6 decades of dabbling in intelligence

LIfetime career award from International Society for Intellligence Research Evanston, Illinois

William Revelle
Northwestern University
Evanston, Illinois USA

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Slides available at https:personality-project.org/sapa

Outline

Introduction
- I am a personality psychologist who studies intelligence
- Research at the Personality, Motivation and Cognition lab

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- Theory development and tests

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- Astronomy as an analogy
- Psychometrics of SAPA

The International Cognitive Ability Resource
- The development of ICAR
- Extensions and applications of ICAR

Development of the *psych* package

Conclusion

The secrets of a lifetime career award

1. Good luck
2. Great mentors
3. Great colleagues
4. Great students
5. Live long enough
6. Good luck

I am a personality psychologist who studies intelligence

1. I have long said that personality is the last refuge of the generalist in psychology.
2. What does that mean?
   - It means that I study the interplay of Affect, Behavior, Cognition and Desire (the ABCDs)
   - That is, how one feels, acts, thinks, and wants.
3. To me, how one thinks and what one knows are fascinating problems but we have known since Tolman and Honzik (1930) that knowing how to do something (competence) is not the same as doing it (performance).
4. It is this interplay between competence and performance that I will address today.
5. For I believe that by understanding "non-cognitive" aspects of personality we can understand the "cognitive" aspects better.

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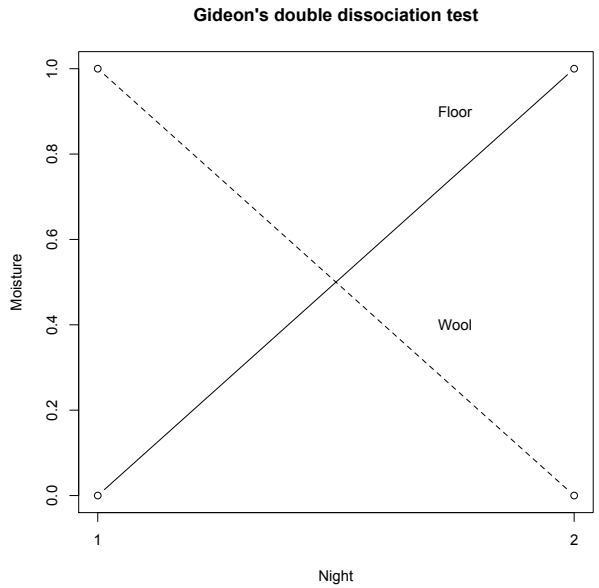
A missionary between two fields

1. I have frequently told my American colleagues in personality that they should include intelligence and cognitive ability in their studies.
2. I have also frequently said to members of this society that they should include personality variables in their studies.
3. I have long viewed personality as including cognitive and non-cognitive aspects of the same field.
4. To these two components, I have been reminded that we should also include interests as drivers of behavioral choice.
5. In Europe, this is the field of individual differences. We should strive to include them both in our studies of human and animal behavior.

I am not the first to address this problem

1. Perhaps the first experimentalist and serious observer of motivation and competence was Gideon. He conducted a within subject study (N=1, God) which showed the first published crossover interaction.
2. More relevant was his assessment of 32,000 volunteers to choose 300 warriors involved measuring desire, affect and knowledge. (McPherson, 1901).
3. This combination of cognitive and non-cognitive aspects of personality for selection was most useful.



Plato and the requirements for leadership

Several centuries later, leadership was said to require cognitive ability and an appropriate temperament.

> *" ... quick intelligence, memory, sagacity, cleverness, and similar qualities, do not often grow together, and ... persons who possess them and are at the same time high-spirited and magnanimous are not so constituted by nature as to live in an orderly and peaceful and settled manner; they are driven any way by their impulses, and all solid principle goes out of them. ... On the other hand, those stable and steadfast and, it seems, more trustworthy natures, which in a battle are impregnable to fear and immovable, are equally immovable when there is anything to be learned; they are always in a torpid state, and are apt to yawn and go to sleep over any intellectual toil."* Plato (nd)

Call for Ability-Personality Integration

2300 years later, in their call for a special issue of the *Journal of Intelligence*, Ziegler et al said:

> *Individual differences research focused in cognitive abilities and personality traits has been relatively successful in predicting human behavior. Very early on, interindividual difference researchers included a wide array of different constructs including personality traits and cognitive abilities. For example, Cattell (1987) proposed a theory of cognitive development which also integrated personality traits. Later, Ackerman (1996) and Ziegler, Danay, Heene, Asendorpf, and Bühner (2012) developed similarly integrative models. These models address the complex dynamic interplay between cognitive abilities and personality, which is particularly relevant from a developmental perspective.*

Ziegler et al, continued:

They went on:

> *However, despite these efforts, there is still little sustained theory and research aimed at integrating both psychological trait foci. In fact, it sometimes appears as if two only slightly overlapping traditions have developed, each using the constructs of the other tradition only as control variables. This is unfortunate because scientists acknowledge the high relevance of addressing the interactions between cognition and personality for enhancing our understanding of human behavior.*

Others have made similar claims

1. Ackerman and Heggestad (1997); Ackerman (1997, 2018); von Stumm et al. (2011) have all examined the personality-intelligence link.
2. For Germans and Austrians, the link is obvious (Brauer and Proyer, 2024) for the study of individual differences includes both temperamental and cognitive variables.
3. Ackerman (1996) reviewed the history of the study of adult intelligence continuing in the tradition of Cronbach and Snow (1981).
4. Other important work is summarized in Kanfer et al. (2014).
5. This is not new: Kelly and Fiske (1950, 1951) suggested that to predict graduate school performance one needed to asses ability, stability and interests. Students need to be able, stable and interested if they are going to succeed.
6. Matt McGue's talk today is a brilliant example of why we need to consider both.

I have addressed this challenge in a number of ways

1. Showing the interactive effect of arousal manipulations with the personality dimension of Introversion-Extraversion on cognitive performance on Graduate Record Exam like tests (Revelle et al., 1976).
2. Showing that the effects found in Revelle et al. (1976) are even more complicated than we thought, and interact with time of day (Revelle et al., 1980).
3. Trying to integrate these effects into one overall model of personality, motivation, and performance (Humphreys and Revelle, 1984).
4. Developing an open source test of ability (ICAR) so that I (and others) could include ability in any study of personality, interests, attitudes, etc. (Condon and Revelle, 2014).
5. Developing and supporting the *psych* package for R to facilitate my and my students studies.

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The PMC lab: Personality, Motivation and Cognition lab

1. All of the research I will discuss today was done with many very talented undergraduate and graduate students, some of whom continue to work with me, as well as colleagues at NU and around the world.
2. Broadly summarizing our research goals, we have labeled our lab as the *Personality, Motivation and Cognition* lab (PMC) although sometimes we also refer to it as the *Telemetrics* lab.
3. Without the collaboration and inspiration of these students and colleagues my research would have been much more boring.

Motivational effects on cognitive processing

1. After I graduated from Pomona and married Eleanor, we went to Sarawak, Malaysia where I taught 6th grade and Eleanor 1st and then 2nd grade in a small (very) upriver school.
2. Following the British System, entrance to secondary school required passing the Common Entrance Examination (set by educators in Cambridge).
3. While the national pass rate was 30%, the pass rate at Nanga Medamit was 0%,
4. My job was to teach enough English, Math, and Social Studies so that my students could get into secondary school.
5. The parents of the children had never been to school, some parents had been headhunters.
6. At the end of the first year, 7 of 18 passed, the second year led to 14 out of 20.
7. This led to my skepticism of cultural differences in ability in that with intense training we could move scores > 2.5 sigma.

Graduate school: measurement, development and motivation

1. In graduate school I was technically supervised by Don Brown but worked also with Warren Norman, Dick Nisbett, Jack Atkinson and Jim Kulik.
2. As long as I could program the data analysis for a developmental study on the effects of cluster colleges on student change (Newcomb et al., 1970, 1971), I was allowed to "follow my nose" - always the best advice for researchers.
3. This led to some psychometric work on cluster analysis with Jim Kulik (Kulik et al., 1970) as well as TAing for Jack Atkinson.
4. While in Peace Corps I had read (devored) books by Hans Eysenck (Eysenck, 1953, 1965, 1964) and then in graduate school tried to integrate his work with that of Atkinson (Atkinson, 1957, 1964, 1974).

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Motivation and the efficiency of performance

1. My dissertation was an ambitious (but unsucessful) attempt to show how combining experimental manipulations with personality could produce evidence for the Yerkes-Dodson "Law" (Yerkes and Dodson, 1908).
2. Most previous demonstrations had been dreadfully underpowered or designed so that most results could be interpreted as supportive.
3. Thus I designed a study to confirm the predictions from Eysenck that stress should interact with introversion-extraversion and lead to a lower peak level for introverts than for extraverts.
4. Following the findings of Zajonc (1965) I used group size (1 vs 2 vs 8 person groups) as social stressors. Other additive stressors were competition, monetary incentive and a loud noise. The results were non-supportive of my hypothesis.

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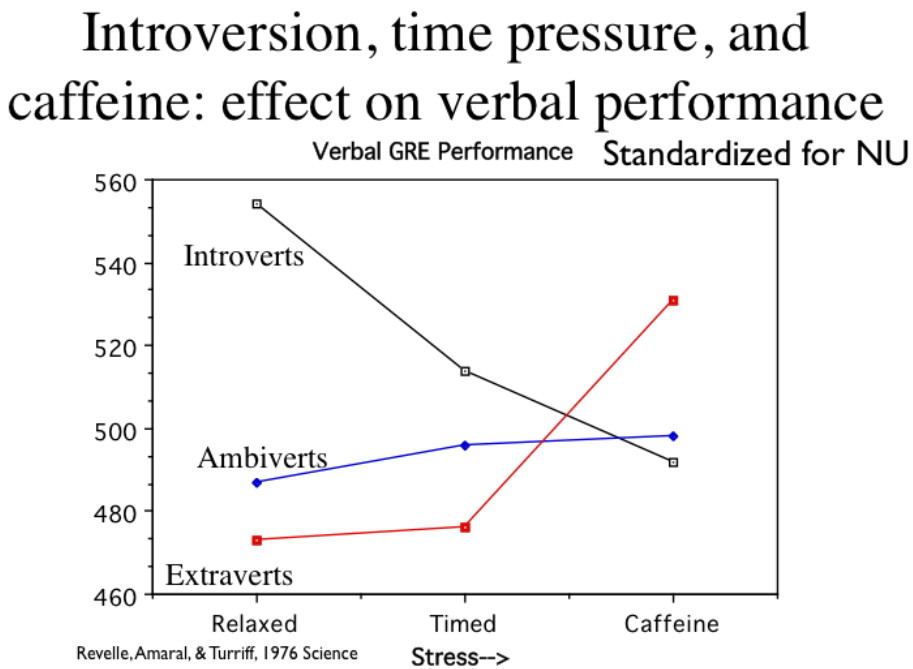
Caffeine as a stressor

1. When discussing my failed results with an advanced undergraduate class, two students suggested;
   - Using practice Graduate Record Exams (GRE) as the stimulus material.
   - Use time stress and caffeine as stressors.
2. Their results were very impressive. (Revelle et al., 1976).
3. I have always been thankful for the suggestions of Phyllis Amaral and Susan Turriff.



Stress reduced the performance of the introverted group by .6 σ while helping the extraverted group by .6 σ.

Failures to replicate explained

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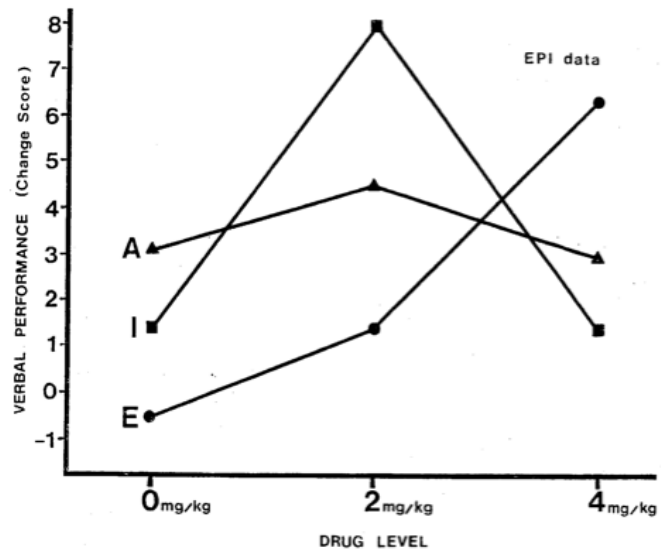
1. A graduate student, Kirby Gilliland, suggested that the prior study using 200 mg of caffeine should have been dosed by body weight (0, 2, or 4 mg/kg of caffeine). He also used the new and "improved" measure of Extraversion, the Eysenck Personality Questionnaire (Eysenck and Eysenck, 1975).
2. But the results did not replicate the Revelle et al. (1976) unless we use the older version, the Eysenck Personality Inventory (Eysenck and Eysenck, 1964)

Extraversion, Caffeine, and Cognitive Performan



Gilliland, 1976

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

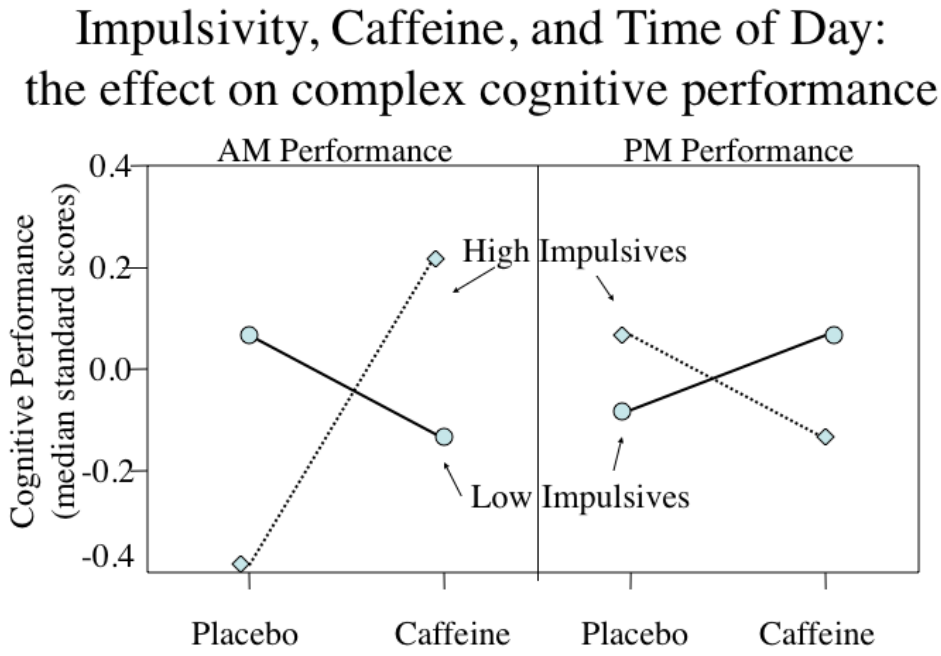
Subsequent replications and extension

With my cognitive colleague, Mike Humphreys, and some very determined graduate students, we finally solved the replicability problem (Revelle et al., 1980).

The crucial variable was impulsivity from the EPI, not the social extraversion as measured by the EPQ.

In addition the effects varied by time of day.

- Every study in the morning showed that low impulsives got worse but high impulsives better when given caffeine.
- This effect reversed in the evening where now the high impulsives got worse and the lower impulsives better with caffeine.



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

Theory development

1. Mike Humphreys and I tried to integrate our results with the theoretical contributions of Atkinson (1964, 1974), Eysenck (1983), and Gray (1970).
2. We wanted to explain how personality and motivational stress interacted to affect cognitive performance.
3. We also wanted to explain the Yerkes and Dodson (1908) "law".
4. We considered three personality traits, the need to achieve, anxiety, and impulsivity.
5. These traits then combined or interacted with situational stressors such as incentives, goal difficulty, ego threat, stimulant drugs, time on task and time of day to affect two motivational variables.
6. We interpreted motivation in terms of direction (on-task effort) and arousal.

Theory development (continued)

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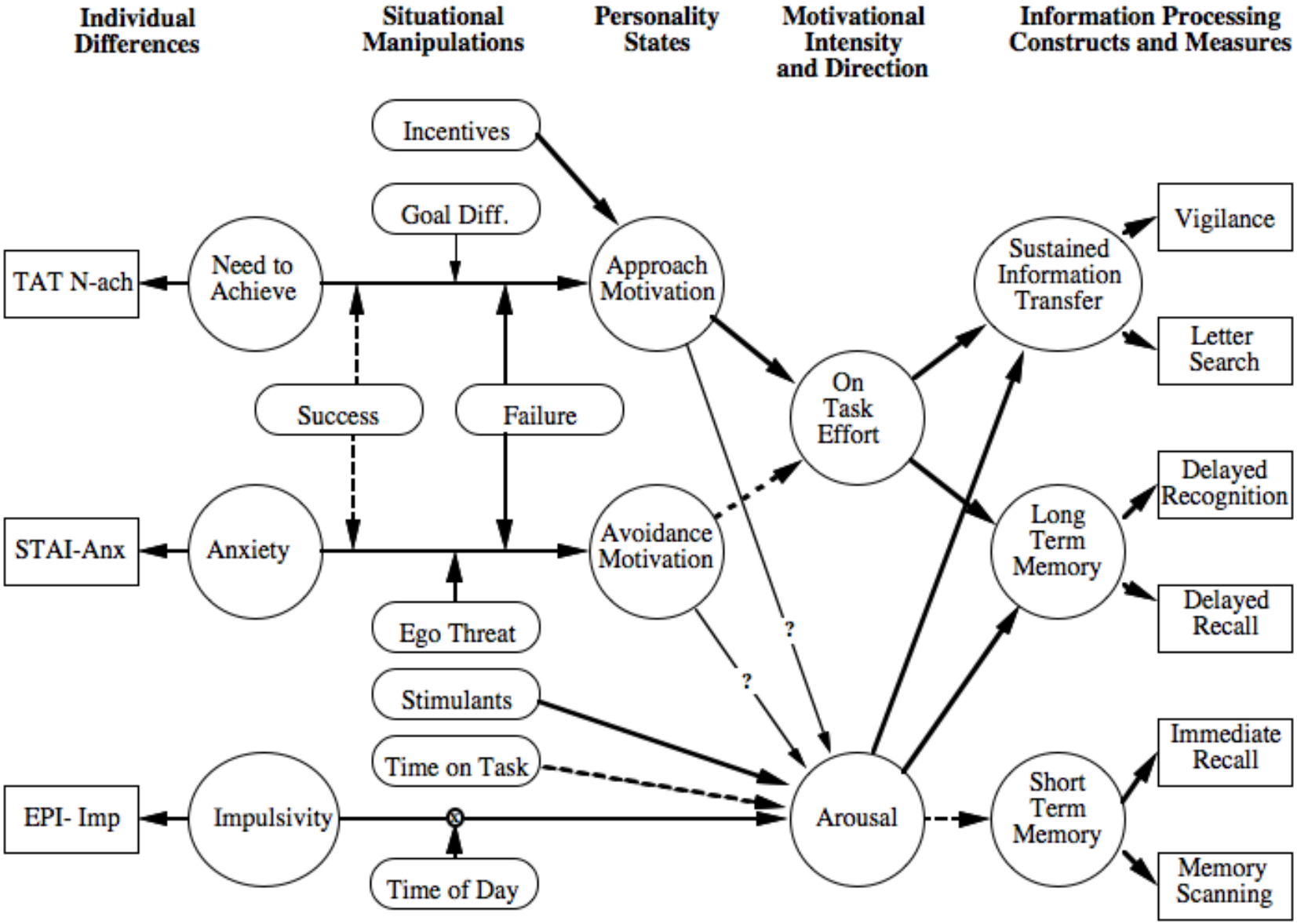
5. These traits then combined or interacted with situational stressors such as incentives, goal difficulty, ego threat, stimulant drugs, time on task and time of day to affect two motivational variables.
6. We interpreted motivation in terms of direction (on-task effort) and arousal.
7. These two components then effect "Sustained Information Transfer" (aka attention), Long term memory and Short term memory.
8. At the time we wrote this paper, we assumed the only people who would ever read it had already reviewed it (Humphreys and Revelle, 1984).

The Humphreys and Revelle (1984) model



Adapted from Humphreys & Revelle, 1984; Revelle, 1989

Yerkes Dodson as two opposing processes

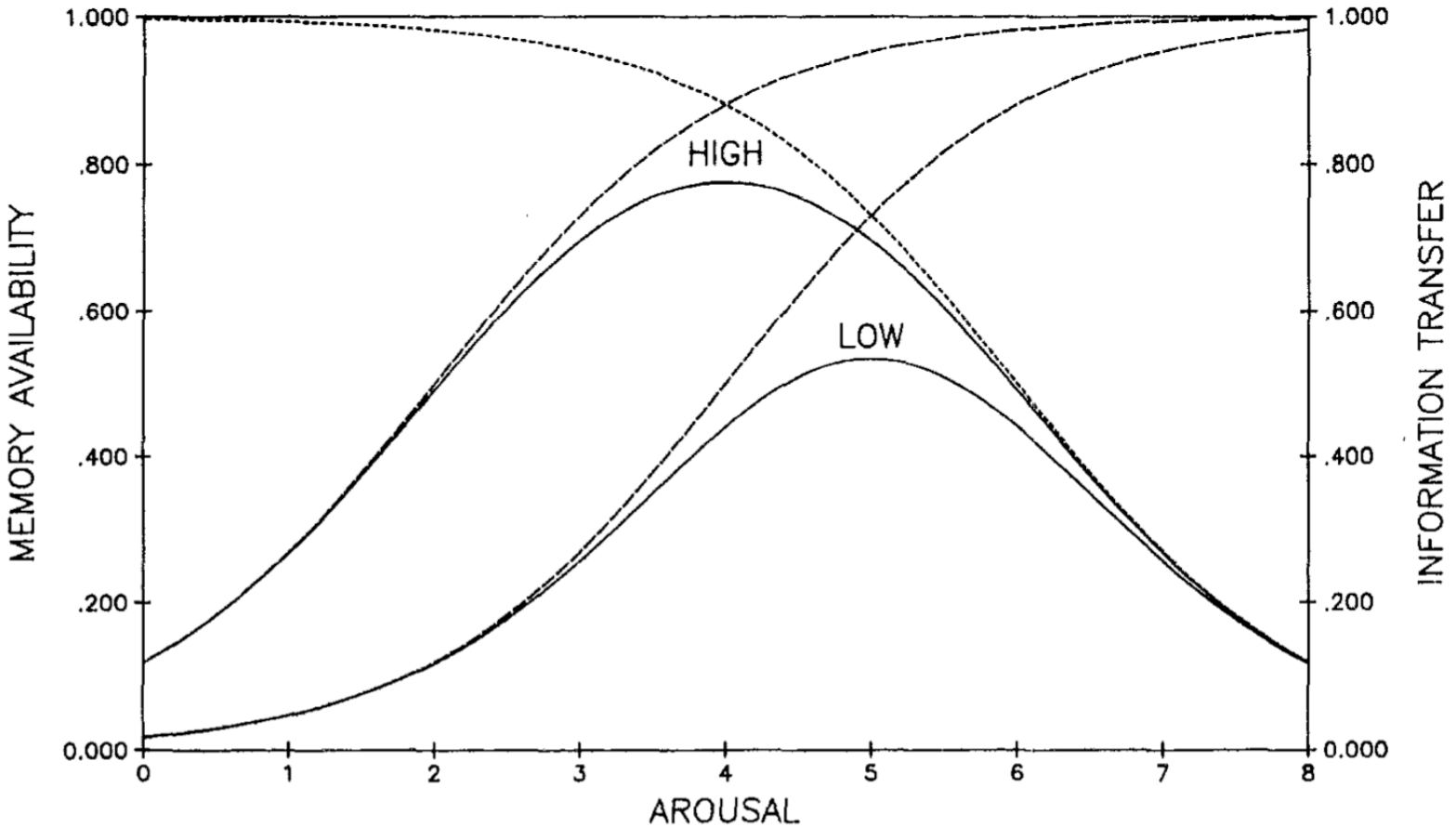


Figure 5. Curvilinearity derived from two opposing monotonic processes. (The effects of effort are to improve the information-transfer resource but not to affect the memory resource.)

Non-monotonicity as a sign of two processes

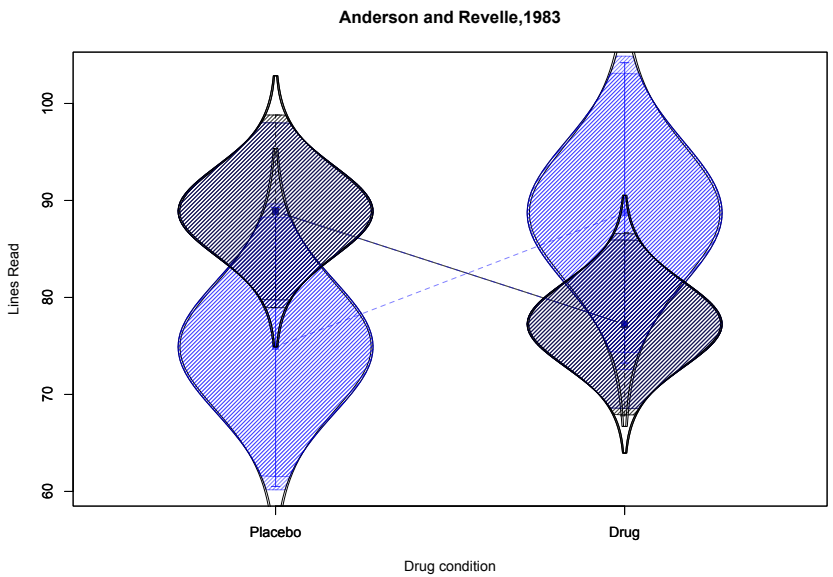
1. When discussing our results with Clyde Coombs he commented, that of course whenever you have a non-monotonic effect that represents the combination of two monotonic processes (Coombs and Avrunin, 1977).
2. The implication is to look for independent processes whenever faced with non-monotonicity,
3. Note that most phenomena are non-linear, but still monotonic.
   - This non-linearity but monotonicity can lead to many interactions that are mere effects of the scaling.
   - This is a particular problem with the study of ability for the problem of ceiling and floor effects has led to many false inferences.

Test of theories

1. With Kris Anderson, we tested theories of motivational affects on cognitive performance and examined performance on proof reading to test the Easterbrook hypothesis (Anderson and Revelle, 1982) and performance on a visual search task (Anderson and Revelle, 1983).
2. Kris and I also discussed the complexities of theory testing and the power of interactive designs in assessing personality-performance relationships (Revelle et al., 1987).
3. With Marjorie Leon we tested three theoretical models of why anxiety impedes cognitive performance (Leon and Revelle, 1985).
4. With Deb Loftus we reviewed and tested various explanations of the effect of arousal on short and long term memory Revelle and Loftus (1990, 1992).

Arousal and the Easterbrook hypothesis

1. With Kris Anderson, we tested theories of motivational affects on cognitive performance and examined performance on proof reading to test the Easterbrook hypothesis (Anderson and Revelle, 1982) and performance on a visual search task (Anderson and Revelle, 1983).
2. Kris and I also discussed the complexities of theory testing and the power of interactive designs in assessing personality-performance relationships (Revelle et al., 1987).



Tests of three theories of the effect of anxiety on cognitive processing

1. Does anxiety hurt performance by distracting attention (Wine, 1971)?
2. Or does anxiety hurt working memory (Eysenck, 1979)?
3. Marjorie Leon and I examined the effects of anxiety on visual analogies varying in memory load and total processing demands (Leon and Revelle, 1985)

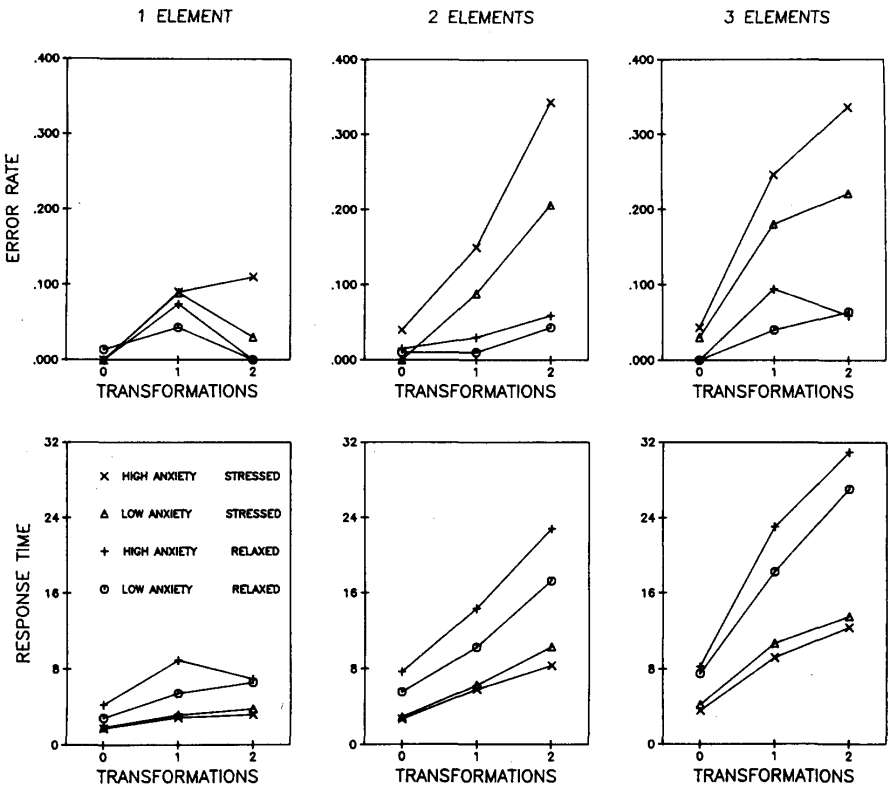
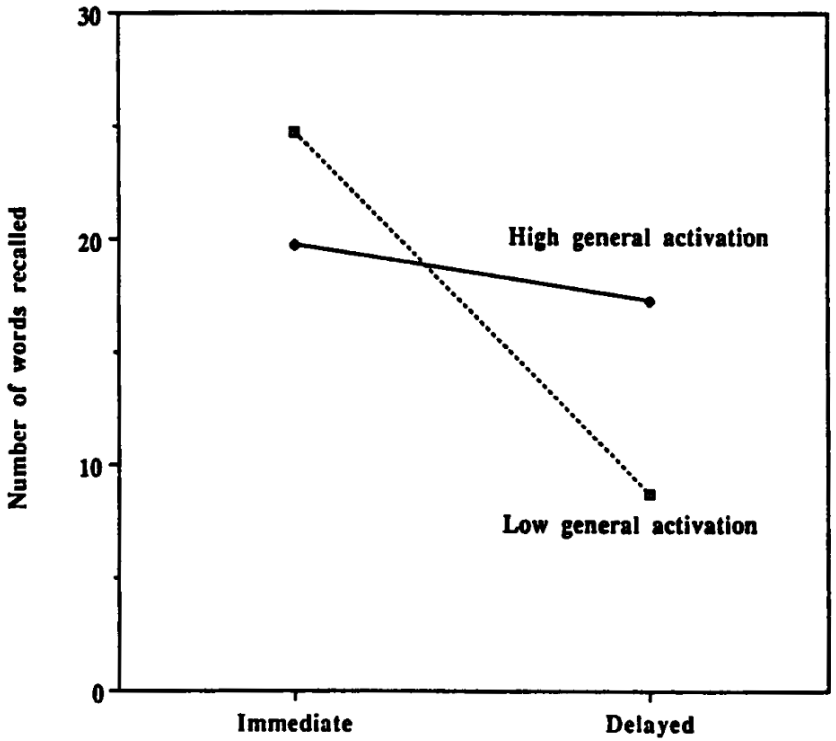


Figure 3. Error rates and response times for true analogies. (Error rates are calculated for all true analogies. Response times are calculated for true analogies that were solved correctly.)

The effect of exercise and arousal on memory

1. There are some strange results suggesting that arousal hurts immediate memory but facilitates long term memory (Geen, 1984)
2. Deb Loftus and I reviewed these non-intuitive findings (Revelle and Loftus, 1992) and then tested the effect with an exercise manipulation (Revelle and Loftus, 1990).



Exercise induced high activation did indeed hurt short term but help long term memory.

SAPA: the Synthetic Aperture Personality Assessment Project

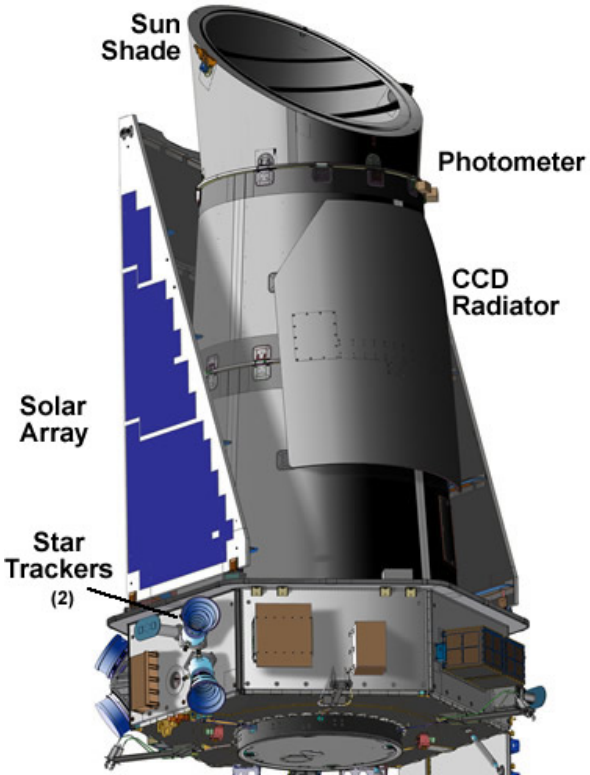
1. Over the past 20 years, we have been collecting data from the web using what we call the SAPA project.
2. Using a Massively Missing Completely at Random (MMCAR) design, we present 50-250 items sampled from $>$ 6400 items.
3. Items are sampled at different rates, some with a sampling frequency of 1%, some 25%-50%. demographic items are given to everybody.
4. Of the items given, a core set of 135 temperament items (the SAPA Personality Inventory or SPI, Condon, 2018) and 60 items from the International Cognitive Ability Resource (ICAR-60 Condon and Revelle, 2014) are oversampled.
5. The SPI items as well as many of the other items were originally taken from the International Personality Item Pool (IPIP Goldberg et al., 2006).

What is SAPA and how does it work: FAQ

1. Why is it called Synthetic Aperture Personality Assessment (SAPA)?
2. If items are missing 95% of the time, how can you possibly measure anything?

A now for something completely different: astronomy

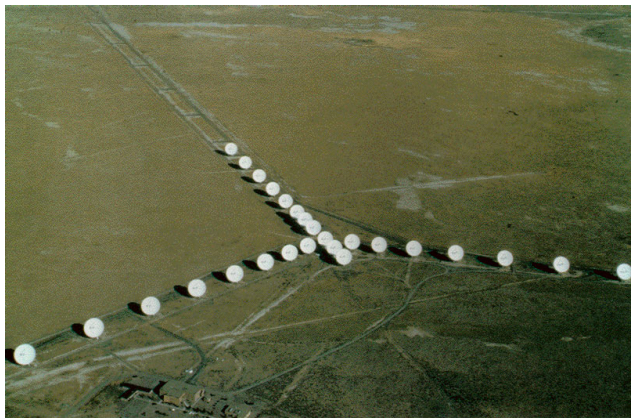
Resolution varies by aperture diameter (bigger is better)

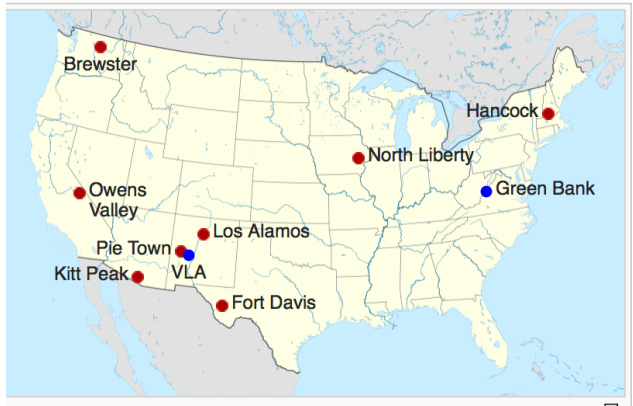


A short diversion: history of radio telescopes

Just as with optical telescopes, resolution varies by aperture diameter (bigger is still better)

Aperture can be *synthetically* increased across multiple telescopes or even multiple observatories





Can we increase N (subjects) and n (items) at the same time?

1. Frederic Lord (1955) introduced the concept of sampling people as well as items.
2. Apply basic sampling theory to include not just people (well known) but also to sample items within a domain (less well known).
3. Basic principle of Item Response Theory and tailored tests.
4. Used by Educational Testing Service (ETS) to pilot items.
5. Used by Programme for International Student Assessment (PISA) in incomplete block design (Anderson et al., 2007).
6. Can we use this procedure for the study of individual differences without being a large company?
7. Yes, apply the techniques of radio astronomy to combine measures synthetically and take advantage of the web.
8. My colleagues and I have discussed this technique for several years as a way of embracing your missingness (Revelle et al., 2010, 2017).

The basic problem: Fidelity versus bandwidth

1. Many personality traits, interests and cognitive abilities are multidimensional and have complex structure.
   - To measure these, we need to have the precision that comes with many participants.
   - But we also need the bandwidth that comes with many items.
   - But participants are reluctant to answer very many items.
2. This has led to the quandary of should you give many people a few items or a few people, many items?
3. Our answer is to do both, but with a *Massively Missing Completely At Random* (MMCAR) data structure.
4. We refer to this technique as *Synthetic Aperture Personality Assessment* (SAPA) to recognize the analogy to synthetic aperture radio astronomy (Revelle et al., 2010, 2017).
5. This is functionally what Frederic Lord (1955, 1977) suggested 65 years ago. It is time to take him seriously.

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SAPA overview

1. At the sapa-project.org we use Synthetic Aperture Personality Assessment (SAPA) methods to assess $\approx 30 - 100K$ participants per month. This is just a technique of Massively Missing Completely at Random (MMCAR) data presentation. Each participant is given a random subset of items chosen from an item pool of more than 6600 items. These items, extended from the International Personality Item Pool (Goldberg, 1999) and the International Cognitive Ability Resource (Condon and Revelle, 2014; Revelle et al., 2020), assess temperament, cognitive ability, interests and attitudes as well as self reported behaviors and demographic information.
2. Conventional psychometric techniques (both classical and IRT) are used to identify homogeneous scales; empirical item selection procedures are use to develop optimal item composites to predict a wide range of criteria. Data analysis code is done using the *psych* package (Revelle, 2025) in R (R Core Team,

Lord (1955) and matrix sampling

1. Given an N (subjects) by n (item) matrix, we can sample:
2. Type 1: Subjects – basic statistical theory
   - $\bar{x}$ and its standard error $\sqrt{\frac{\sigma^2}{N-1}}$
   - r_{xy} and its standard error $\sqrt{\frac{1-r^2}{N-2}}$
3. Type 2: Items – this is the basis of classical reliability theory especially domain sampling (Tryon, 1957, 1959):
   - $KR_{20} = \alpha = \lambda_3$ represent the correlation of a test with a test just like it sampled from a larger population of items.
   - ω_h and ω_t similarly are estimates of what the general factor, ω_h, or total, ω_t, correlation would be with another representation in the domain. (See Revelle and Condon, 2019, for everything you want to know about reliability but were afraid to ask).
4. Type 12: Matrix sampling of subjects and items
   - Special case is balanced incomplete blocks (BIB).
   - General case is Missing Completely at Random (MCAR).

3 Methods of collecting 256 subject * items data

1) 8 x 32 complete

```
46213634521143453443645331212414
21243623166421516154432261516513
51661351155165463622224435623344
11141343362332215612152135614522
25353121264561433433232246526411
61335154566424114612641225353516
24634342151536242425413513435116
11554654453123111162423325516334

Type 1 = sample subjects

Type 2 = sample items

Type 12 sample items and subjects
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2) 32 x 8 complete

```
46323114
25443314
43315423
26314145
41435614
42236153
62421344
35234443
34514166
63415154
44441342
13514321
66365663
12264546
31466135
32645514
66151251
14411441
62443636
33316236
63325425
11531126
61155546
33245361
52241654
63212356
24414663
63661414
45555223
14364433
```

12) 32 x 32 MCAR p=.25

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..3..2..6.....4.55.......44.....
..........4..6..45..3.4..6....1
6..3.......6.1.....6.2.......5.6
....3522......5.3...3......5....
....3.2.2.......3..2......65..5.
.....51....324.........23......5
....552............25...54.5....
...44.4.5....3..6...6........3..
....61.523.2....2...........3...
5............42.4..6.5......61.
....3....3.6..1.4...1..5......5.
1....54..........2.4.33..6......
4.....52..6.....44.3...........2
..44...1........1..42....5..1...
..1..3.......2..3.521.......6...
.......3.142.........22......12.
.4...2..........3..162...4.....4
..4..6..3.4...1....5.33.........
5..........243..5....41......1..
..5..3..4...4.4..5..1.........4.
.....4.......3..5.2.....64.4..4.
...1.1.2...6....4......55....2..
.....3..2..53.....2..2.3.3......
......1...2..43...3.13........5.
...2.........4..54...2.3..62....
22.......332..1.....5......6....
...5..3.4.....3....5.241.......5
......63.1.......6...5..4..2....
..2.4..5..........52.4.....44...
2.55.....2.....6.....6.....55...
```

3 Methods of collecting 256 subject * items data

1) complete (Ideal)	2) Sample people	3) Items
22552141414336514122645166143244	22552141414336514122645166143244	22552141
32144265454235634562343524256611	.....	32144265
43553143152141541641526114551151	.....	43553143
52654223445614444431162645313124	.....	52654223
62222255242315442652355414213325	.....	62222255
22125412454242154221456444214564	.....	22125412
65113311244511226522615346451412	.....	65113311
54436452425245244554632246526466	.....	54436452
55223643555215245514633426121226	55223643555215245514633426121226	55223643
35522554332664265346655451531612	.....	35522554
63261241341466311243222233323541	63261241341466311243222233323541	63261241
32224431433144451645255464435552	.....	32224431
11564655513111334341463561655541	11564655513111334341463561655541	11564655
24532624664444656366642463322555	.....	24532624
25516362264523255665245644125611	.....	25516362
32255635422342631523143414221354	.....	32255635
23244456631411361161615126144214	.....	23244456
34526633236542563633625123624421	.....	34526633
13451522616451531355135621451536	13451522616451531355135621451536	13451522
31625444241623135123121345134162	.....	31625444
44252526365556663522524162313453	.....	44252526
54361436651313615433261662235132	.....	54361436
46635454552135645224352362433436	46635454552135645224352362433436	46635454
26511624245416441145655363265265	.....	26511624
63512331235542645524352562623235	.....	63512331
11523665433656446452523322216333	11523665433656446452523322216333	11523665
56436532623253433145633663651242	.....	56436532
15136366233651513351113353151452	.....	15136366
46321152211446344326554442255226	.....	46321152
62156523111352364233551656146433	.....	62156523
65342552265235623362261561363	65342552265235623362261561363	65342552

12 (Matrix) Sampling Methods of collecting 256 subject * items data

a) 32 x 16 balanced incomplete

```
..............4122645166143244
..............4562343524256611
..............1641526114551151
..............4431162645313124
..............2652355414213325
.......45424215........44214564
.......24451122........46451412
.......42524524........46526466
.......55521524........26121226
.......33266426........51531612
.......3414663112432222........
.......4331444516452554........
.......5131113343414635........

25353121264561433433232246526411
61335154566424114612641225353516
24634342151536242425413513435116
11554654453123111162423325516334
```

b) 32 x 8 complete

```
46323114
25443314
43315423
26314145
41435614
42236153
62421344
35234443
34514166
63415154
44441342
13514321
66365663
12264546
31466135
32645514
66151251
14411441
62443636
33316236
63325425
11531126
61155546
33245361
52241654
63212356
24414663
63661414
45555223
14364433
```

c) 32 x 32 MCAR p=.25

```
..3..2..6.....4.55.......44...
..........4..6..45..3.4..6....
6..3.......6.1.....6.2.......5
....3522......5.3...3......5..
....3.2.2.......3..2......65..
.....51....324.........23.....
....552............25...54.5..
...44.4.5....3..6...6........3
....61.523.2....2...........3.
5.............42.4..6.5......6
....3....3.6..1.4...1..5......
1....54.........2.4.33..6.....
4.....52..6.....44.3..........
..44...1........1..42....5..1.
..1..3.......2..3.521.......6.
.......3.142.........22......1
.4...2.........3..162...4.....
..4..6..3.4...1....5.33.......
5..........243..5....41......1
..5..3..4...4.4..5..1.........
.....4.......3..5.2.....64.4..
...1.1.2...6....4......55....2
.....3..2..53.....2..2.3.3....
......1...2..43...3.13........
...2.........4..54...2.3..62..
22.......332..1.....5......6..
...5..3.4.....3....5.241.....4.
......63.1.......6...5.....4..2
..2.4..5..........52.4.....44.
2.55.....2.....6.....6.....55.
```

Using SAPA to study the structure of personality

1. With the ability to build up large correlation matrices from the MMCAR data we were able to examine personality structure.
2. Josh Wilt developed his ABCD scales using items specifically emphasizing Affective, Behavioral, Cognitive or Motivational (Desire) content (Wilt and Revelle, 2015)
3. David Condon examined the structure of 696 items from the IPIP that were common to many published scales. From these 696 he was able to identify 135 that sampled the big few quite well, but also could be used to measure 27 "little' or interstitial factors Condon (2018).

The International Cognitive Ability Resource: measuring intelligence on the web

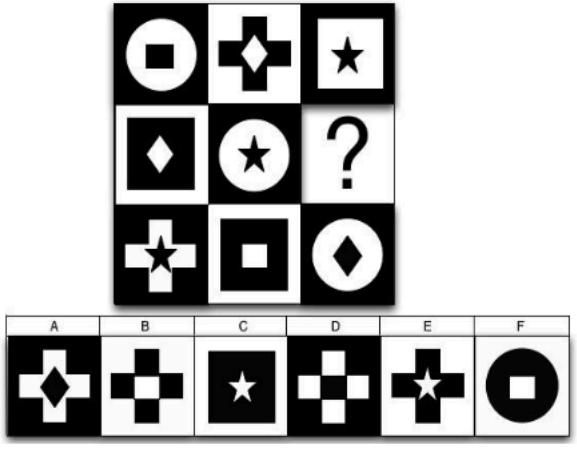
1. Wanting to broaden some web based research we had started to study Right Wing Authoritarianism with Greg Laun (Revelle and Laun, 2004), Melissa Liebert, another very clever undergraduate, developed some preliminary items to measure cognitive ability as part of a study of musical preferences (Liebert, 2006).
2. At a meeting in Krakow we reported the first use of our web based ability items and discussed how they relate to other dimensions of individual differences (Revelle et al., 2010).

ICAR (Condon and Revelle, 2014)

1. David Condon then took this beginning set of items and improved them as well validating them against a standard test of ability (the Shipley, 2009) and national data of the ability scores of college majors.
2. With some European colleagues, this resulted in the ICAR, an open source measure of cognitive ability. (Condon and Revelle, 2014).
3. In 2014 we released the first public domain version of what has become the ICAR.
4. The original 4 domains measured in the ICAR were
   - 9 Letter and Number Series items,
   - 11 Matrix Reasoning items,
   - 16 Verbal Reasoning items
   - 24 Three-Dimensional Rotation
5. A 16 item subset of the measure, the *ICAR Sample Test*, aka ICAR16 was a balanced set of 4 from each domain.

Example ICAR items

Matrix Reasoning



Verbal Reasoning

What number is one fifth of one fourth of one ninth of 9(

(1) 2 (2) 3 (3) 4 (4) 5 (5) 6 (6) 7

If the day after tomorrow is two days before Thursday, then what day is it today?

(1) Friday (2) Monday (3) Wednesday

(4) Saturday (5) Tuesday (6) Sunday

Letter and Number Series

In the following alphanumeric series, what letter comes next?

I J L O S

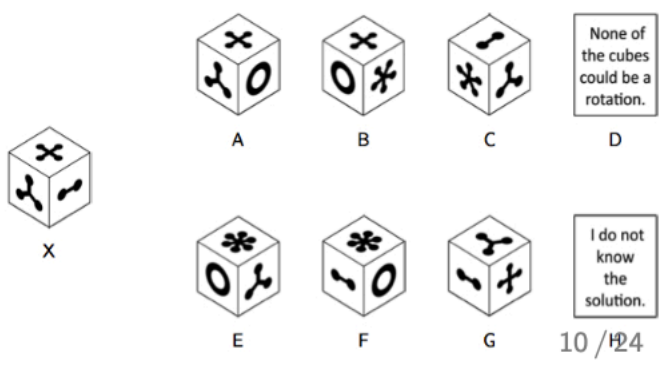
(1) T (2) U (3) V (4) X (5) Y (6) Z

In the following alphanumeric series, what letter comes next?

Q S N P L

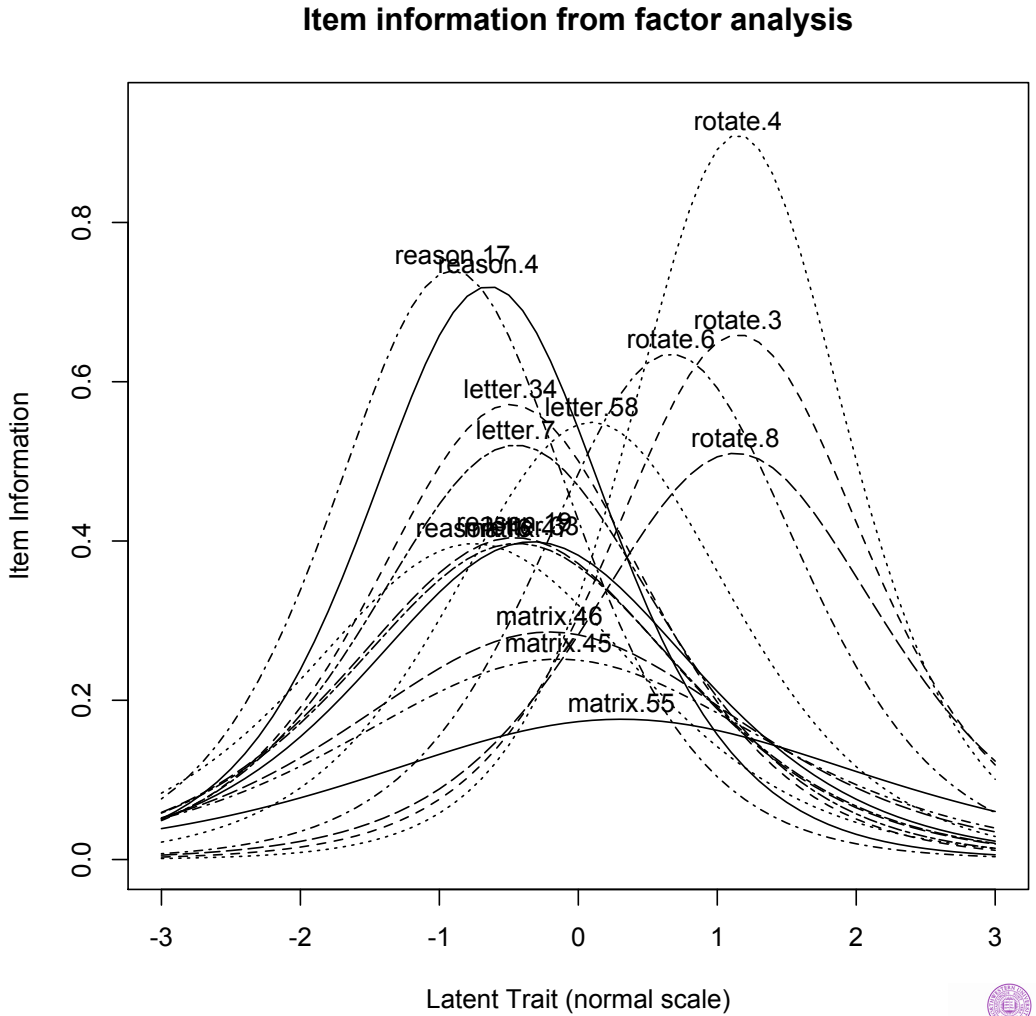
(1) J (2) H (3) I (4) N (5) M (6) L

Three-Dimensional Rotation



Item information for the ICAR 16

1. In the spirit of open science, data for 1525 participants on the ICAR16 are available in *psychtools* in R
2. The information curves are drawn using the `irt.fa` function in *psych*, which, like most of the functions in *psych*, was developed to handle the severe missingness of our SAPA data.



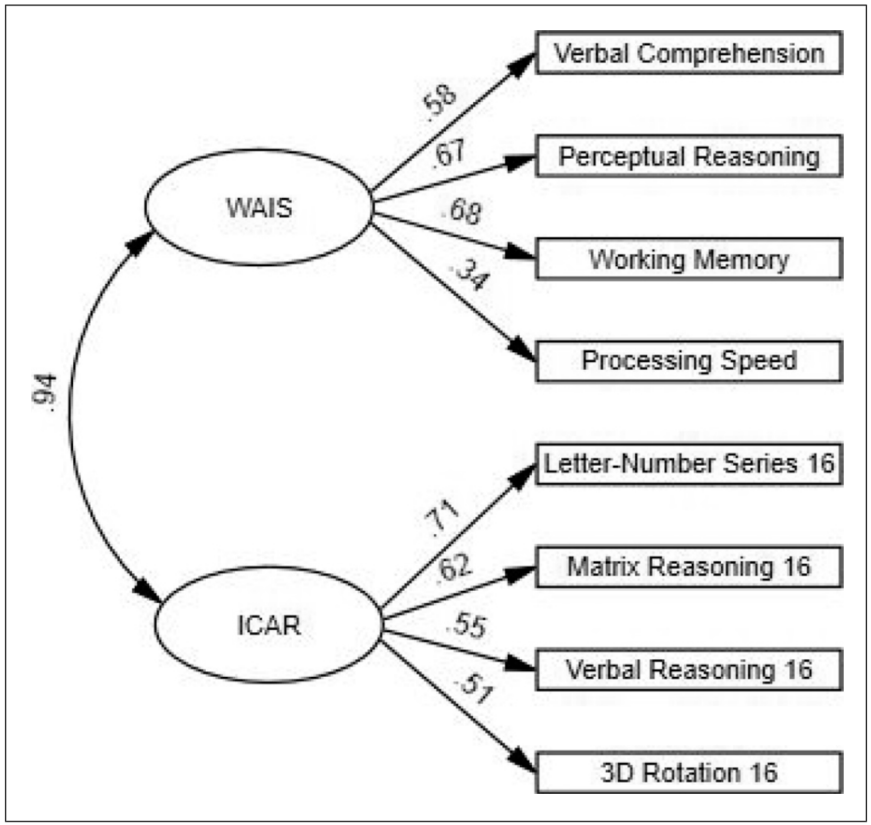
1. Subsequent item development and validation has extended the original four domains to $>$ 19 item types.
2. Additional cognitive items have been developed by David Condon and our other colleagues at the ICAR project (Gühne et al., 2020)
3. The newer measures include a
   - forced choice compound remote associates test (Mather et al., 2024)
   - two dimensional rotations (Mather and Condon, 2023)
   - propositional reasoning
   - figural analogies
   - numeracy,
   - map use
   - more complex matrix reasoning problems
   - Computer generated number series have been validated against the original items and added to ICAR (Loe et al., 2018).

Ripoff or useful?

1. When David, Liz and I submitted an article to *Current Directions* one reviewer suggested that to compare the ICAR to the Stanford Binet is analogous to comparing a cheap ripoff to a Versace handbag.
2. However, not everyone can afford a Versace handbag.
3. We view the utility of ICAR in terms of its wide range of applications in just the past few years.
4. Measurement invariance was tested for by Young et al. (2019).
5. The validity data correlating with "gold standard" measures found a correlation of .81 with the full scale IQ .94 with the CFA estimated "g"" factor (Young and Keith, 2020).
6. There are at least 232 uses of the ICAR in the recent literature (79 in Dworak et al., 2021, 153 since then), Dworak (personal communication, 2025).

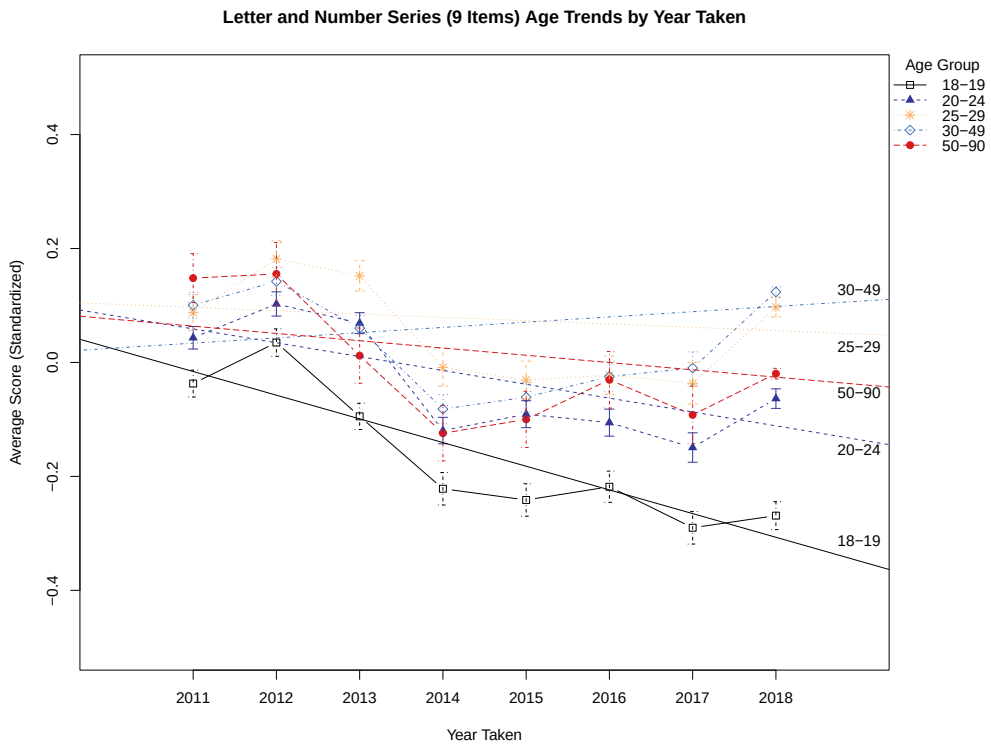
Validation vs the WAIS

1. Young and Keith (2020) reported validity data correlating with "gold standard" measures found a correlation of .81 with the full scale IQ from the WAIS and .94 with the CFA estimated "g"" factor.

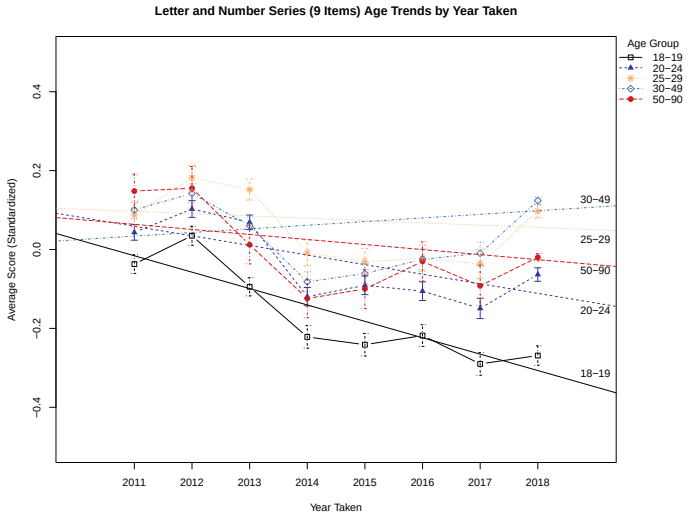


ICAR over time: examing the Flynn Effect

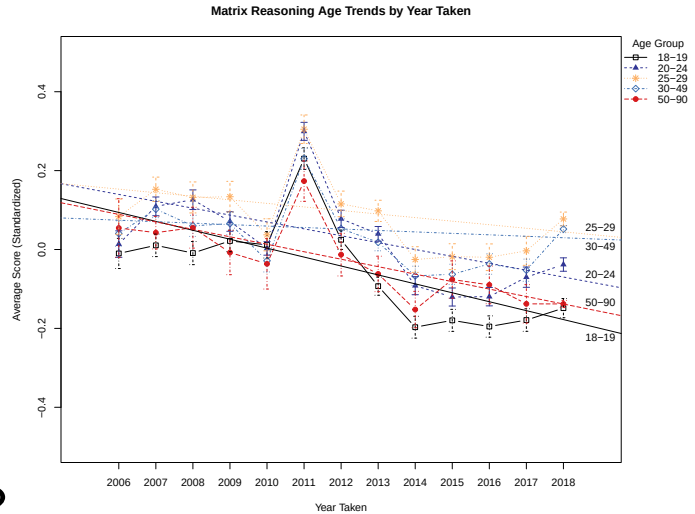
1. Elizabeth Dworak, David Condon and I have reported SAPA based ICAR data over time, showing changes (or lack of changes) over 8 years (Dworak et al., 2023).
2. We needed to correct for various changes in the ICAR over the years as new items were added.



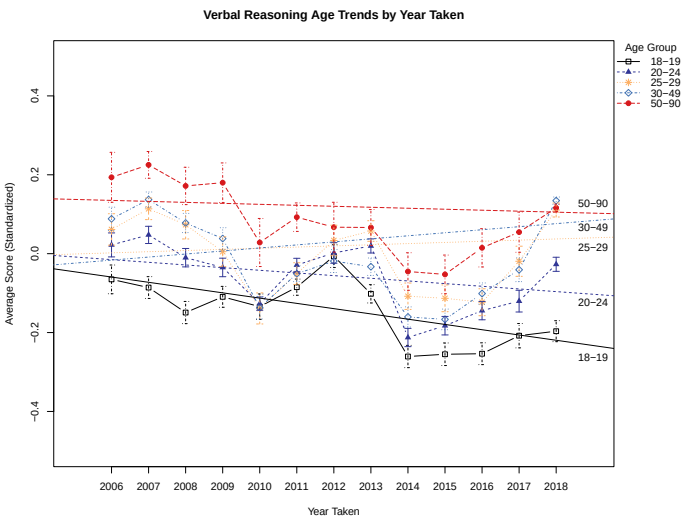
ICAR changes over 8 years by age vary by subtest



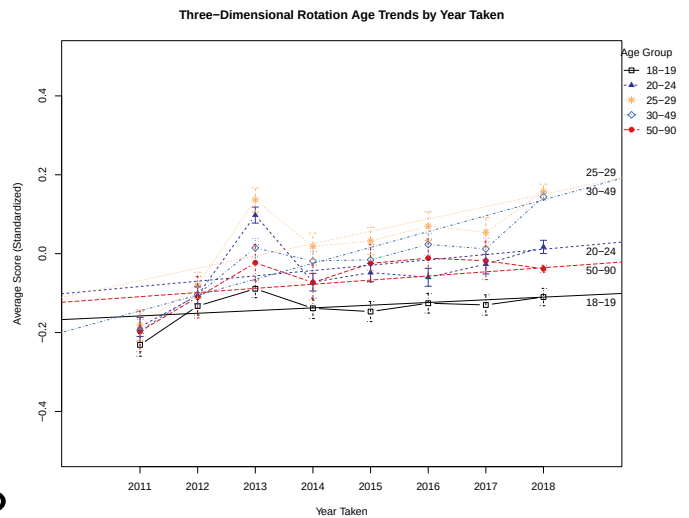
LN



MR



VR



3DR

ICAR extensions: Compound Remote Associates Test

1. Mednick (1962) had popularized the use of remote associations as they relate to intelligence and creativity.
2. Bowden and Jung-Beeman (2003) gave normative results for compound remote associate tests which they related to the "Ah ha" or insight effect.
3. David Condon generalized the Remote Associates Test to a multiple choice format which is now being given on the SAPA site.
   - Consider the words pine, crab, sauce
   - The word that links these three words starts with s, d, t, r, b, a, none of these, I don't know.
4. Mather et al. (2024) report the development and validation of the multiple-choice compound remote associates test.

College majors with high scores on the CRAT

Table 3 Top-scoring university majors in descending order of percentile rank on associative ability

Major	CRA	LN	MR	R3D	VR	FA	PR
Classical languages (Latin and Greek)	99	84	85	97	99	95	93
American studies	99	59	75	72	94	63	97
Poetry writing	98	70	66	68	77	68	75
Fiction writing	97	66	69	73	86	62	95
Anthropology	97	80	75	93	97	84	96
Neuroscience	96	100	100	100	100	100	100
Comparative literature studies	95	77	68	75	84	71	83
Classical studies	94	57	70	92	95	86	92
Spanish	93	64	60	67	97	56	82
Slavic languages	92	82	87	68	98	77	98

Notes: The majors are sorted by percentile on the new CRA item set. Percentile ranks for other cognitive abilities are also presented. LN = letter–number series, MR = matrix reasoning, R3D = three-dimensional rotation, VR = verbal reasoning, FA = figural analogies, PR = propositional reasoning

The percentiles of scores on the CRAT as well as Letter-Number series, Matrix Reasoning, 3 dimensional rotation, Verbal Reasoning, Figural Analogies and Propositional Reasoning are shown as well (Mather et al., 2024)

Occupations with high scores on the CRAT

Table 4 Top-scoring occupations in descending order of percentile rank on associative ability

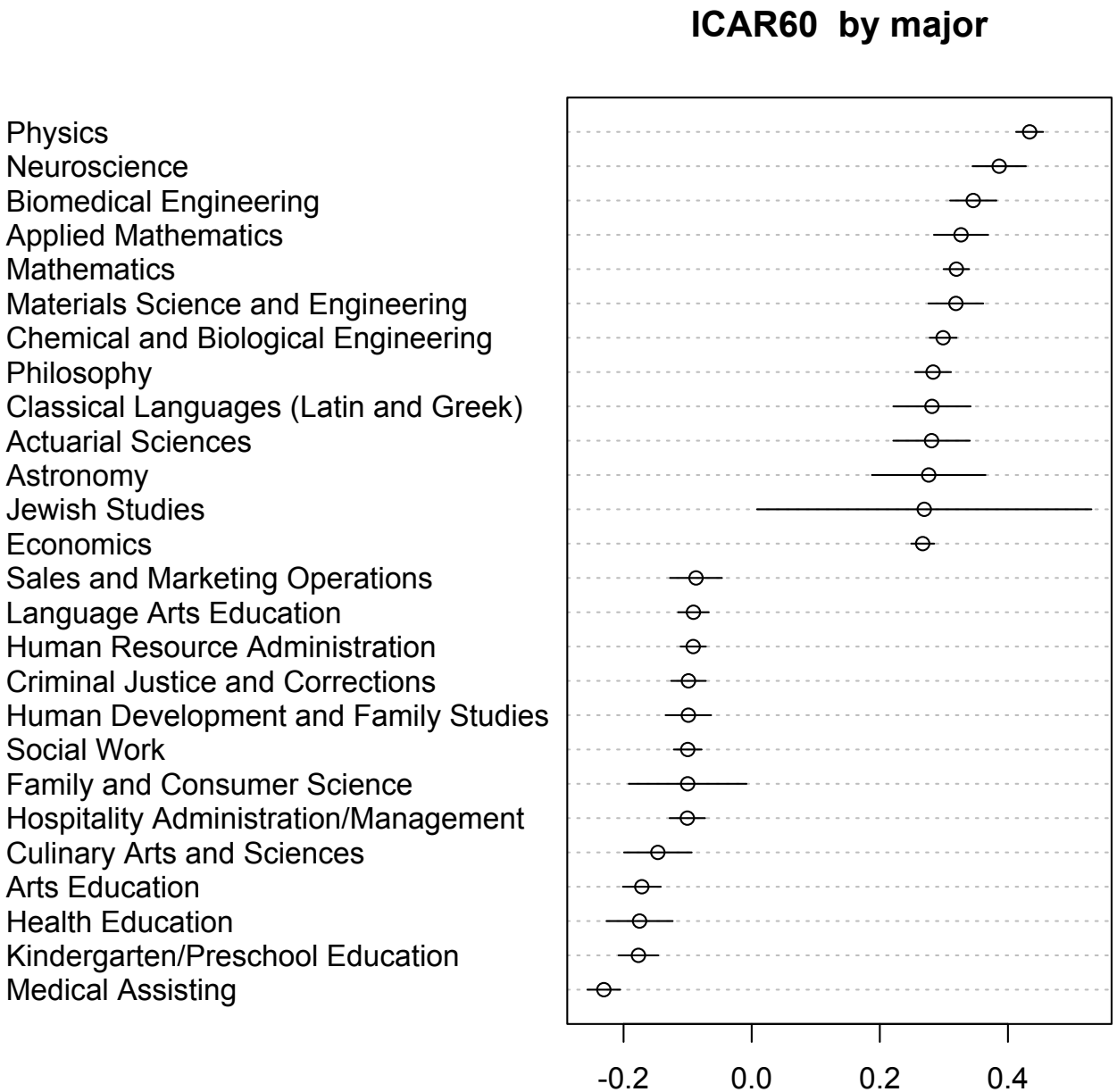
Occupation	CRA	LN	MR	R3D	VR	FA	PR
Education administrator – postsecondary	96	90	70	86	92	60	84
Writer	95	68	54	57	75	66	73
Physicist	94	98	98	99	97	97	97
Postsecondary teacher – philosophy or religion	94	87	87	78	90	92	93
Editor	93	69	66	77	84	71	78
Environmental scientist	93	92	87	86	93	87	94
Veterinarian	92	81	82	83	79	77	83
Other – biological scientist	92	94	96	95	96	94	95
Postsecondary teacher - mathematical science	91	93	93	93	88	83	94
Regulatory affairs manager	91	75	70	62	91	86	95

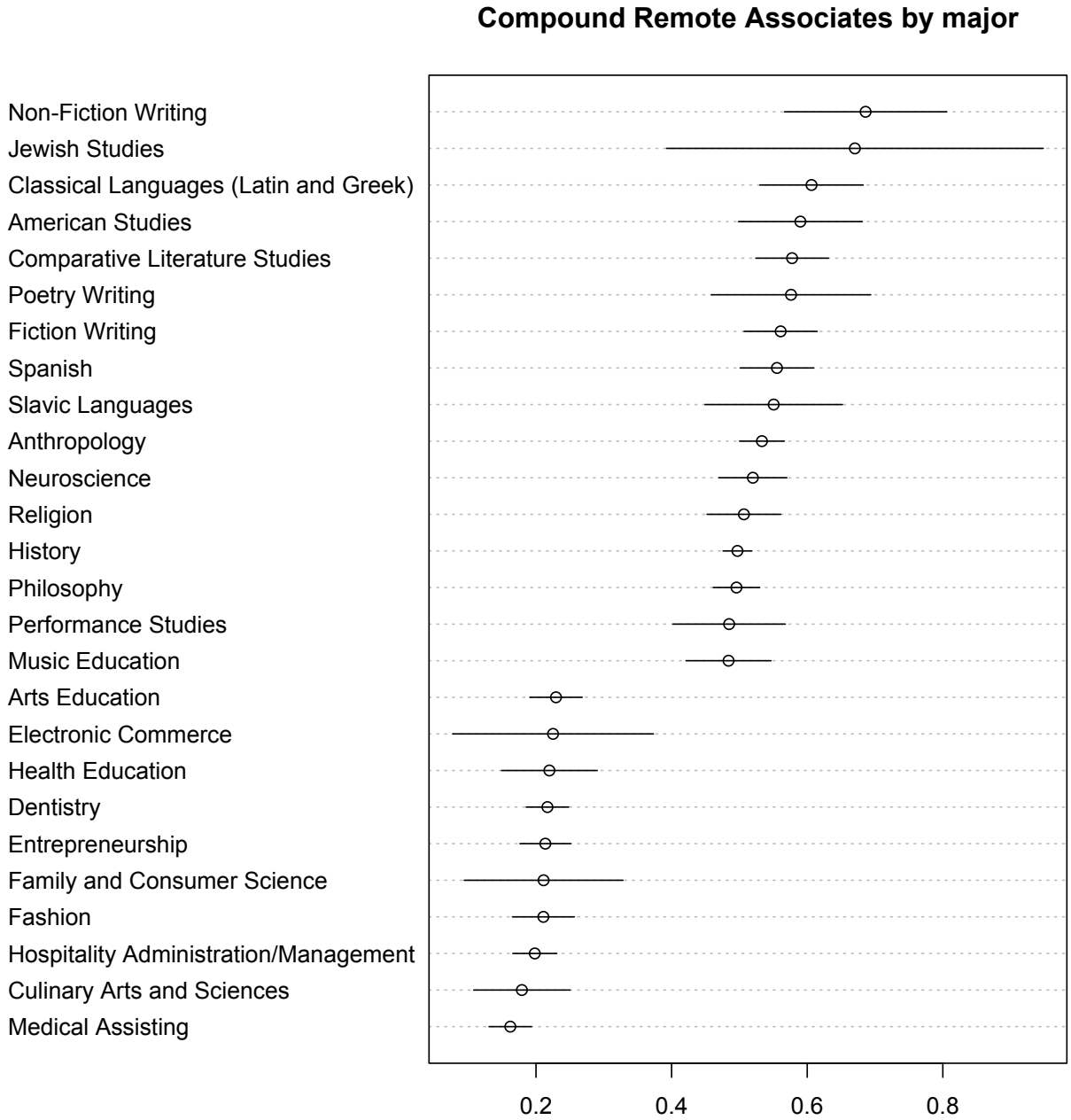
Notes: The majors are sorted by percentile on the new CRA item set. Percentile ranks for other cognitive abilities are also presented. LN = letter–number series, MR = matrix reasoning, R3D = three-dimensional rotation, VR = verbal reasoning, FA = figural analogies, PR = propositional reasoning

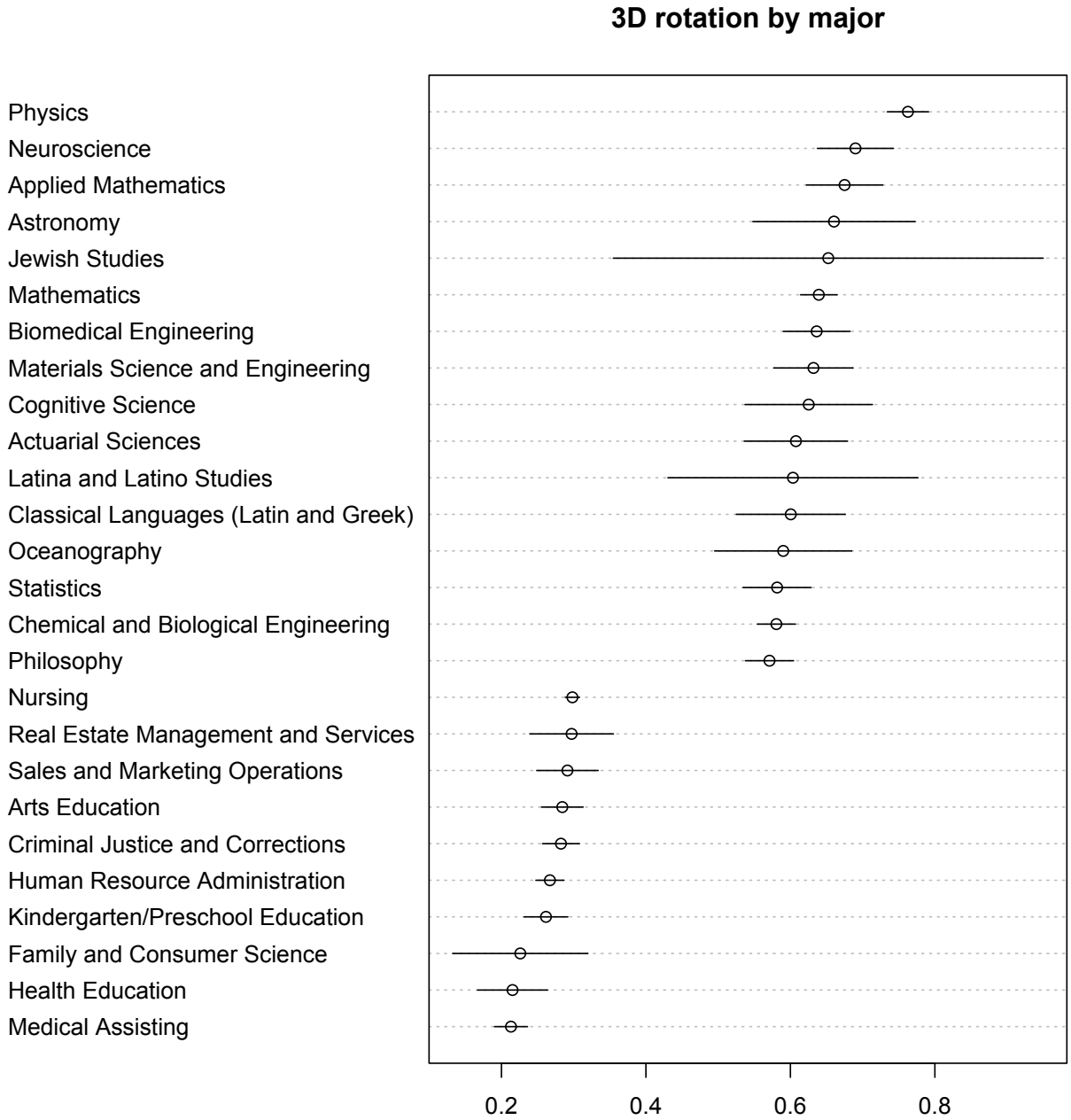
The percentiles of scores on the CRAT as well as Letter-Number series, Matrix Reasoning, 3 dimensional rotation, Verbal Reasoning, Figural Analogies and Propositional Reasoning are shown as well (Mather et al., 2024)

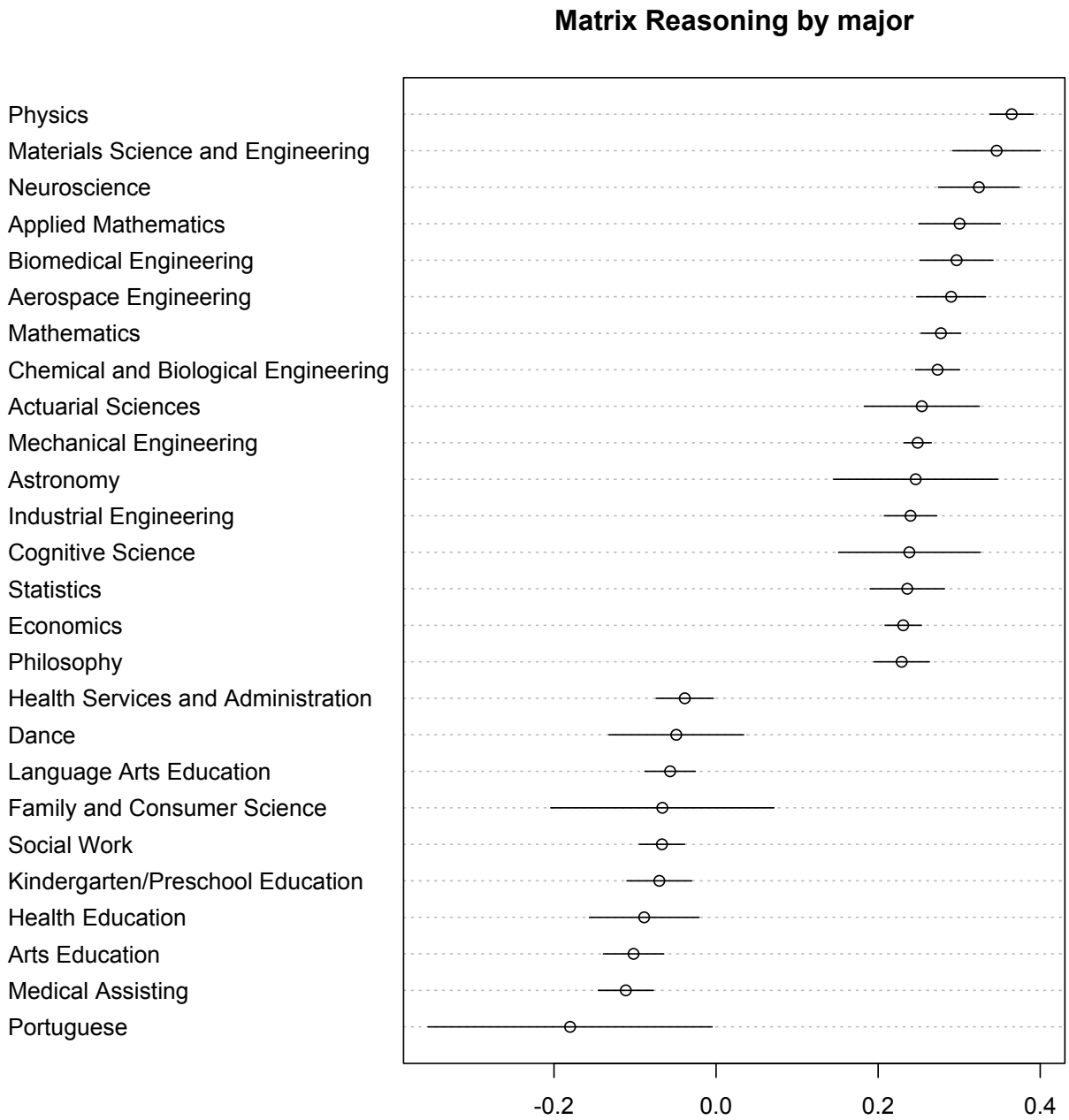
ICAR and the subtests

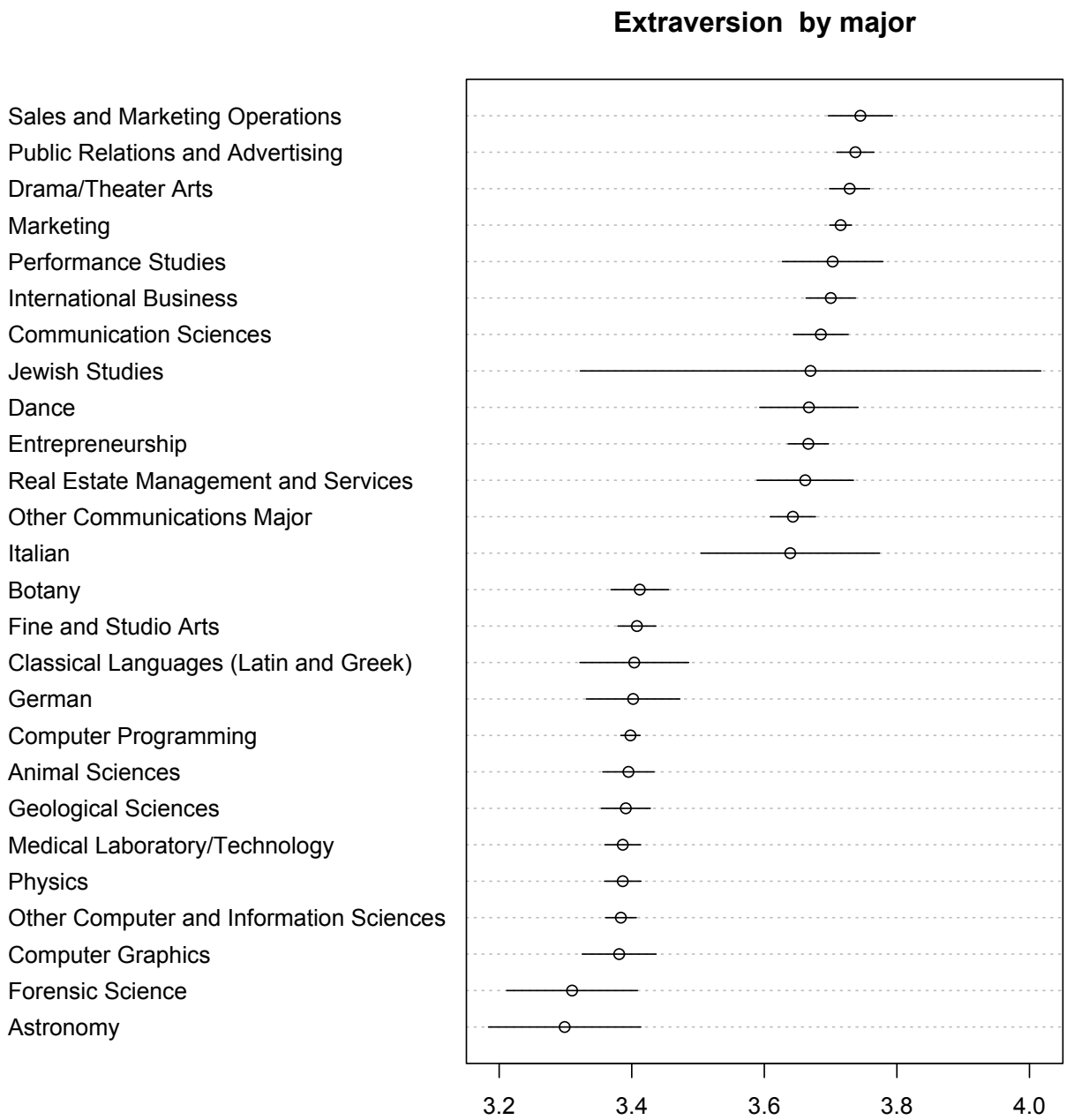
1. From 644,495 SAPA subjects from 2017-2019 I looked at ICAR and SPI scores by major.
2. The SAPA Personality Inventory (SPI) (Condon, 2018) has 135 items formed into five broad factors and 27 interstiial factors.
3. What follows is a very quick summary of the ICAR dimensions and a few of the SPI dimensions.

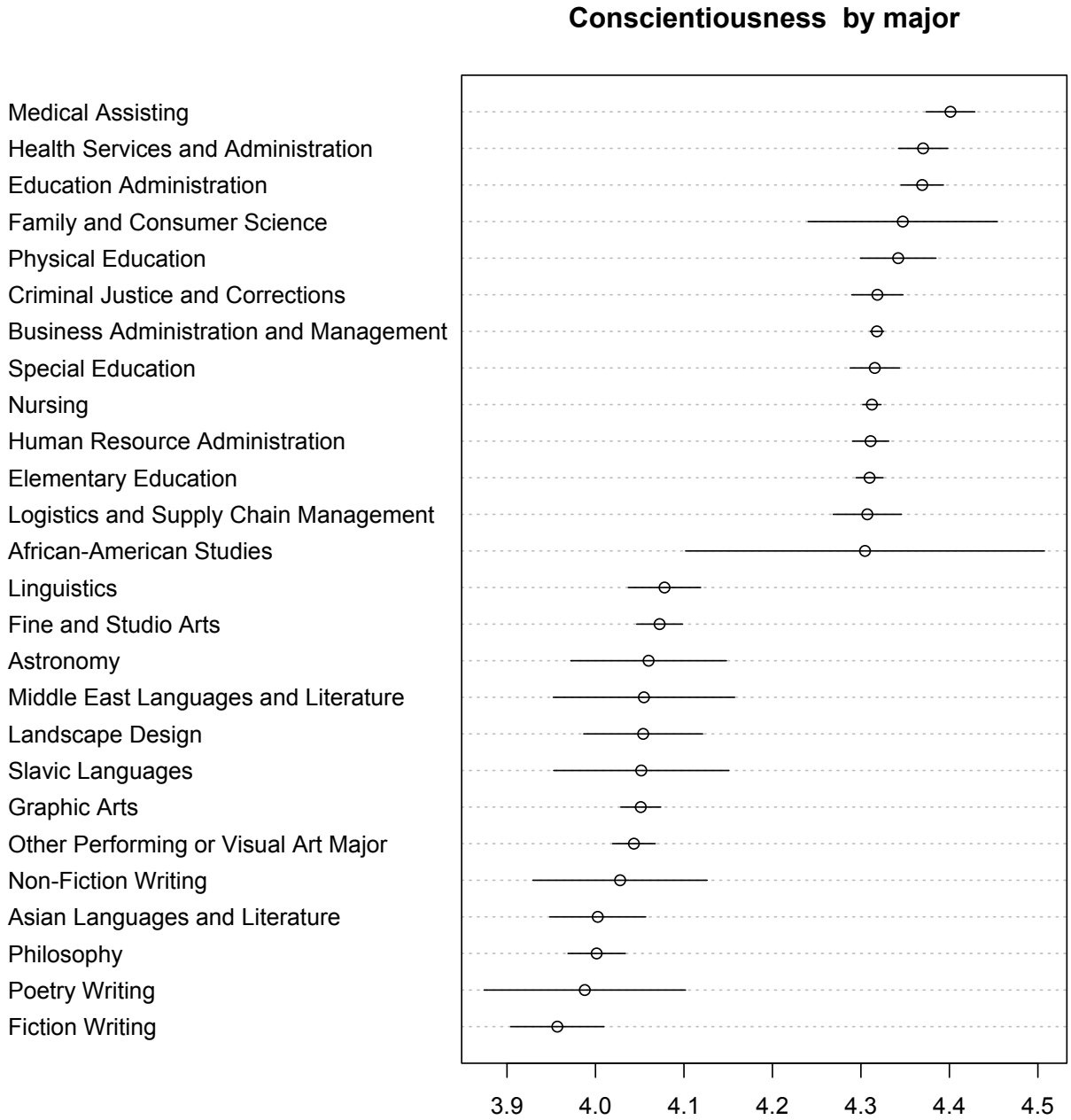

ICAR60 by major
Physics
Neuroscience
Biomedical Engineering
Applied Mathematics
Mathematics
Materials Science and Engineering
Chemical and Biological Engineering
Philosophy
Classical Languages (Latin and Greek)
Actuarial Sciences
Astronomy
Jewish Studies
Economics
Sales and Marketing Operations
Language Arts Education
Human Resource Administration
Criminal Justice and Corrections
Human Development and Family Studies
Social Work
Family and Consumer Science
Hospitality Administration/Management
Culinary Arts and Sciences
Arts Education
Health Education
Kindergarten/Preschool Education
Medical Assisting
-0.2
0.0
0.2
0.4

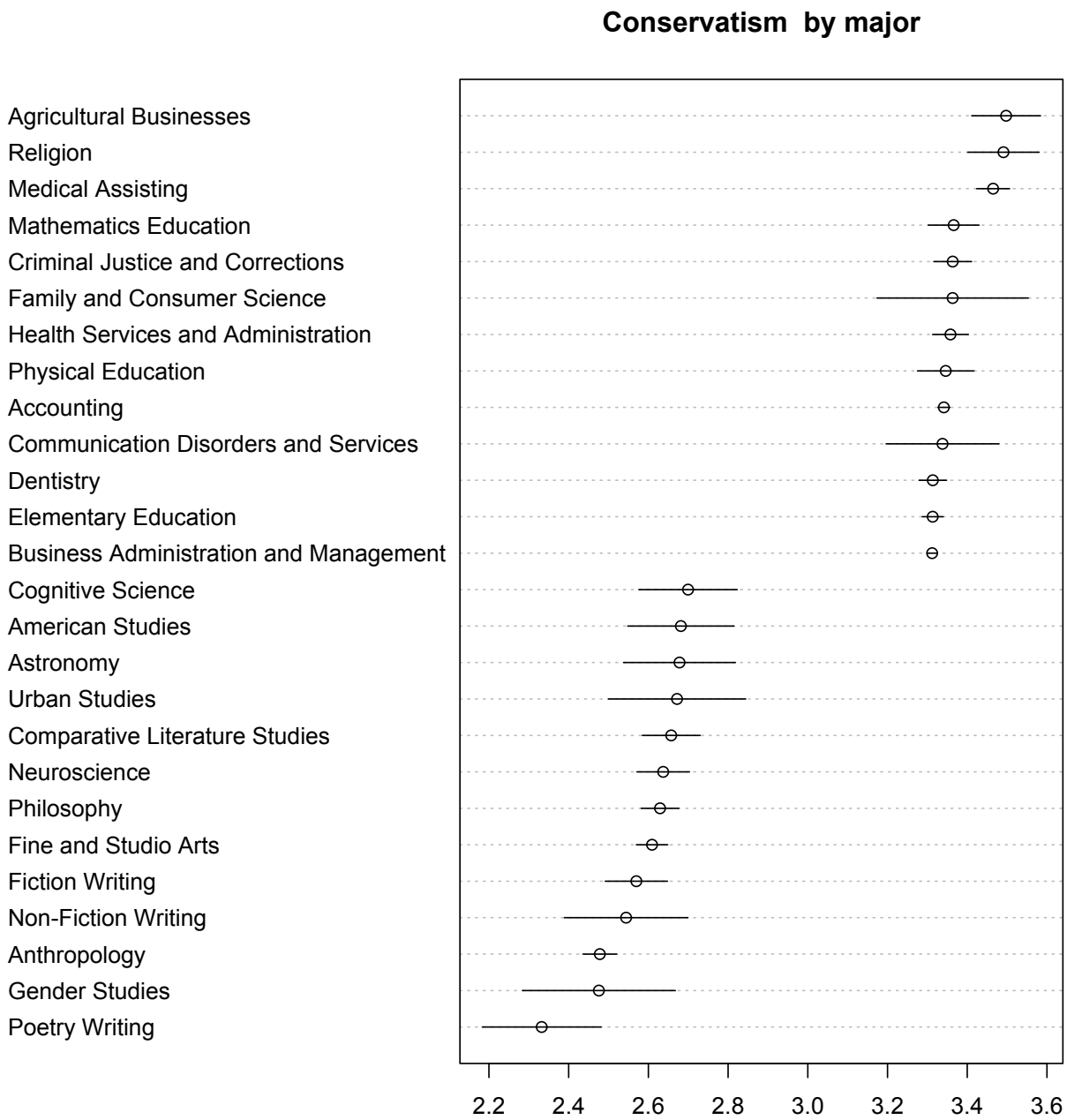

Compound Remote Associates by major
Non-Fiction Writing
Jewish Studies
Classical Languages (Latin and Greek)
American Studies
Comparative Literature Studies
Poetry Writing
Fiction Writing
Spanish
Slavic Languages
Anthropology
Neuroscience
Religion
History
Philosophy
Performance Studies
Music Education
Arts Education
Electronic Commerce
Health Education
Dentistry
Entrepreneurship
Family and Consumer Science
Fashion
Hospitality Administration/Management
Culinary Arts and Sciences
Medical Assisting
0.2
0.4
0.6
0.8


3D rotation by major
Physics
Neuroscience
Applied Mathematics
Astronomy
Jewish Studies
Mathematics
Biomedical Engineering
Materials Science and Engineering
Cognitive Science
Actuarial Sciences
Latina and Latino Studies
Classical Languages (Latin and Greek)
Oceanography
Statistics
Chemical and Biological Engineering
Philosophy
Nursing
Real Estate Management and Services
Sales and Marketing Operations
Arts Education
Criminal Justice and Corrections
Human Resource Administration
Kindergarten/Preschool Education
Family and Consumer Science
Health Education
Medical Assisting
0.2
0.4
0.6
0.8

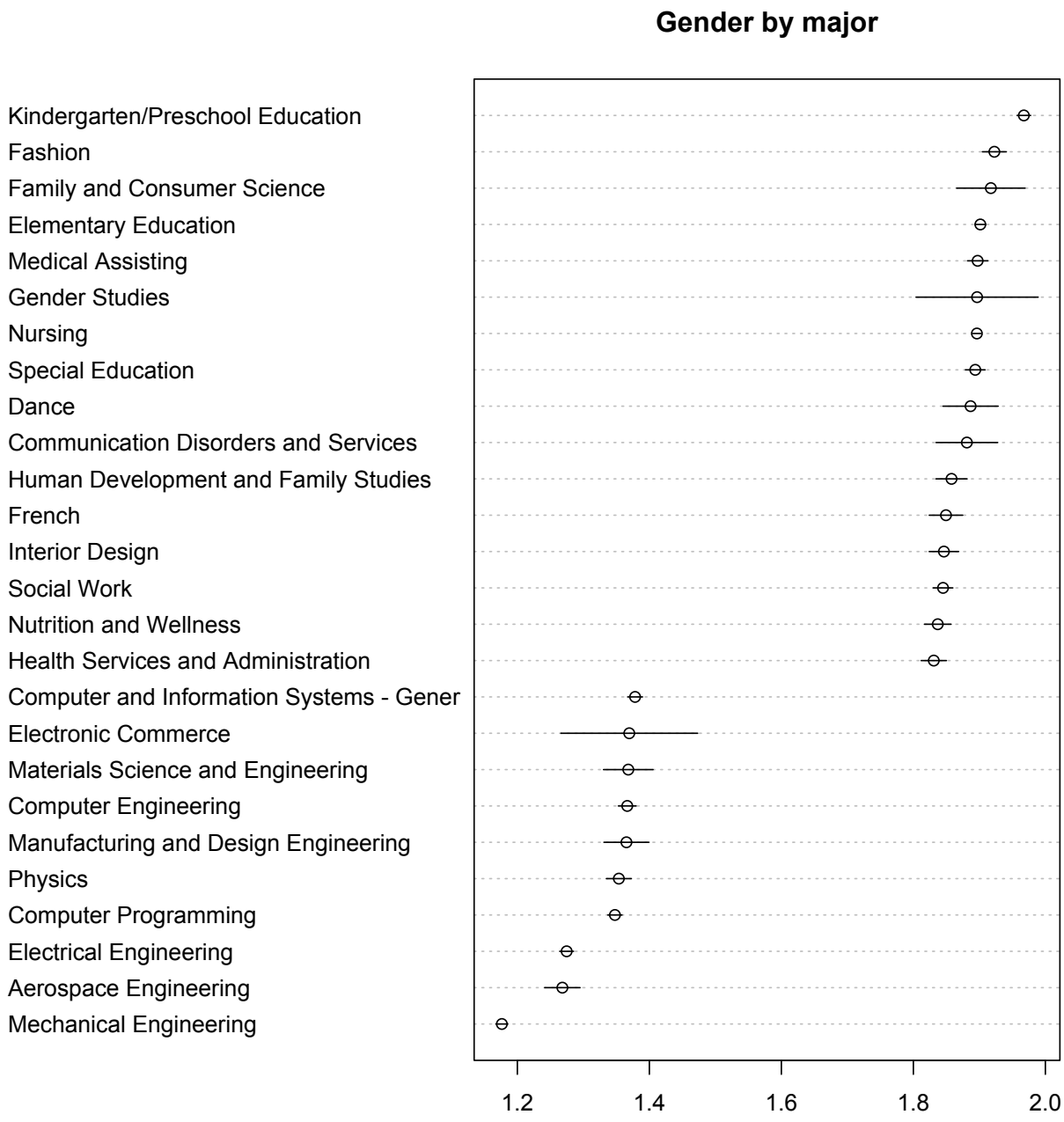

Matrix Reasoning by major
Physics
Materials Science and Engineering
Neuroscience
Applied Mathematics
Biomedical Engineering
Aerospace Engineering
Mathematics
Chemical and Biological Engineering
Actuarial Sciences
Mechanical Engineering
Astronomy
Industrial Engineering
Cognitive Science
Statistics
Economics
Philosophy
Health Services and Administration
Dance
Language Arts Education
Family and Consumer Science
Social Work
Kindergarten/Preschool Education
Health Education
Arts Education
Medical Assisting
Portuguese
-0.2
0.0
0.2
0.4


Extraversion by major
Sales and Marketing Operations
Public Relations and Advertising
Drama/Theater Arts
Marketing
Performance Studies
International Business
Communication Sciences
Jewish Studies
Dance
Entrepreneurship
Real Estate Management and Services
Other Communications Major
Italian
Botany
Fine and Studio Arts
Classical Languages (Latin and Greek)
German
Computer Programming
Animal Sciences
Geological Sciences
Medical Laboratory/Technology
Physics
Other Computer and Information Sciences
Computer Graphics
Forensic Science
Astronomy
3.2
3.4
3.6
3.8
4.0


Conscientiousness by major
Medical Assisting
Health Services and Administration
Education Administration
Family and Consumer Science
Physical Education
Criminal Justice and Corrections
Business Administration and Management
Special Education
Nursing
Human Resource Administration
Elementary Education
Logistics and Supply Chain Management
African-American Studies
Linguistics
Fine and Studio Arts
Astronomy
Middle East Languages and Literature
Landscape Design
Slavic Languages
Graphic Arts
Other Performing or Visual Art Major
Non-Fiction Writing
Asian Languages and Literature
Philosophy
Poetry Writing
Fiction Writing
3.9
4.0
4.1
4.2
4.3
4.4
4.5


Conservatism by major
Agricultural Businesses
Religion
Medical Assisting
Mathematics Education
Criminal Justice and Corrections
Family and Consumer Science
Health Services and Administration
Physical Education
Accounting
Communication Disorders and Services
Dentistry
Elementary Education
Business Administration and Management
Cognitive Science
American Studies
Astronomy
Urban Studies
Comparative Literature Studies
Neuroscience
Philosophy
Fine and Studio Arts
Fiction Writing
Non-Fiction Writing
Anthropology
Gender Studies
Poetry Writing
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6

Extensions and applications of ICAR



The psych package for R

1. Although not technically limited to intelligence research, the development of the *psych* package for R was meant to supplement the open source nature of my research.
2. Partly driven by the need to handle SAPA type data and to validate the ICAR items, *psych* is meant as a Swiss Army Knife for data analysis.
   - That is, it is not the best tool for any problem.
   - But is a collection of pretty good tools for data analysis in general and psychometrics in general.
3. *psych* has been under development for the past 20 years and has a new update at least semi-annually.
   - These updates contain the inevitable bug fixes (from bugs reported by users).
   - More importantly, the updates include new functions that I have developed to further my (or my students') research.

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Particularly useful psych functions

1. Although we all have our favorite functions, of the > 500 in *psych* the ones most useful for ability research include:

describe	Descriptive statistics
statsBy	Basic multilevel statistics by group.
fa	For conventional factor analysis.
irt.fa	To do 2PL IRT based upon the factor analysis of polychoric or tetrachoric correlations.
scoreOverlap	To find the correlations between scales with overlapping items.

2. Several vignettes describe the use of *psych* in more detail.
   - scoring scales, finding ω, factor analysis and its alternatives, mediation analysis. etc.

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The secrets of a lifetime career award

1. Good luck
2. Great mentors
3. Great colleagues
4. Great students
5. Live long enough
6. Good luck

Slides available at https:personality-project.org/sapa

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