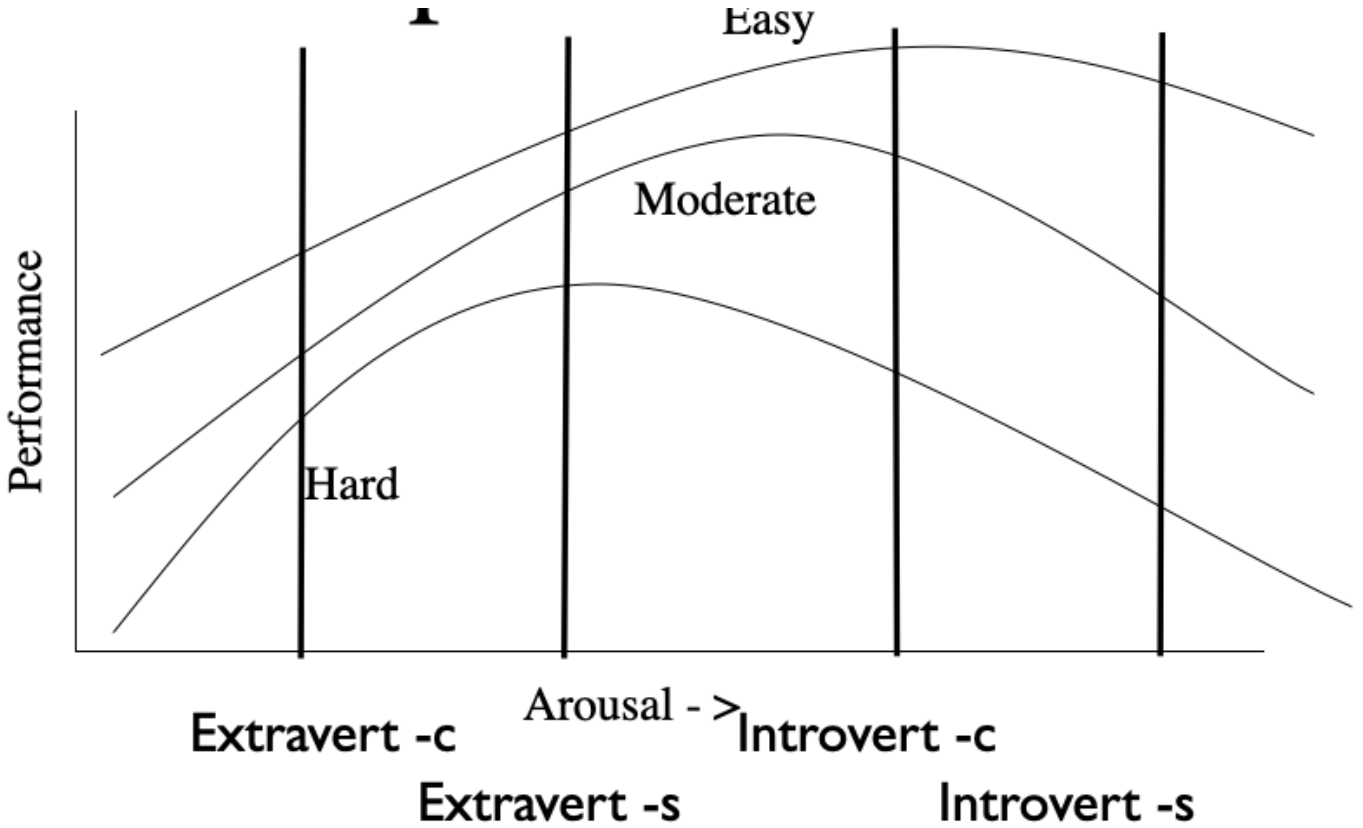
Does personality make a difference?

1. Important Life Criteria
   - Longevity Friedman, Tucker, Schwartz, Tomlinson-Keasey, Martin, Wingard & Criqui (1995)
   - Job Performance Schmidt & Hunter (2004)
   - Psychological well being
2. Laboratory tasks
   - Cognitive sensitivities and biases (MacLeod & Mathews, 1988, 2012)
   - Systematic pattern of results with cognitive performance by stress manipulations (e.g., Anderson, 1990; Anderson & Revelle, 1994; Revelle, Amaral & Turriff, 1976; Revelle, Humphreys, Simon & Gilliland, 1980; Revelle, 1993)

Early attempts at theory testing

1. Subject variable (Introversion-extraversion)
2. Stress manipulation (1 variable)
   - Noise
   - Sleep deprivation
   - Threat
3. Predict and observe interaction.
4. But, 3 out of 4 effects fit theory!

Problem with simple studies: most predictions work



Early attempts at theory testing

How to manipulate arousal

1. Presence of others–social facilitation (Zajonc, 1965)
2. Competition
3. Monetary Incentives
4. Noise

Multiple levels of arousal manipulation

Combine variables into progressively more arousing

1. Relaxed alone
2. Relaxed together (group size 2)
3. Competing together (group size 2)
4. Competing together for money (group size 2)
5. Competing together for money (group size 8)
6. Competing together for money (group size 8 in noisey room)

Measurement of arousal using skin conductance

Early attempt

1. Prediction of personality by stress manipulation
2. With 6 levels of stress, an observed interaction would confirm theory
3. Result:
   - Arousal went down as group size went up!
   - Performance went up as incentives increase

(Revelle, 1973)

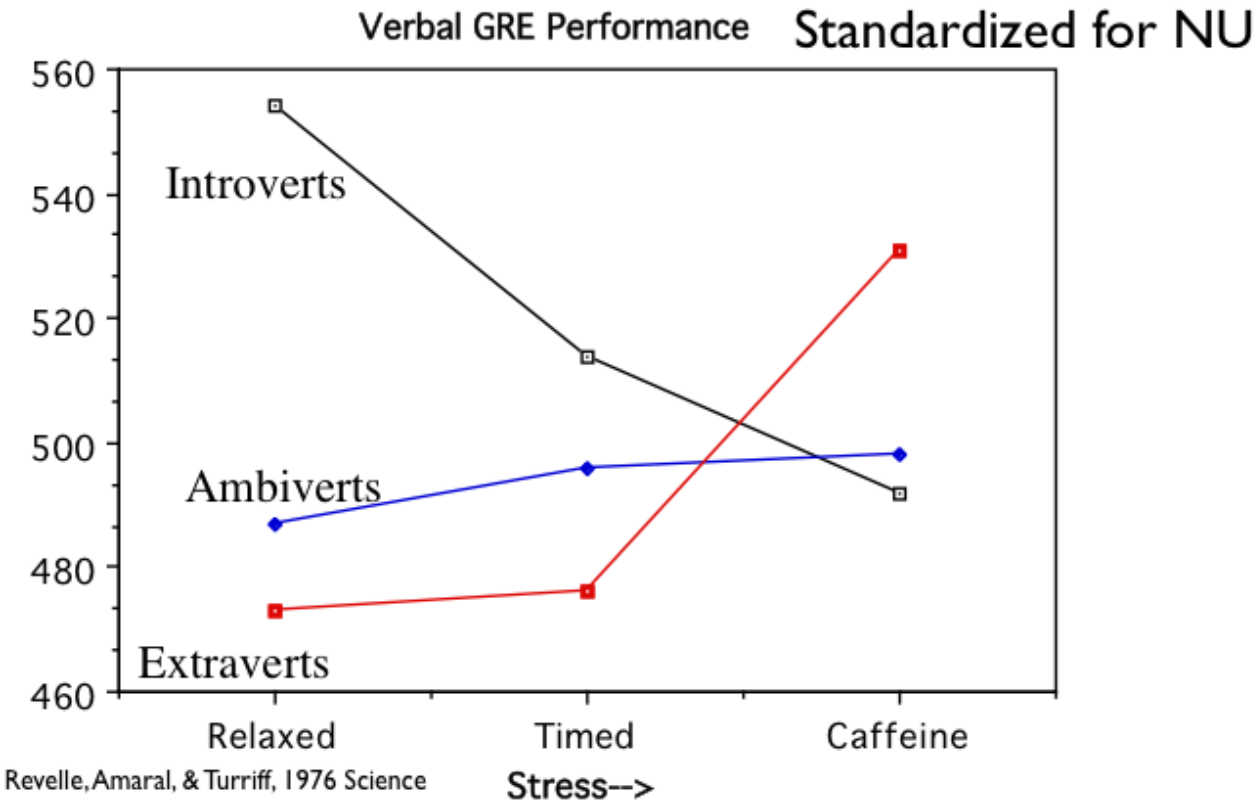
Revelle, Amaral and Turriff (1976)

1. Introversion-extraversion as assessed by self report
2. Placebo-Caffeine to induce arousal
3. 200 mg of caffeine vs. 200 mg of placebo
4. Practice Graduate Record Exams
5. 3 levels of stress (repeated within subjects)
   - No time pressure
   - Time pressure + placebo
   - Time pressure + caffeine

The advantages of smart undergraduates! (Revelle et al., 1976)

Revelle et al. (1976)

Introversion, time pressure, and caffeine: effect on verbal performance



Replicability is the hallmark of Science

1. Kirby Gilliland improved on the earlier paper by
2. Dosing by body weight rather than a fixed amount
3. Used 3 levels of caffeine (0, 2 and 4mg/kg bodyweight)
4. Used the new and improved version of Extraversion, the Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975)
5. Correlations of the old EPI (Eysenck & Eysenck, 1964) and the new EPQ were at the level of the reliabilities, implying equivalence.

Replicability is the hallmark of science

But Gilliland (1976, 1980) did not replicate!

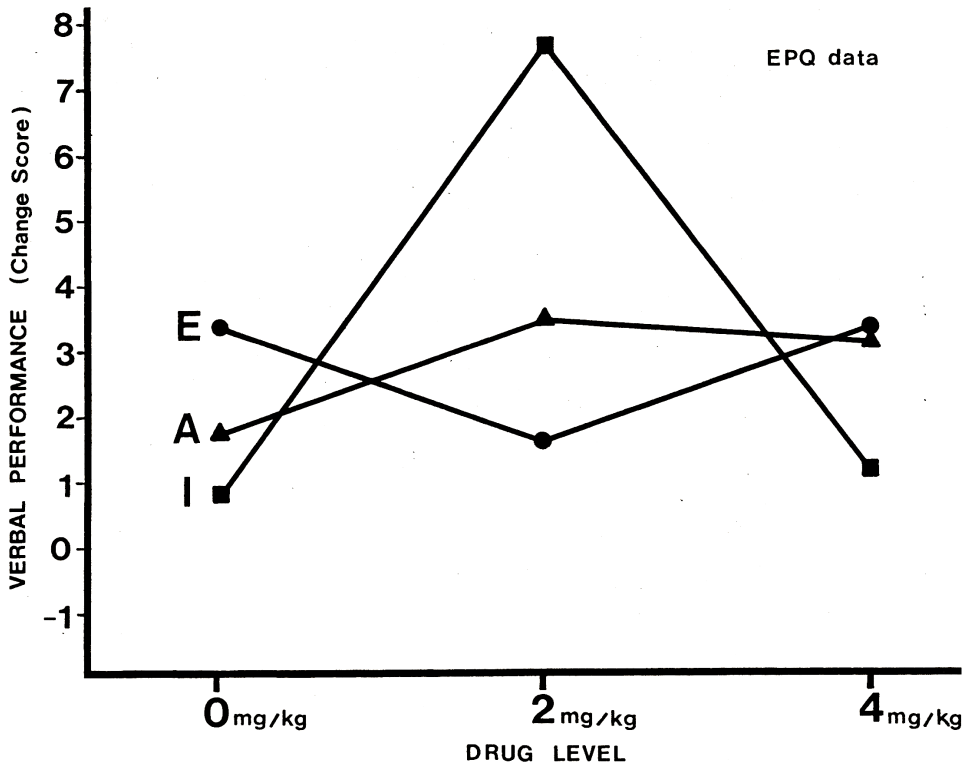


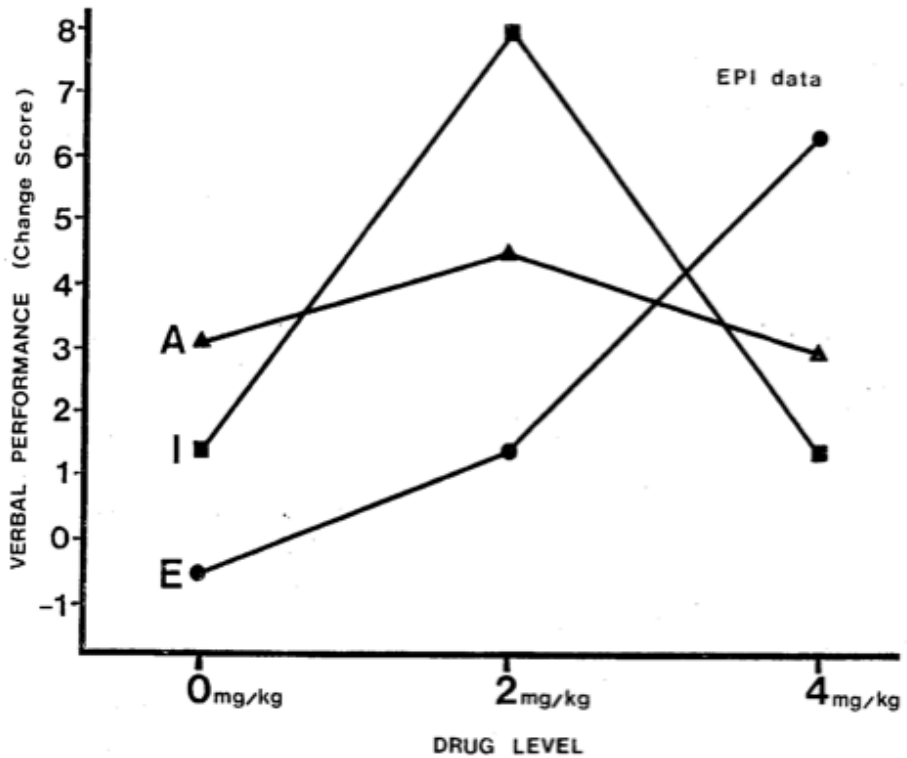
Figure 8. EPQ based group means for change in number of items correctly answered on GRE practice tests.

26

Replicability is the hallmark of science

But when rescoring using the old EPI data, the results did replicate!

Extraversion, Caffeine, and Cognitive Performance



Gilliland, 1976

Figure 9. EPI based group means for change in number of items correctly answered on GRE practice tests.

Gilliland failure to replicate – further investigations

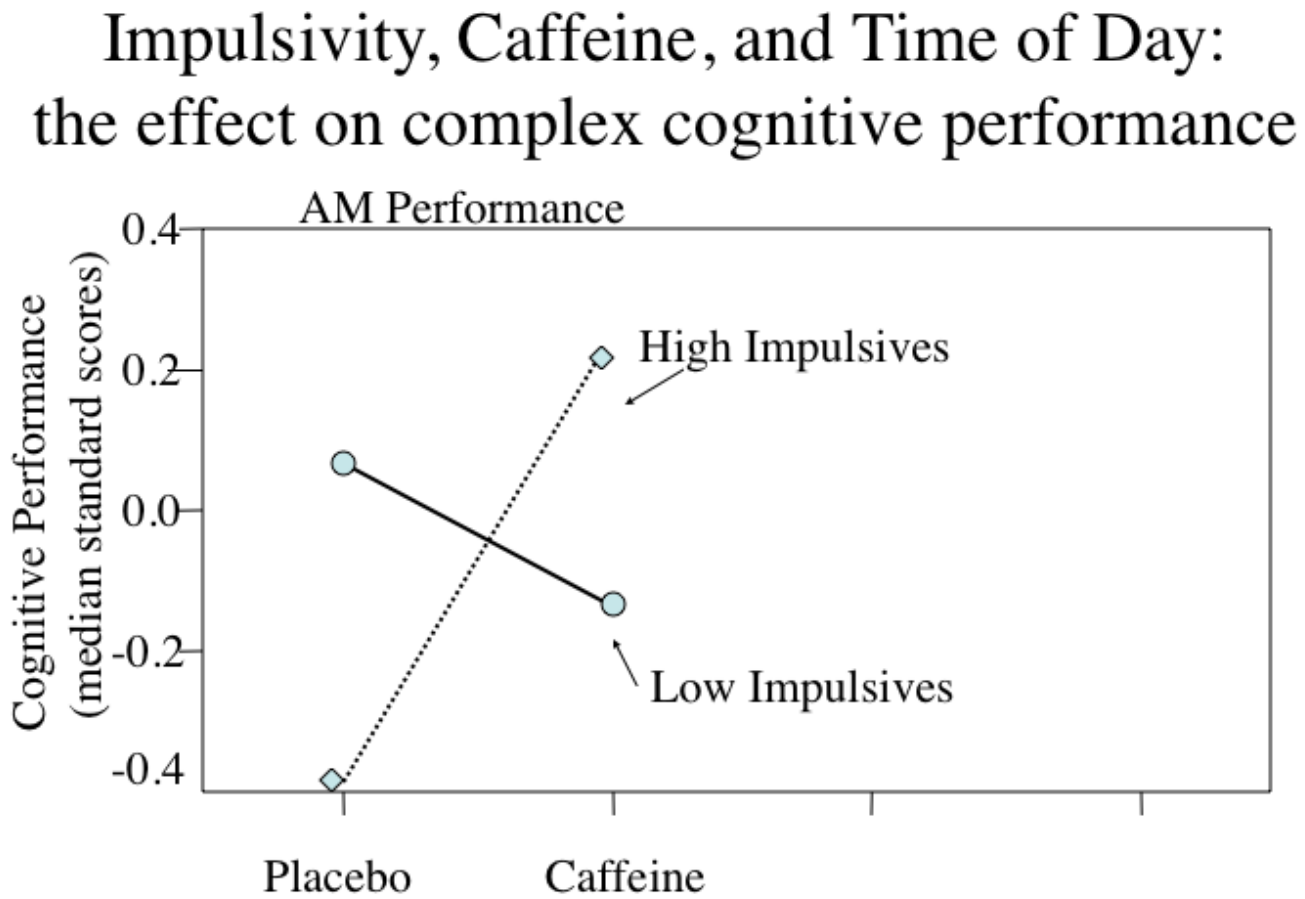
1. Complete failure to find original result
2. Post hoc reanalysis on partial set of subjects who had EPI showed the effect was there
3. Impulsivity, not Extraversion is critical variable
4. But is this data snooping, or a real effect?
5. Avoid HARKing! (Hypothesis After Results are Known)

Subsequent studies, many failures to replicate

1. Results were due to:
2. Adaptation to lab?
3. Theory predicts extraverts should be stimulated when arriving
4. Type of task
5. GREs, math, verbal analogies
6. Incentives of situation?

Replicability is the hallmark of science

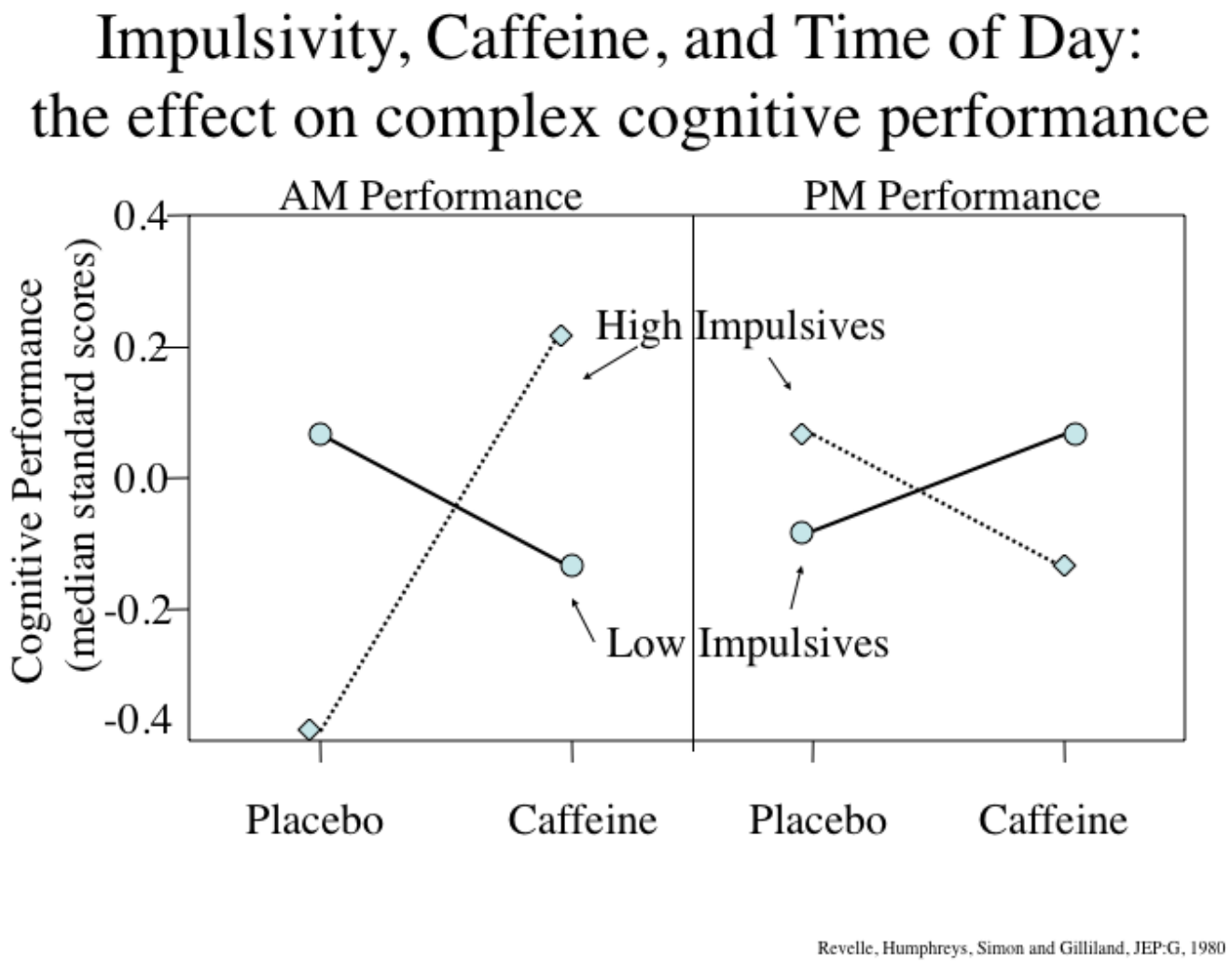
Every morning result showed one effect



Revelle, Humphreys, Simon and Gilliland, JEP:G, 1980

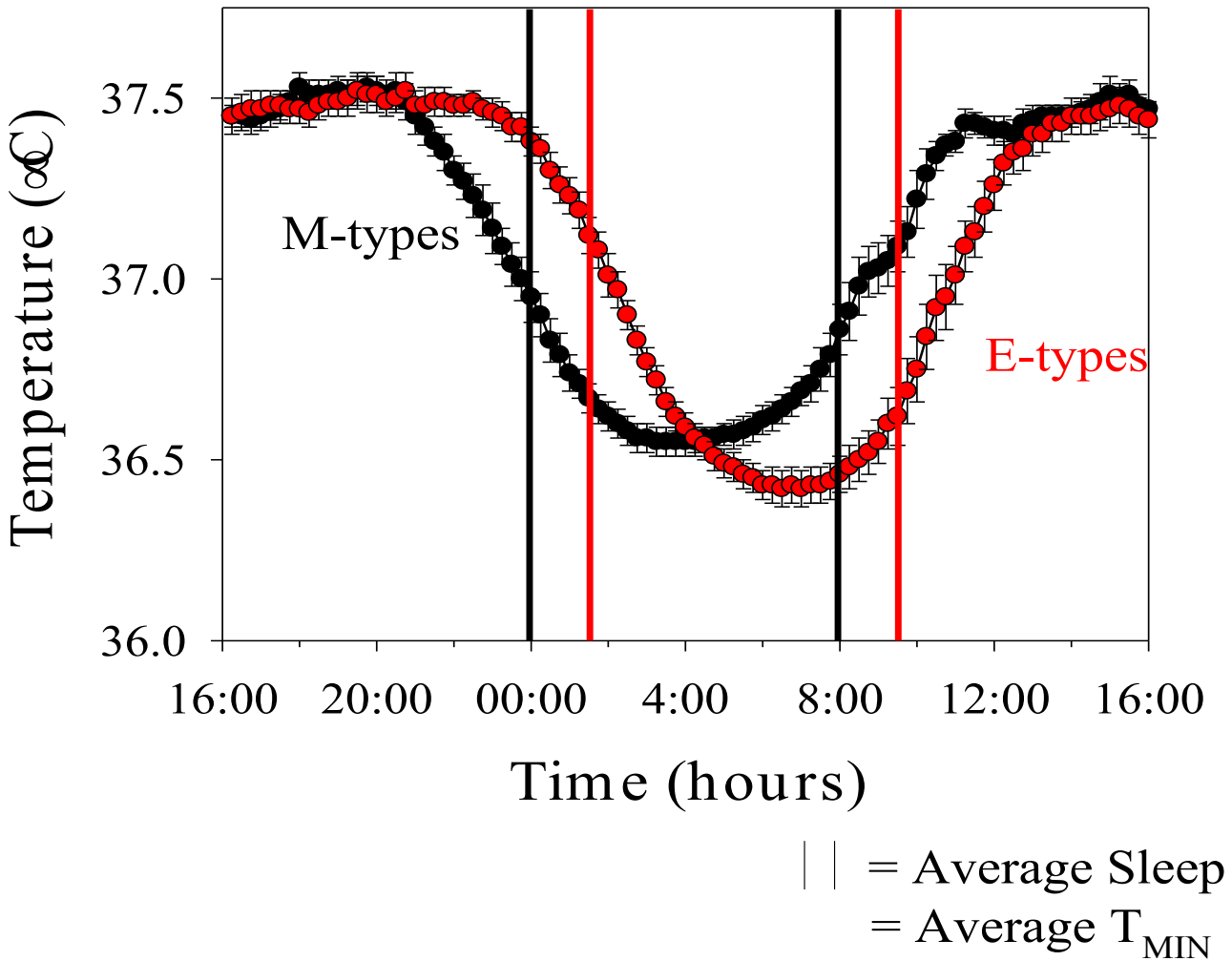
Replicability is the hallmark of science

Every evening study showed opposite effect



Revelle, Humphreys, Simon and Gilliland, JEP:G, 1980

Individual differences in diurnal rhythm of body temperature



Baehr, Revelle & Eastman (2000)

Integrating Personality, Motivation, and Cognition

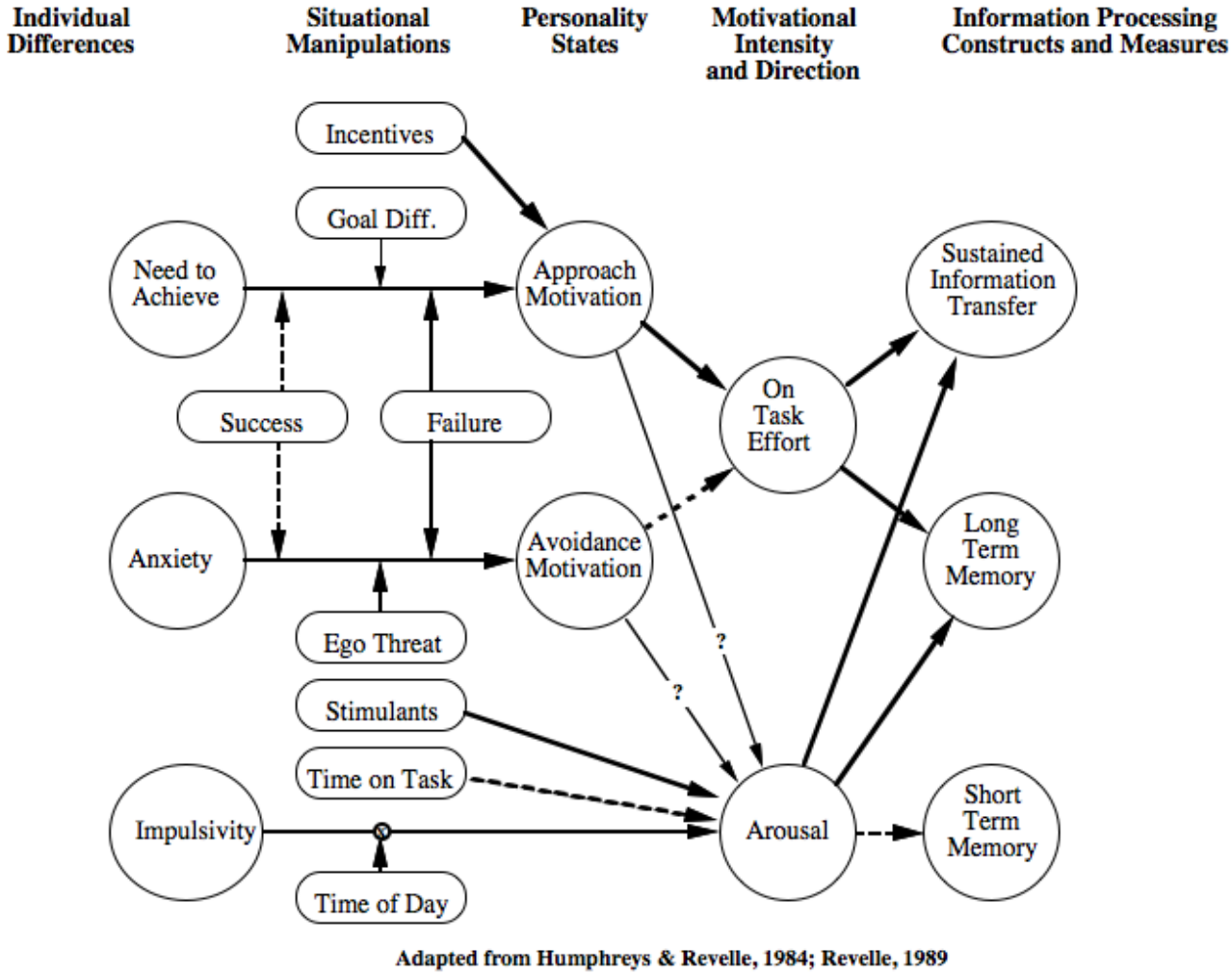
1. Working with Mike Humphreys (Humphreys & Revelle, 1984) and Kris Anderson (Revelle, Anderson & Humphreys, 1987; Revelle & Anderson, 1992), we developed a theoretical integration of our experimental work with the concepts of arousal and effort.
2. Based upon European work on arousal and cognitive processes Broadbent (1971) as well as motivational work on achievement motivation (Atkinson, 1957, 1964, 1974) and anxiety research Mandler & Sarason (1952); Wine (1971) we proposed:
   -
   - Arousal increases resource availability
   - Arousal facilitates attention processes
   - Arousal hinders short term memory processes
   - Anxiety and Achievement motivation affects the allocation of attention.

Personality and Cognition: a synthesis

1. Personality Traits x situational cues produce Motivational States
2. Motivational States (arousal and on task effort) affect cognitive processes:
   - Arousal facilitates Sustained Information Transfer (SIT)
   - On task effort facilitates SIT.
   - Arousal inhibits Working Memory
   - Inverted U between arousal and performance is the result of these two processes

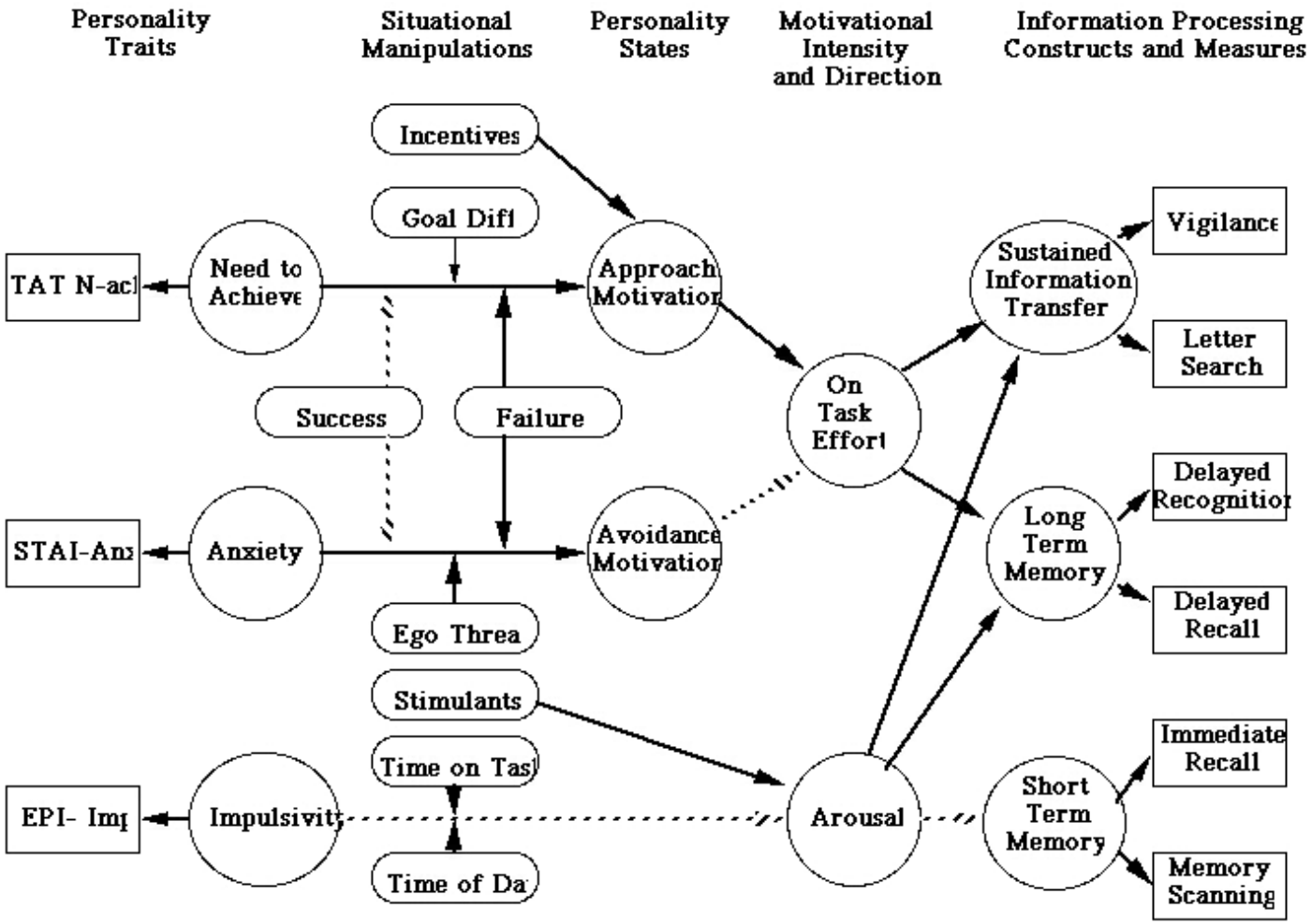
Humphreys & Revelle (1984); Revelle (1989, 1993)

Personality, Arousal and Cognition: Construct Level



Humphreys & Revelle (1984); Revelle (1989, 1993)

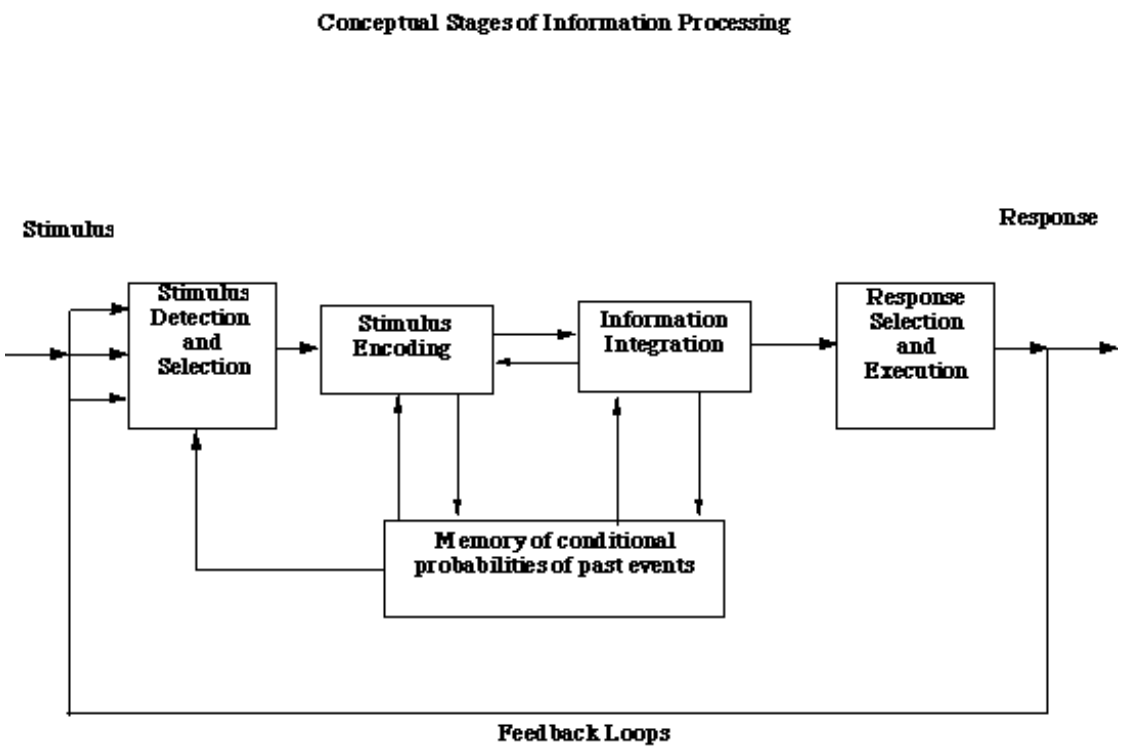
Personality, Arousal and Cognition: Measures and constructs



Humphreys & Revelle (1984); Revelle (1989, 1993)

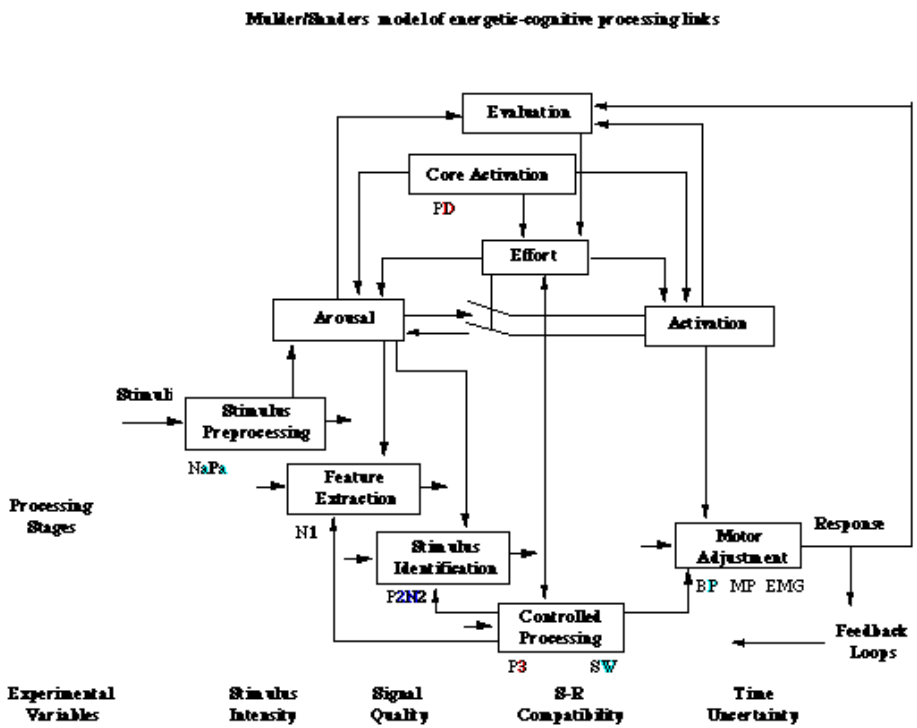
Cognitive processing – stages of processing

Simple Box diagram of the flow of information processing

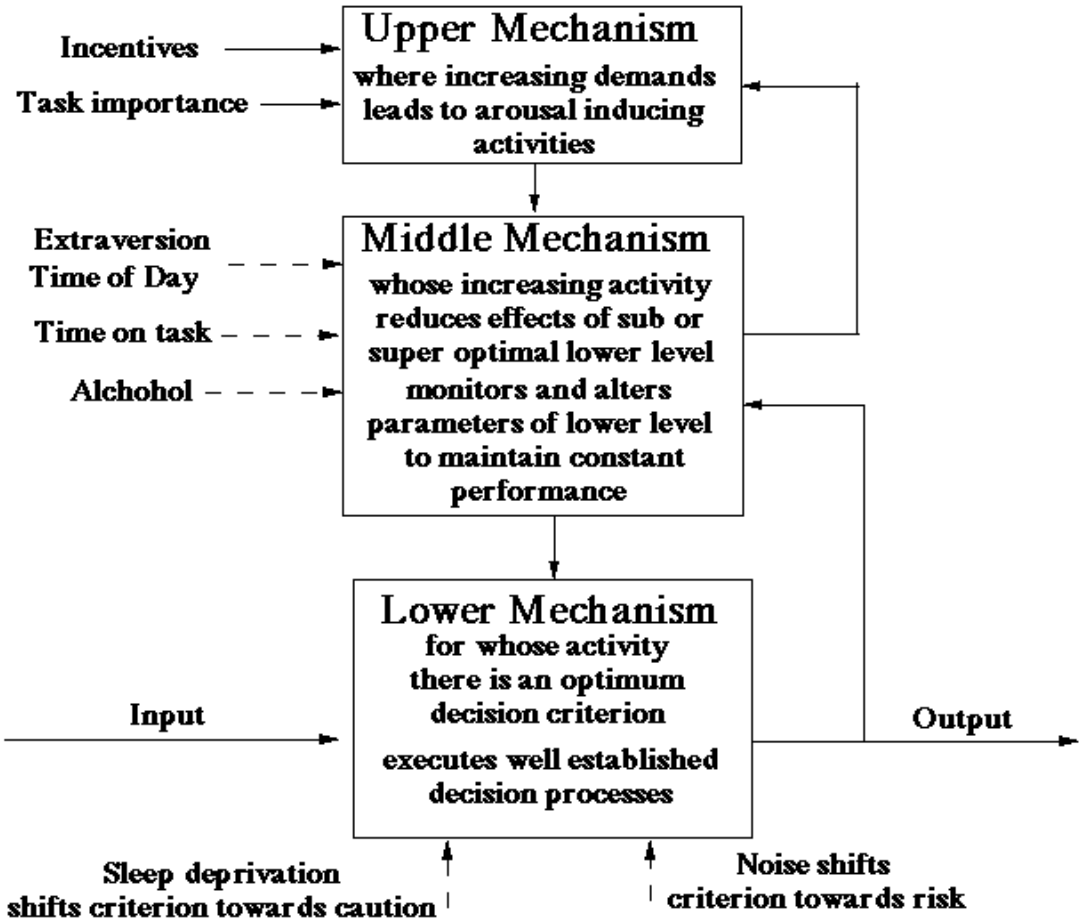


Cognitive processing – physiology of stages

(Revelle, 1993) Adapted from Sanders (1986)



Cognitive processing –levels of processing

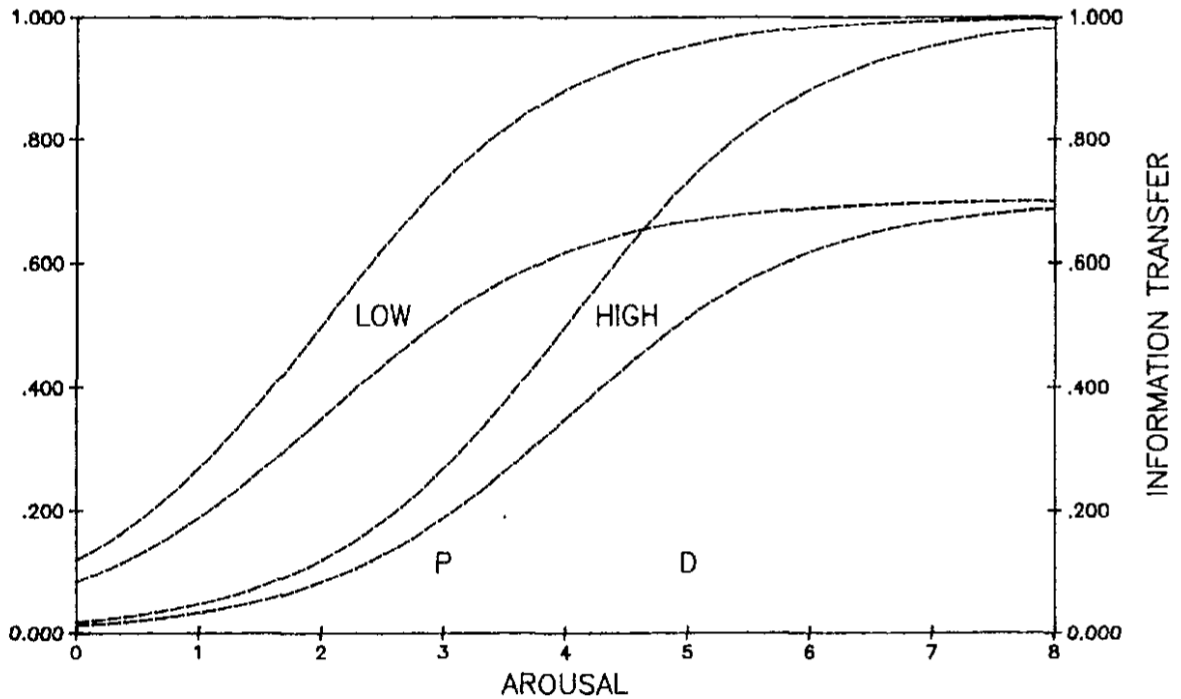


Revelle (1993) organization in terms of Levels of Processing from Broadbent (1971).

Personality affects each stage of processing

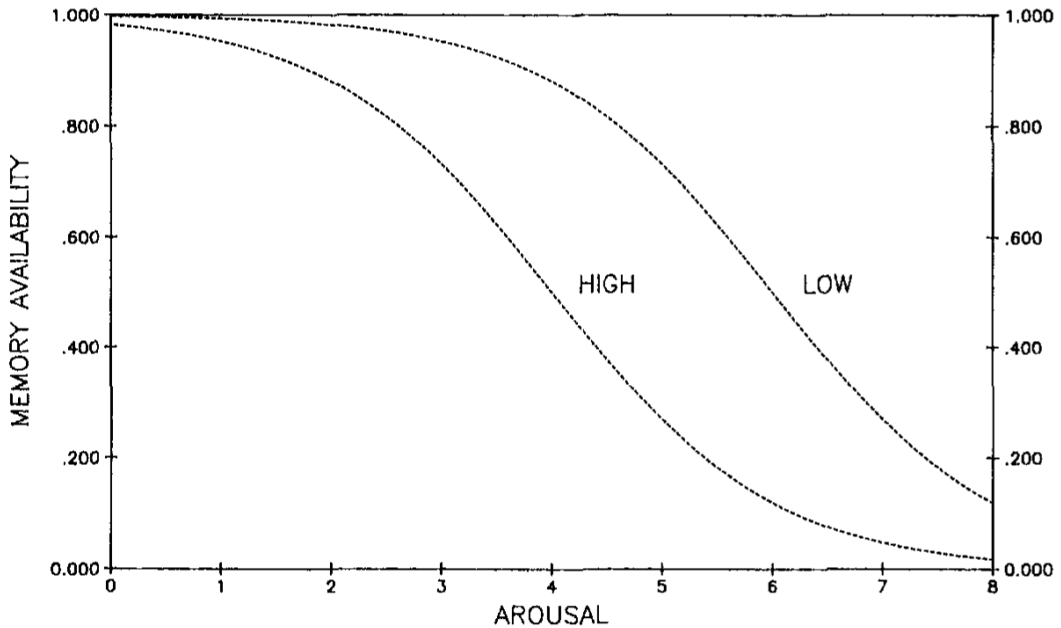
1. Introversion facilitates detection in vigilance tasks
2. Anxiety facilitates detection of threat terms
3. Depression facilitates memory for negative events
4. Intelligence facilitates processing speed

Presumed effect of effort and arousal on Information Transfer



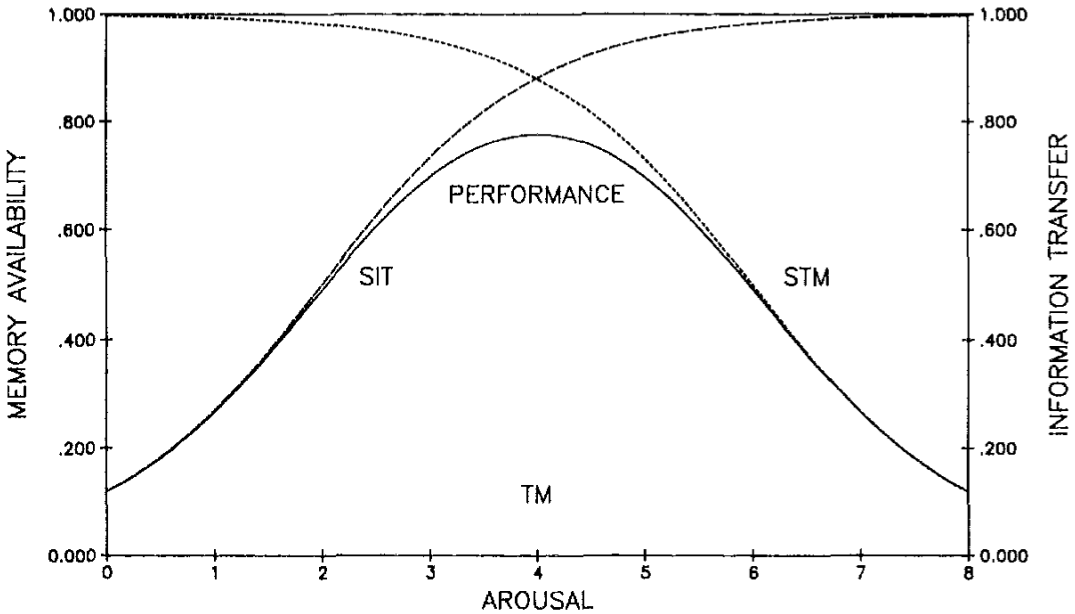
Attention (information transfer) increases with arousal, effort, and skill/training. Placebo and Drug differ in their arousal levels. (Humphreys & Revelle, 1984)

Presumed effect of arousal on Short Term Memory



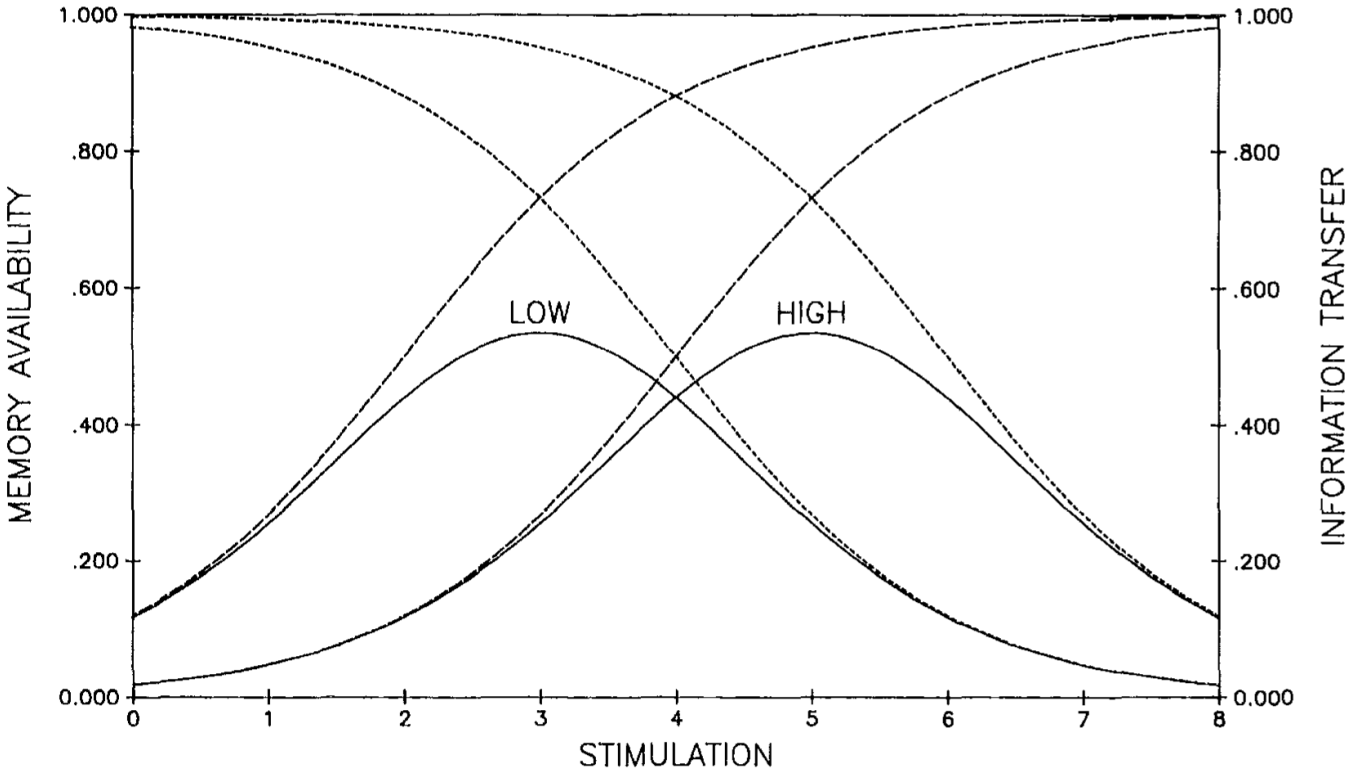
Short Term memory is hindered by increases in arousal. (Humphreys & Revelle, 1984)

Complex performance as f(arousal, STM, SIT)



Complex performance requires attention (SIT) and working memory (STM). The combination of two monotonic processes produces an inverted U. (Humphreys & Revelle, 1984)

Complex performance as f(impulsivity, arousal, STM, SIT)



Complex performance for high and low impulsive subjects (in the morning) reflects arousal differences and the combination of attention and memory demands. (Humphreys & Revelle, 1984)

Our experiment

1. In a sense, the simulation is a theory of the relationship between these four sets of variables
   - person characteristics,
   - situational characteristics,
   - intervening motivational states,
   - and cognitive performance.
2. The parameters of the model have been set to reflect empirical estimates of the strength of various relationships.
3. Several nuisance variables have been added to more properly simulate the problems of experimental design.

Simulation as theory testing

1. This simulation of the theory may be used as a test of the theory as well as a tool for understanding the complexity of research.
2. That is, although one may want to study the full model, because of the limitations of one's time and energy, one may study only a limited aspect of the model.
3. The student's objective is two fold: to better understand a limited aspect of a particular psychological theory, and to try to understand what are the relationships that have been specified in the model.

Simulation experiment is web based

1. The simulation is a web based program that allows you to "collect" the data on the web and then save the resulting output file to your computer to do subsequent analyses.
2. The biggest question is what should you study.
3. To answer this, you need to consider the variables available.
4. The underlying model is a function of the IVs and SVs.
5. Your job is to try to estimate the underlying model.
6. The model is psychologically plausible and is based upon prior results.

IVs, SVs, and DVs

Independent variables that are under control of the experimenter may be categorized as experimental variables and subject variables.

Experimental variables (IVs) may be manipulated by the experimenter.

Subject variables (SVs) are characteristics of the subjects that may be measured but not manipulated.

Dependent variables (DVs) are those variables thought be caused by the IVs and SVs. They are causally downstream from IVs and SVs.

IVs, SVs in this study

1. Independent Variables
   - **Drug** Placebo or Caffeine (you need to specify how much and how administered).
   - **Time of Day** Subjects may be run between 8 am and 10 pm (22:00 hours)
2. Subject Variables
   - **Sex** Males (1) or Females (2)
   - **Anxiety** Traits are stable characteristics of subjects. Trait anxiety is the tendency to feel tense and nervous in many situations. You need to specify how you measure them.
   - **Impulsivity** Trait impulsivity is the general tendency to do and say things rapidly, without stopping to think.
   - **Subject Number** One subject is run per day, so as S# increases, the subjects are later in the quarter.

Dependent variables (DVs) in this study

1. Motivational state variables

   Energetic arousal Feelings of energy and alertness versus sleepiness and tiredness. How are you measuring it?

   Tense arousal Feelings of tension and frustration versus calmness and relaxation.

2. Cognitive performance may be organized in terms of the total complexity of the task and the specific combination of memory load and of attention. Some complex tasks show an inverted U shaped relationship with arousal, others show a positive monotonic relationship, others a negative monotonic relationship. (Humphreys & Revelle, 1984)

3. Cost It is more expensive to select subjects at the extreme of the distributions of anxiety and impulsivity because this requires mass testing and then rejecting many subjects to get the special subjects.

Selecting variables

1. The values of the Independent and Subject variables may be specified by the experimenter for each subject, or may be allowed to vary randomly.
2. If allowed to vary randomly, the experimental variables will be assigned values in a uniform random distribution.
3. The subject variables may either be specified (this simulates choosing particular subjects based upon a pretest) or may be allowed to vary randomly.
4. If varying, they will be assigned values based upon samples from a normal distribution.
5. If subjects are selected for particular values on a personality dimension, this is the same as rejecting many potential subjects and thus the Cost of running grows more rapidly than the simple number of subjects who participate.

Anderson, K. J. (1990). Arousal and the inverted-U hypothesis: A critique of Neiss's "reconceptualizing arousal". *Psychological Bulletin*, *107*(1), 96–100.

Anderson, K. J. (1994). Impulsivity, caffeine, and task difficulty: A within-subjects test of the Yerkes-Dodson law. *Personality and Individual Differences*, *16*(6), 813–829.

Anderson, K. J. & Revelle, W. (1994). Impulsivity and time of day: Is rate of change in arousal a function of impulsivity? *Journal of Personality and Social Psychology*, *67*(2), 334–344.

Atkinson, J. W. (1957). Motivational determinants of risk-taking behavior. *Psychological Review*, *64*, 359–372.

Atkinson, J. W. (1964). *An introduction to motivation.* Van Nostrand.

Atkinson, J. W. (1974). Strength of motivation and efficiency of performance. In J. W. Atkinson & J. O. Raynor (Eds.), *Motivation and Achievement* (pp. 117–142). New York: Winston (Halsted Press/Wiley).

Baehr, E. K., Revelle, W., & Eastman, C. I. (2000). Individual differences in the phase and amplitude of the human circadian temperature rhythm: with an emphasis on morningness-eveningness. *Journal of Sleep Research*, *9*(2), 117–127.

Broadbent, D. (1971). *Decision and stress*. London: Academic Press.

Broadhurst, P. L. (1957). Emotionality and the Yerkes-Dodson Law. *Journal of Experimental Psychology*, *54*, 345–352.

Broadhurst, P. L. (1959). The interaction of task difficulty and motivation: The yerkes-dodson law revived. *Acta Psychologica*, *16*, 321–338.

Duffy, E. . (1962). *Activation and behavior.* Oxford, England: Wiley.

Duffy, E. (1951). The concept of energy mobilization. *Psychological Review*, *58*(1), 30–40.

Eysenck, H. J. (1967). *The biological basis of personality*. Springfield: Thomas.

Eysenck, H. J. & Eysenck, S. B. G. (1964). *Eysenck Personality Inventory*. San Diego, California: Educational and Industrial Testing Service.

Eysenck, H. J. & Eysenck, S. B. G. (1975). *Manual of the Eysenck Personality Questionnaire (Junior and Adult)*. Kent, UK: Hodder & Stoughton.

Friedman, H. S., Tucker, J. S., Schwartz, J. E., Tomlinson-Keasey, C., Martin, L. R., Wingard, D. L., & Criqui, M. H. (1995). Psychosocial and behavioral predictors of longevity: The aging and death of the "termites". *American Psychologist*, *50*(2), 69 – 78.

Gilliland, K. (1976). *The Interactive Effect of Introversion-extroversion with Caffeine Induced Arousal on Verbal Performance*. PhD thesis, Northwestern University.

Gilliland, K. (1980). The interactive effect of introversion-extraversion with caffeine induced arousal on verbal performance. *Journal of Research in Personality*, *14*(4), 482 – 492.

Hebb, D. O. (1955). Drives and the c. n. s. (conceptual nervous system). *Psychological Review*, *62*(4), 243 – 254.

Humphreys, M. S. & Revelle, W. (1984). Personality, motivation, and performance: A theory of the relationship between individual differences and information processing. *Psychological Review*, *91*(2), 153–184.

MacLeod, C. & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *The Quarterly journal of experimental psychology*, *40*(4), 653–670.

MacLeod, C. & Mathews, A. (2012). Cognitive bias modification approaches to anxiety. *Annual review of clinical psychology*, *8*, 189–217.

Malmo, R. B. (1959). Activation: A neuropsychological dimension. *Psychological review*, *66*(6), 367–386.

Mandler, G. & Sarason, S. (1952). A study of anxiety and learning. *Journal of Abnormal and Social Psychology*, *47*, 166–173.

Revelle, W. (1973). *Introversion/extraversion, skin conductance and performance under stress*. PhD thesis, University of Michgan, Ann Arbor, Michigan.

Revelle, W. (1989). Personality, motivation, and cognitive performance. In P. R. Ackerman & R. Cudeck (Eds.), *Learning and Individual Differences: Abilities, Motivation, and Methodology.* (pp. 297–341). Erlbaum.

Revelle, W. (1993). Individual differences in personality and motivation: 'non-cognitive' determinants of cognitive performance. In A. Baddeley & L. Weiskrantz (Eds.), *Attention: Selection, awareness, and control: A tribute to Donald Broadbent* (pp. 346–373). New York, NY: Clarendon Press/Oxford University Press.

Revelle, W. (2016). Hans Eysenck: Personality theorist. *Personality and Individual Differences*, *103*, 32 – 39. Hans Eysenck: One Hundred Years of Psychology.

Revelle, W., Amaral, P., & Turriff, S. (1976). Introversion-extraversion, time stress, and caffeine: effect on verbal performance. *Science*, *192*, 149–150.

Revelle, W. & Anderson, K. J. (1992). Models for the testing of theory. In A. Gale & M. Eysenck (Eds.), *Handbook of Individual Differences: Biological Perspectives* chapter 4, (pp. 81–113). Chichester, England: John Wiley and Sons.

Revelle, W., Anderson, K. J., & Humphreys, M. S. (1987). Empirical tests and theoretical extensions of arousal-based theories of personality. In J. Strelau & H. Eysenck (Eds.), *Personality Dimensions and Arousal* (pp. 17–36). New York: Plenum.

Revelle, W., Humphreys, M. S., Simon, L., & Gilliland, K. (1980). Interactive effect of personality, time of day, and caffeine: A test

of the arousal model. *Journal of Experimental Psychology General*, *109*(1), 1–31.

Sanders, A. F. (1986). Energetical states underlying task performance. In G. Hockey, A. Gaillard, & G. H. Coles (Eds.), *Energetics and human information processing* (pp. 139–154). Dordrecht: Matinus Nijhoff.

Schmidt, F. L. & Hunter, J. (2004). General mental ability in the world of work: occupational attainment and job performance. *Journal of personality and social psychology*, *86*(1), 162.

Thayer, R. E. (1970). Activation states as assessed by verbal report and four psychophysiological variables. *Psychophysiology*, *7*(1), 86–94.

Thayer, R. E. (1978). Toward a psychological theory of multidimensional activation (arousal). *Motivation and Emotion*, *2*(1), 1–34.

Thayer, R. E. (2000). Mood. In A. E. Kazdin (Ed.), *Encyclopedia of psychology*, volume 5 (pp. 294–295). Washington, DC ; New

York, NY: American Psychological Association; Oxford University Press 508 pp.

Wine, J. (1971). Test anxiety and direction of attention. *Psychological Bulletin*, *76*(2), 92–104.

Yerkes, R. & Dodson, J. (1908). The relation of strength of stimuli to rapidity of habit-information. *Journal of Comparative Neurology and Psychology*, *18*, 459–482.

Zajonc, R. B. (1965). Social facilitation. *Science*, *149*(3681), 269–274.