6 decades of dabbling in intelligence

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

William Revelle
Northwestern University
Evanston, Illinois USA

NORTHWESTERN
UNIVERSITY

July, 2025
Slides available at https:personality-project.org/sapa

Outline

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.

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. 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.

Gideon's double dissociation test
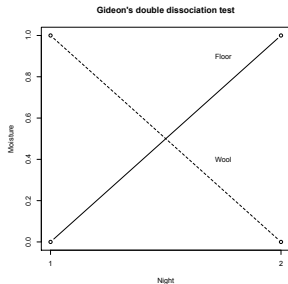
Plato and the requirements for leadership

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)*

Introduction
○○○○○●○○
○○

Motivation
○○○○○○
○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○○○○
○○○○○○○○○○○○○○

psych
○○

Conclusion
○

References

Personality and Ability

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.*

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○●○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○○○○○○○○○○○

Personality and Ability

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, the link is obvious (Brauer and Proyer, 2024)
   for the study of individual differences includes those
   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).

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).

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 they could get into secondary school.

5. The parents of the children had never been to school, some 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.

Introduction
00000000
00

Motivation
0●0000
000000000

SAPA data
0000
0000000

ICAR
000000
00000000000000

psych
00

Conclusion
0

References

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 and then in graduate school tried to integrate his work with that of Atkinson.

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.

Introduction
○○○○○○○○
○○

Motivation
○○○●○○
○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○○○○
○○○○○○○○○○○○○

psych
○○

Conclusion
○

References

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.

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

Verbal GRE Performance   Standardized for NU
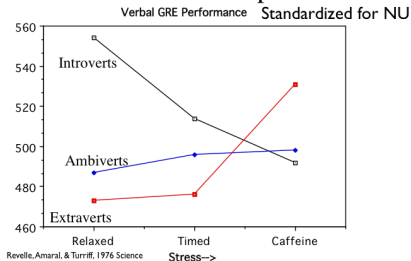
Stress reduced the performance of the introverted group by .6 σ while helping the extraverted group by .6 σ.

Failures to replicate explained

,

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
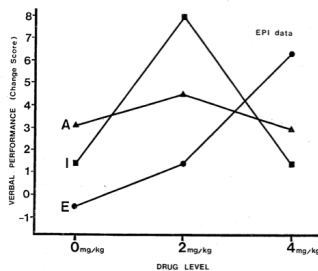
Gilliland, 1976

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

Introduction
00000000
00

Motivation
0000000
0000000000

SAPA data
0000
0000000

ICAR
0000000
0000000000000

psych
00

Conclusion
0

References

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 impulses got worse but high impulses better when given caffeine.
- This effect reversed in the evening where now the high impulses got worse and the lower impulses better with caffeine.

Impulsivity, Caffeine, and Time of Day: the effect on complex cognitive performance

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
OOOOOOO   OOOOOO   OOOO   OOOOOO   OO   O
OO   ●OOOOOOO   OOOOOOO   OOOOOOOOOOOOOOO
Theory development and tests
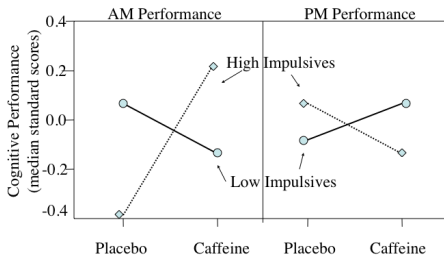
Theory development

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)

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.

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
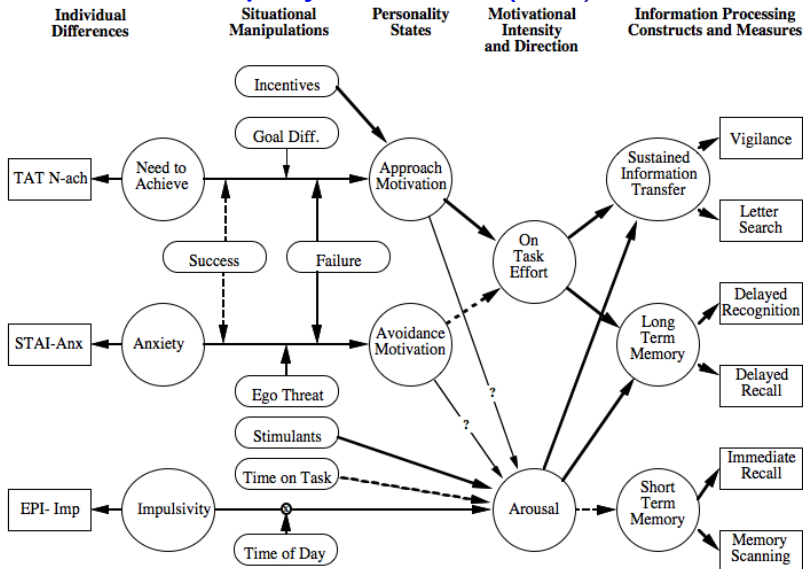
Adapted from Humphreys & Revelle, 1984; Revelle, 1989

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○●○○○○○○   ○○○○○○○   ○○○○○○○○○○○○○○○
Theory development and tests

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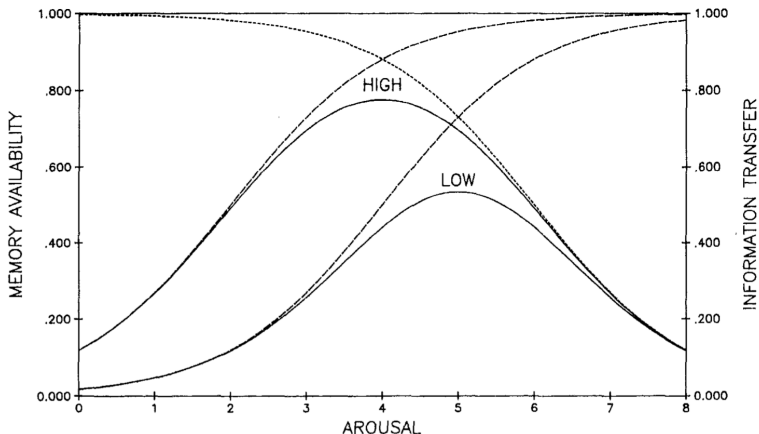
Figure 5. Curvilinearity derived from two opposing monotonic processes. (The effects of effort are to improve the information-transfer resource but not to affect the memory resource.)

Introduction   **Motivation**   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○●○○○○   ○○○○○○○   ○○○○○○○○○○○○○○○
Theory development and tests

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.

Introduction   **Motivation**   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○●○○○   ○○○○○○○   ○○○○○○○○○○○○○○○

Theory development and tests

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).

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○●○○   ○○○○○○○   ○○○○○○○○○○○○○○○○
Theory development and tests

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).

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).

Introduction   **Motivation**   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○●○   ○○○○○○○   ○○○○○○○○○○○○○○○○   ○
Theory development and tests
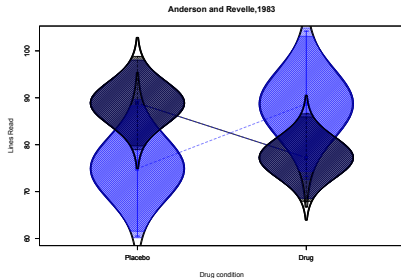
Tests of three theories of the effect of anxiety on cognitive processing

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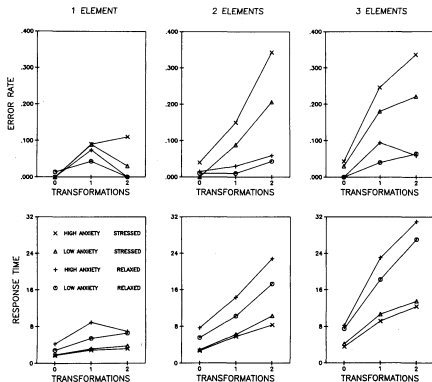
Figure 3. Error rates and response times for true analogies. (Error rates are calculated for all true analogies. Response times are calculated for true analogies that were solved correctly.)

Introduction   **Motivation**   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○○●   ○○○○○○○   ○○○○○○○○○○○○○○○
Theory development and tests

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.

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○   ○○○○○○   ●○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○○○○○○○○○○○○
Astronomy as an analogy
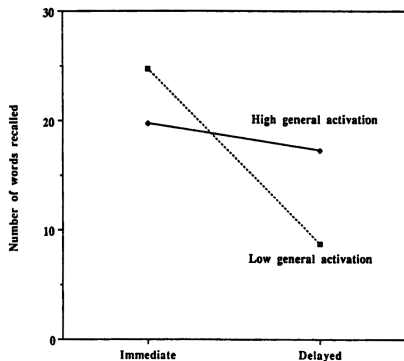
SAPA: the Synthetic Aperture Personality Assessment Project

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).

Introduction
○○○○○○○○
○○

Motivation
○○○○○○
○○○○○○○○○

SAPA data
○●○○
○○○○○○○

ICAR
○○○○○○
○○○○○○○○○○○○○○

psych
○○

Conclusion
○

References

Astronomy as an analogy

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)

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○   ○○○○○○   ○○○●   ○○○○○○   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○○○○○○○○○○○
Astronomy as an analogy
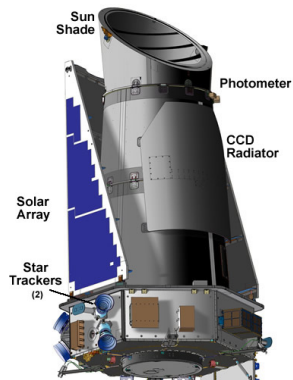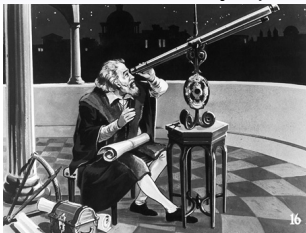
A short diversion: history of radio telescopes

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

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○○○○   ●○○○○○○   ○○○○○○○○○○○○○○○

Psychometrics of SAPA

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).

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○○○○   ○●○○○○○   ○○○○○○○○○○○○○○○

Psychometrics of SAPA

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.

Introduction
○○○○○○○○
○○

Motivation
○○○○○○
○○○○○○○○○

SAPA data
○○○○
○○○●○○○○

ICAR
○○○○○○
○○○○○○○○○○○○○○○

psych
○○

Conclusion
○

References

Psychometrics of SAPA

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).

Introduction Motivation **SAPA data** ICAR psych Conclusion References
○○○○○○○○ ○○○○○○ ○○○○ ○○○○○○ ○○ ○
○○ ○○○○○○○○○ ○○○○ ○○○○●○○ ○○○○○○○○○○○○○○○○

Psychometrics of SAPA

3 Methods of collecting 256 subject * items data

1) 8 x 32 complete   2) 32 x 8 complete   12) 32 x 32 MCAR p=.25

```
46213634521143453443645331212414    46323114    ..3..2..6.....4.55.......44.....
21243623166421516154432261516513    25443314    ...........4..6..45..3.4..6....1
51661351155165463622224435623344    43315423    6..3......6.1....6.2.......5.6
11141343362332215612152135614522    26314145    ....3522......5.3..3......5....
25353121264561433433232246526411    41435614    ....3.2.2.......3..2......65..5.
61335154566424114612641225353516    42236153    .....51...324.........23......5
24634342151536242425413513435116    62421344    ....552..........25...54.5....
11554654453123111624233255516334    35234443    ...44.4.5....3..6...6.........3..
                                    34514166    ....61.523.2....2.........3...
Type 1 = sample subjects            63415154    5.............42.4..6.5......61.
                                    44441342    ....3....3.6..1.4...1..5......5.
                                    13514321    1....54.........2.4.33..6......
                                    66365663    4.....52..6....44.3.........2
Type 2 = sample items               12264546    ..44...1........1..42....5..1...
                                    31466135    ..1..3.......2..3.521.......6...
                                    32645514    .......3.142.........22....12.
                                    66151251    .4..2..........3..162...4.....4
                                    14411441    ..4..6..3.4...1....5.33.........
Type 12 sample items and subjects   62443636    5...........243..5....41......1..
                                    33316236    ..5..3..4...4.4..5..1.........4.
                                    63325425    .....4......3..5.2....64.4..4.
                                    11531126    ...1.1.2...6....4......55...2..
                                    61155546    .....3..2..53.....2..2.3.3......
                                    33245361    ......1...2..43...3.13........5.
                                    52241654    ...2........4..54...2.3..62....
                                    63212356    22.......332..1.....5......6....
                                    24414663    ...5..3.4.....3....5.241......
                                    63661414    ......63.1......6...5..4..2
                                    45555223    ..2.4..5..........52.4.....44...
                                    14364433    2.55....2...6.....6....55.
                                    21461416    .5........4...6341.4..2
```

Introduction   Motivation   **SAPA data**   ICAR   psych   Conclusion   References
00000000   000000000   0000   000000   00   0
              000000000   0000000●0   0000000000000000

Psychometrics of SAPA

3 Methods of collecting 256 subject * items data

1) complete (Ideal)	2) Sample people	3) Items
2255214141433651412264516614324	2255214141433651412264516614324	22552141
3214426545423563456234352424256611	....	32144265
4355314315214154164152611455151	....	43553143
5265422344561444443116264531312	....	52654223
6222225542231544265235541421332	....	62222255
2212541245424215422145644421456	....	22125412
6511331124451122652261534645141	....	65113311
5443645242524245445546322465264	....	54436452
5522364355521524551463342612122	5522364355521524551463342612122	55223643
3552255433266426534665545153161	....	35522554
6326124134146631124322223332354	6326124134146631124322223332354	63261241
3222443143314445164525546443555	....	32224431
1156465551311133434146356165554	1156465551311133434146356165554	11564655
2453262466444465636664246332255	....	24532624
2551636226452325566524564412561	....	25516362
3225563542234263152314341422135	....	32255635
2324445663141136116161512614421	....	23244456
3452663323654256363632651236244	....	34526633
1345152261645153135513562145153	1345152261645153135513562145153	13451522
3162544424162313512312134513416	....	31625444
4425252636555666352252412623134	....	44252526
5436143665131361543326166223513	....	54361436
4663545455213564522435236243343	4663545455213564522435236243343	46635454
2651162424541644114565536326526	....	26511624
6351233123554264552435256262323	....	63512331
1152366543365644645252332221633	1152366543365644645252332221633	11523665
5643653262325343314563366365124	....	56436532
1513636623365151335111335315145	....	15136366
4632115221144634432655444225522	....	46321152
6215652313135236423355165614643	....	62156523
6534255226525523623326156136223	6534255226525523623326156136223	65342552

12 (Matrix) Sampling Methods of collecting 256 subject * items data
a) 32 x 16 balanced incomplete b) 32 x 8 complete c) 32 x 32 MCAR p=.25

```
...............4122645166143244    46323114    ..3..2..6......4.55......44...
...............4562343524256611    25443314    ..........4..6..45..3.4..6...
...............1641526114551151    43315423    6..3......6.1....6.2......5
...............4431162645313124    26314145    ....3522....5.3...3......5..
...............2652355414213325    41435614    ....3.2.2......3..2.....65..
.......45424215........44214564    42236153    .....51...324.........23.....
.......24451122........46451412    62421344    ...552..........25...54.5..
.......42524524........46526466    35234443    ...44.4.5...3..6...6......3
.......55521524........26121226    34514166    ....61.523.2...2...........3.
.......33266426........51531612    63415154    5..........42.4..6.5......6
.......3414663112432222........    44441342    ....3....3.6..1.4...1..5......
.......4331444516452554........    13514321    1...54.........2.4.33..6....
.......5131113343414635........    66365663    4.....52..6....44.3.........
                                   12264546    ..44...1........1..42....5..1.
2535321264561433433232246526411    31466135    ..1..3......2..3.521......6.
6133515456642411461264122535316    32645514    ......3.142.........22.....1
2463434215153624242541351343516    66151251    .4...2..........3..162...4....
1155465445312311116242332551634    14411441    ..4..6..3.4...1...5.33.......
                                   62443636    5...........243..5...41......1
                                   33316236    ..5..3..4...4.4..5..1.........
                                   63325425    .....4.....3..5.2.....64.4..
                                   11531126    ...1.1.2...6....4......55...2
                                   61155546    .....3..2..53.....2..2.3.3....
                                   33245361    ......1...2..43...3.13........
                                   52241654    ...2.........4..54...2.3..62..
                                   63212356    22.......332..1.....5......6..
                                   24414663    ...5..3.4....3....5.241 ...
                                   63661414    ......63.1......6...5.4.....
                                   45555223    ..2.4..5.........52.4.....44.
                                   14364433    2.55.....2......6.....6..3..5..
                                   21461416    ...5........4...6341.4..2..
```

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
00000000   000000   0000   ●00000 00   0
00   000000000   0000000   00000000000000000

The development of ICAR

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, 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.

Introduction
○○○○○○○○○
○○

Motivation
○○○○○○○
○○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○●○○○
○○○○○○○○○○○○○○○○

psych
○○

Conclusion
○

References

The development of ICAR

Example ICAR items

Matrix Reasoning
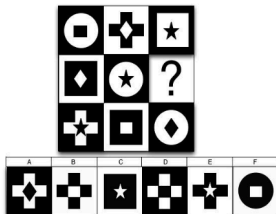
Verbal Reasoning

What number is one fifth of one fourth of one ninth of 90

(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
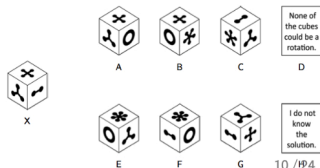
Item information for the ICAR 16

1. In the spirit of open science, data for 4000 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.

Item information from factor analysis
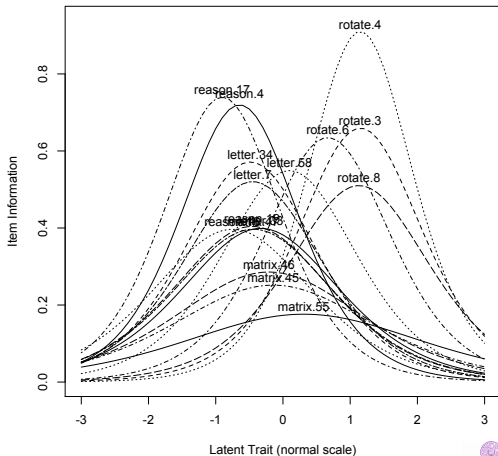
Introduction   Motivation   SAPA data   **ICAR**   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○●○   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○○○○○○○○○○○○
The development of ICAR

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).

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○●   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○○○○○○○○○○○○
The development of ICAR

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).

Introduction
○○○○○○○○
○○

Motivation
○○○○○○○
○○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○○○○
●○○○○○○○○○○○○○○

psych
○○

Conclusion
○

References

Extensions and applications of ICAR

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.
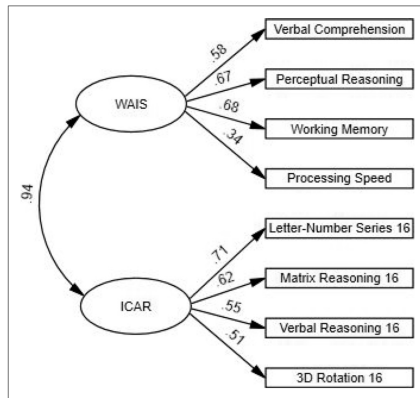
ICAR over time: examing the Flynn Effect

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.
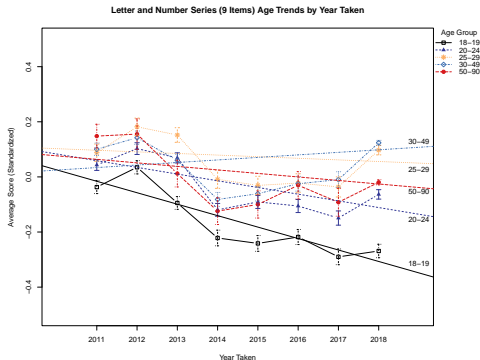
Letter and Number Series (9 Items) Age Trends by Year Taken

ICAR changes over 8 years by age vary by subtest

LN

MR

VR
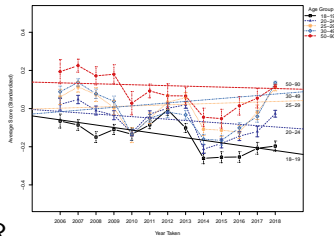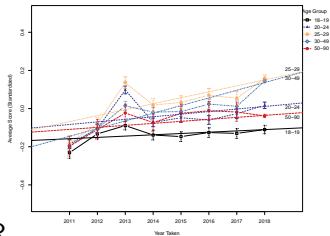
3DR

ICAR extensions: Compound Remote Associates Test

1. Mednick (1962) 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
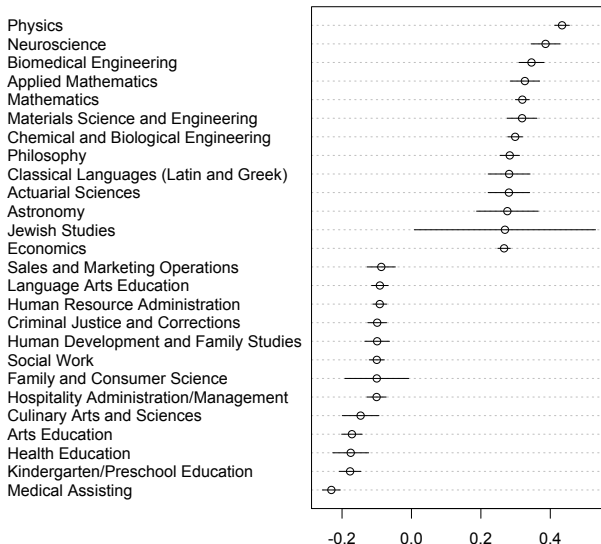
The percentiles of scores on the CRAT as well as Letter-Number series, Matrix Reasoning, 3 dimensional rotation, Verbal Reasoning, Figural Analogies and Propositional Reasoning are shown as well (Mather et al., 2024)

NORTHWESTERN
UNIVERSITY

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○○○   ○○○○   ○○○○○○○   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○●○○○○○○○○○○   ○○
Extensions and applications of ICAR

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)

Introduction   Motivation   SAPA data   ICAR   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○○   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○○○●○○○○○○○○
Extensions and applications of ICAR

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.

Introduction
OOOOOOO
OO

Motivation
OOOOOO
OOOOOOOOO

SAPA data
OOOO
OOOOOOO

ICAR
OOOOOO
OOOOOOO●OOOOOOO

psych
OO

Conclusion
O

References

Extensions and applications of ICAR

ICAR60 by major

Introduction
○○○○○○○○
○○

Motivation
○○○○
○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○○○○
○○○○○○○○○●○○○○○○○

psych
○○

Conclusion
○

References

Extensions and applications of ICAR

Compound Remote Associates by major

Introduction
○○○○○○○○
○○

Motivation
○○○○○○○○○
○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○○○○
○○○○○○○○○○●○○○○○○

psych
○○

Conclusion
○

References
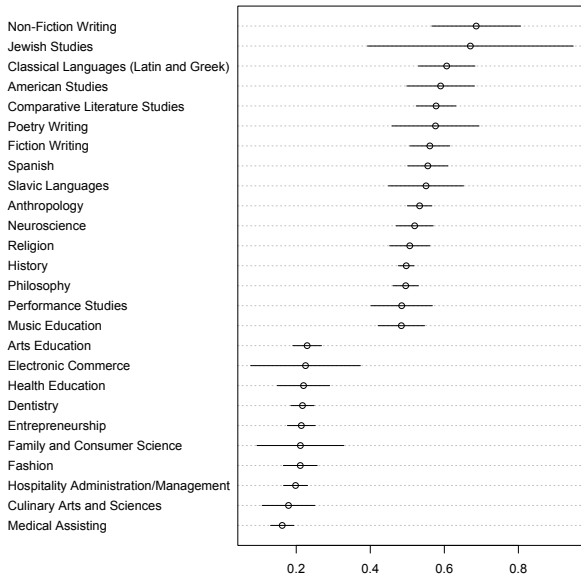
Extensions and applications of ICAR

3D rotation by major
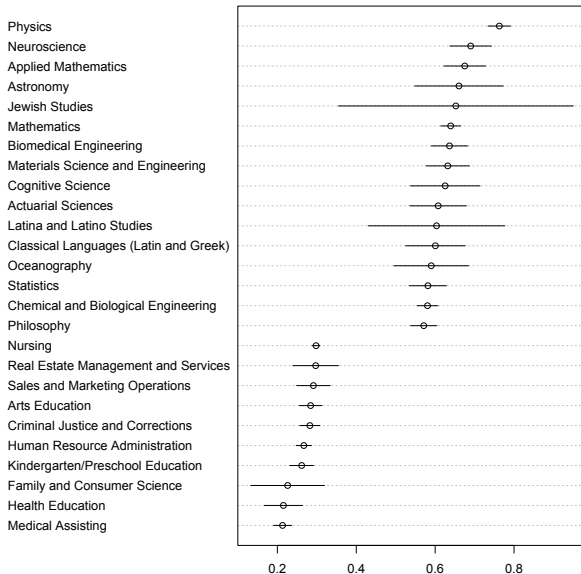
Introduction   Motivation   SAPA data   **ICAR**   psych   Conclusion   References
○○○○○○○○   ○○○○○○   ○○○○   ○○○○○○   ○○   ○
○○   ○○○○○○○○○   ○○○○○○○   ○○○○○○○○○○○●○○○○○
Extensions and applications of ICAR

Matrix Reasoning by major
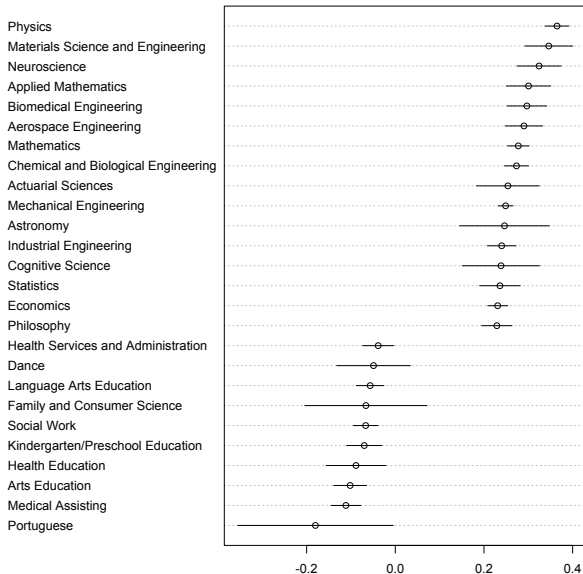
Extraversion by major

Conscientiousness by major

Introduction
○○○○○○○○
○○

Motivation
○○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○○○○
○○○○○○○○○○○○○○●○

psych
○○

Conclusion
○

References
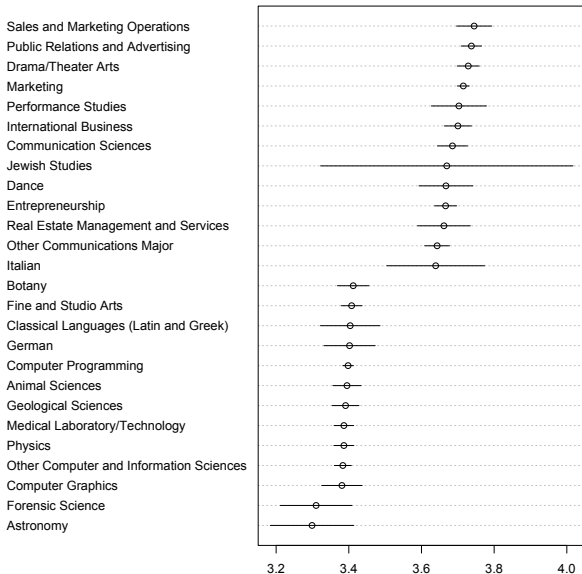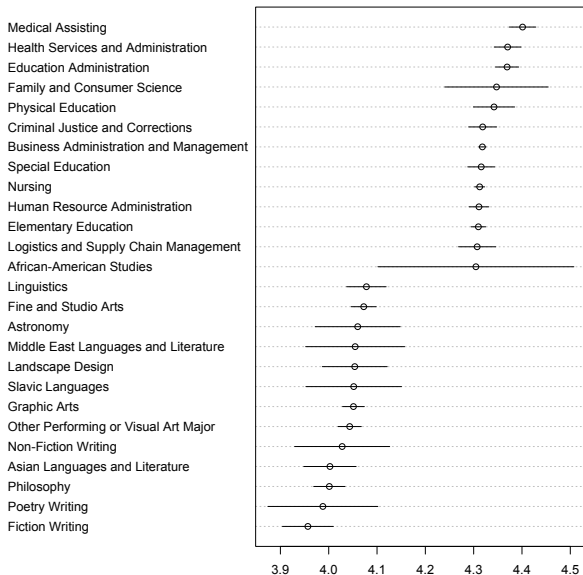
Extensions and applications of ICAR

Conservatism by major

Introduction
○○○○○○○○
○○

Motivation
○○○○○
○○○○○○○○○

SAPA data
○○○○
○○○○○○○

ICAR
○○○○○○
○○○○○○○○○○○○○○○●

psych
○○

Conclusion
○

References
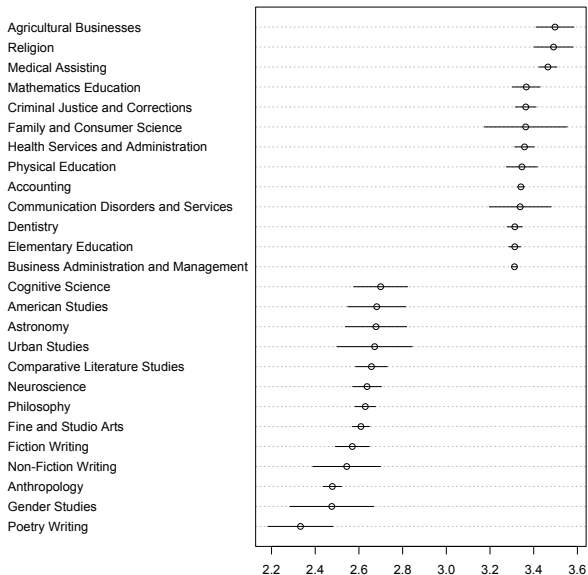
Extensions and applications of ICAR

Gender by major
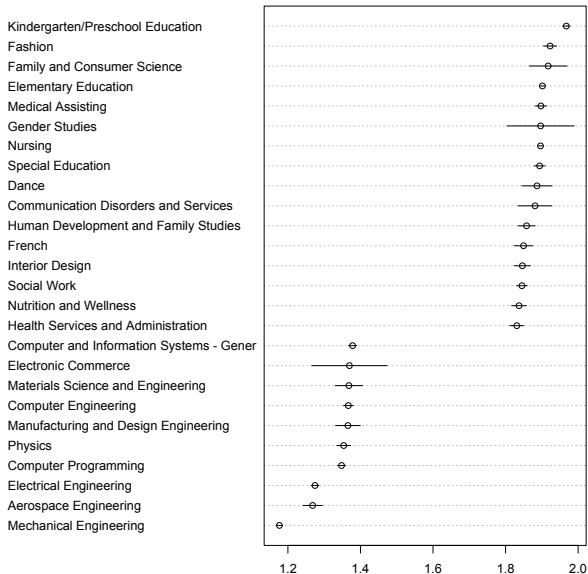
The psych package for R

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.

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.

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

Ackerman, P. L. (1996). A theory of adult intellectual development: Process, personality, interests, and knowledge. *Intelligence*, 22(2):227–257.

Ackerman, P. L. (1997). Personality, self-concept, interests, and intelligence: Which construct doesn't fit? *Journal of Personality*, 65(2):171–204.

Ackerman, P. L. (2018). The search for personality–intelligence relations: Methodological and conceptual issues. *Journal of Intelligence*, 6(2).

Ackerman, P. L. and Heggestad, E. D. (1997). Intelligence, personality, and interests: Evidence for overlapping traits. *Psychological Bulletin*, 121(2):219–245.

Anderson, J., Lin, H., Treagust, D., Ross, S., and Yore, L. (2007). Using large-scale assessment datasets for research in science and mathematics education: Programme for International Student Assessment (PISA). *International Journal of Science and Mathematics Education*, 5(4):591–614.

Anderson, K. J. and Revelle, W. (1982). Impulsivity, caffeine, and proofreading: A test of the Easterbrook hypothesis. *Journal of Experimental Psychology: Human Perception and Performance*, 8(4):614–624.

Anderson, K. J. and Revelle, W. (1983). The interactive effects of caffeine, impulsivity and task demands on a visual search task. *Personality and Individual Differences*, 4(2):127–134.

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

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

Bowden, E. M. and Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, & Computers*, 35(4):634–639.

Brauer, K. and Proyer, R. T. (2024). Introduction to the special issue "personality and individual differences". *Journal of Intelligence*, 12(8).

Condon, D. M. (2018). The SAPA Personality Inventory: An empirically-derived, hierarchically-organized self-report personality assessment model. *PsyArXiv*.

Condon, D. M. and Revelle, W. (2014). The International Cognitive Ability Resource: Development and initial validation of a public-domain measure. *Intelligence*, 43:52–64.

Coombs, C. and Avrunin, G. S. (1977). Single-peaked functions and the theory of preference. *Psychological Review*, 84(2):216 – 230.

Cronbach, L. J. and Snow, R. E. (1981). *Aptitudes and instructional methods: A handbook for research on interactions*. Irvington, New York.

Dworak, E. M., Revelle, W., and Condon, D. M. (2023). Looking

for Flynn effects in a recent online U.S. adult sample: Examining shifts within the SAPA project. *Intelligence*, 98.

Dworak, E. M., Revelle, W., Doebler, P., and Condon, D. M. (2021). Using the International Cognitive Ability Resource as an open source tool to explore individual differences in cognitive ability. *Personality and Individual Differences*, 169.

Eysenck, H. (1983). Is there a paradigm in personality research? *Journal of Research in Personality*, 17(4):369 – 397.

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

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

Eysenck, M. W. (1979). Anxiety, learning, and memory: A reconceptualization. *Journal of Research in Personality*, 13(4):363–385.

Geen, R. G. (1984). Preferred stimulation levels in introverts and extroverts: Effects on arousal and performance. *Journal of Personality and Social Psychology*, 46(6):1303 – 1312.

Goldberg, L. R. (1999). A broad-bandwidth, public domain, personality inventory measuring the lower-level facets of several five-factor models. In Mervielde, I., Deary, I., De Fruyt, F., and Ostendorf, F., editors, *Personality psychology in Europe*, volume 7, pages 7–28. Tilburg University Press, Tilburg, The Netherlands.

Goldberg, L. R., Johnson, J. A., Eber, H. W., Hogan, R., Ashton, M. C., Cloninger, C. R., and Gough, H. G. (2006). The international personality item pool and the future of public-domain personality measures. *Journal of Research in Personality*, 40(1):84–96.

Gray, J. A. (1970). The psychophysiological basis of introversion-extraversion. *Behaviour Research and Therapy*, 8(3):249–266.

Gühne, D., Doebler, P., Condon, D. M., Luo, F., and Sun, L. (2020). Validity and reliability of automatically generated propositional reasoning items: A multilingual study of the challenges of verbal item generation. *European Journal of Psychological Assessment*.

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

Kanfer, R., Ackerman, P. L., and Cudeck, R. (2014). *Abilities, motivation and methodology: the Minnesota Symposium on Learning and Individual Differences*. Routledge.

Kulik, J. A., Revelle, W. R., and Kulik, C. (1970). Scale construction by hierarchical cluster analysis. University of Michigan, unpublished paper.

Leon, M. R. and Revelle, W. (1985). Effects of anxiety on

analogical reasoning: A test of three theoretical models. *Journal of Personality and Social Psychology*, 49(5):1302–1315.

Liebert, M. (2006). A public-domain assessment of music preferences as a function of personality and general intelligence. Honors Thesis. Department of Psychology, Northwestern University.

Loe, B., Sun, L., Simonfy, F., and Doebler, P. (2018). Evaluating an automated number series item generator using linear logistic test models. *Journal of Intelligence*, 6(2):20.

Lord, F. M. (1955). Estimating test reliability. *Educational and Psychological Measurement*, 15:325–336.

Lord, F. M. (1977). Some item analysis and test theory for a system of computer-assisted test construction for individualized instruction. *Applied Psychological Measurement*, 1(3):447–455.

Mather, K. A. and Condon, D. M. (2023). Development of a public-domain measure of two-dimensional rotation ability and

preliminary evidence for discriminant validity among occupations. *Journal of Intelligence*, 11(10).

Mather, K. A., Weston, S. J., and Condon, D. M. (2024). Scaling a common assessment of associative ability: Development and validation of a multiple-choice compound remote associates task. *Behavior Research Methods*, 56(7):1–29.

McPherson, W. B. (1901). Gideon's water-lappers. *Journal of the American Oriental Society*, 22:70–75.

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, 69(3):220–232.

Newcomb, T. M., Brown, D. R., Kulik, J. A., D. J. Reimer, D., and Revelle, W. (1970). Self selection and change. In Gaff, J., editor, *The Cluster College*. Jossey-Bass, San Francisco.

Newcomb, T. M., Brown, D. R., Kulik, J. A., Reimer, D. J., and Revelle, W. (1971). The University of Michigan's Residential College. In *The New Colleges: Towards an Appraisal*. American College Testing Program, Iowa City.

Introduction
00000000
00

Motivation
000000000
000000000

SAPA data
0000
0000000

ICAR
000000
00000000000000

psych
00

Conclusion
0

References

Plato (n.d.). *Plato The Republic : the complete and unabridged Benjamin Jowett translation (1892)*. Oxford Univeristy Press, Oxford, 3rd edition.

R Core Team (2025). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Revelle, W. (2025). *psych:Procedures for Psychological, Psychometric, and Personality Research*. Northwestern University, Evanston, https://CRAN.r-project.org/package=psych, 2.5.3 edition. R package version 2.5.3.

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

Revelle, W., Anderson, K. J., and Humphreys, M. S. (1987). Empirical tests and theoretical extensions of arousal-based

theories of personality. In Strelau, J. and Eysenck, H., editors, *Personality Dimensions and Arousal*, pages 17–36. Plenum, New York.

Revelle, W. and Condon, D. M. (2019). Reliability from α to ω: A tutorial. *Psychological Assessment.*, 31(12):1395–1411.

Revelle, W., Condon, D. M., Wilt, J., French, J. A., Brown, A., and Elleman, L. G. (2017). Web and phone based data collection using planned missing designs. In Fielding, N. G., Lee, R. M., and Blank, G., editors, *Sage Handbook of Online Research Methods*, chapter 37, pages 578–595. Sage Publications, Inc., 2nd edition.

Revelle, W., Dworak, E. M., and Condon, D. M. (2020). Cognitive ability in everyday life: the utility of open source measures. *Current Directions in Psychological Science*, 29(4):358–363.

Revelle, W., Humphreys, M. S., Simon, L., and 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.

Revelle, W. and Loftus, D. A. (1990). Individual-differences and arousal - implications for the study of mood and memory. *Cognition and Emotion*, 4(3):209–237.

Revelle, W. and Loftus, D. A. (1992). The implications of arousal effects for the study of affect and memory. In Christianson, S.-A., editor, *The handbook of emotion and memory: Research and theory*, pages 113–149. Lawrence Erlbaum Associates, Inc, Hillsdale, NJ, England.

Revelle, W., Wilt, J., and Rosenthal, A. (2010). Individual differences in cognition: New methods for examining the personality-cognition link. In Gruszka, A., Matthews, G., and Szymura, B., editors, *Handbook of Individual Differences in Cognition: Attention, Memory and Executive Control*, chapter 2, pages 27–49. Springer, New York, N.Y.

Shipley, W. C. (2009). *Shipley-2: manual*. Western Psychological Services.

Tolman, E. C. and Honzik, C. (1930). Introduction and removal of reward, and maze performance in rats. *University of California Publications in Psychology*, 4:257–275.

Tryon, R. (1957). Communality of a variable: Formulation by cluster analysis. *Psychometrika*, 22(3):241–260.

Tryon, R. (1959). Domain sampling formulation of cluster and factor analysis. *Psychometrika*, 24(2):113–135.

von Stumm, S., Chamorro-Premuzic, T., and Ackerman, P. (2011). Re-visiting intelligence–personality associations. In Chamorro-Premuzic, T., Furnham, A. F., and von Stumm, S., editors, *The Wiley-Blackwell Handbook of Individual Differences*, pages 217–241. Wiley-Blackwell.

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

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

Young, S. R. and Keith, T. Z. (2020). An examination of the convergent validity of the icar16 and wais-iv. *Journal of Psychoeducational Assessment*, 0(0):0734282920943455.

Young, S. R., Keith, T. Z., and Bond, M. A. (2019). Age and sex invariance of the International Cognitive Ability Resource (ICAR). *Intelligence*, 77:101399.

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