ICAR News

Issue One
09 | 15

Editorial

by David M. Condon

Welcome to the first volume of ICAR News, the newsletter of the ICAR project for public-domain measures of cognitive ability. ICAR News will feature short articles about topics of interest to users or developers of the International Cognitive Ability Resource, including:

- Changes or updates to existing ICAR item types
- New item types: short introductions and reviews about ICAR item types
- Development tools: discussion of useful and novel approaches for developing new types
- Methodology: advice and discussion about methods for validation and analysis
- Profiles of ICAR applications and developers

The editors of ICAR News currently includes several of the lead investigators of the ICAR Project: David Condon, Philipp Doebler, Heinz Holling, William Revelle, John Rust, and Luning Sun (see below for profiles).

in this **issue**

This first volume includes a short piece by Philipp Doebler on the design process of an item generator for figural analogy items.

This newsletter is intended to fill the gap between correspondence on the **ICAR wiki** and scientific journal publications. Submission from outside users are welcome -- in fact, the submission of high quality articles on topics of interest to the ICAR community is critical to the success of ICAR news. No formal review process currently exists, but articles will be reviewed by the editorial board to ensure the quality of the newsletter. Submissions should be sent to the editors via email to **admin@icar-project.com**.

We hope that you will find this newsletter to be a useful resource for implementations of the International Cognitive Ability Resource and for cognitive ability research more generally. And, we're also very thankful for your enthusiastic and ongoing support so far in the development of this public-domain resource!

David M. Condon
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ICAR at a glance

by the ICAR core team

The International Cognitive Ability Resource (ICAR) is a public-domain and open-source tool that aims to provide a large dynamic bank of cognitive ability measures for use in a variety of applications. Since 2014, ICAR has been funded by a grant from the Open Research Area (ORA) for the Social Sciences which includes participation from national funding agencies in the United States (NSF), Germany (DFG), and the United Kingdom (ESRC).

By encouraging the use, revision, and ongoing development of public-domain cognitive ability measures among qualified research groups, ICAR will further understanding about the structure of cognitive abilities as well as the nature of associations between cognitive ability constructs and other variables. ICAR draws heavily on automatic item

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The ICAR Wiki

The growing Wiki offers public domain resources.

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generation techniques which yield items with predictable psychometric qualities. The impact of this international collaboration will be the creation of a platform for more standardized assessment and more rapid scientific progress among the disciplines and research groups which use cognitive ability measures to diagnose impairments, evaluate the correlates of various abilities, and predict important life outcomes.

Profiles of key investigators from each of the participating labs are given below.

David Condon is currently an Assistant Professor in the Department of Medical Social Sciences at Northwestern University in the United States. In addition to the development of cognitive ability assessment tools, David's research interests include evaluation of the relationships between cognitive ability and personality, interests, health and creative achievement.

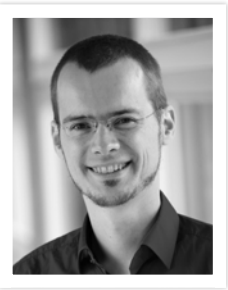
Philipp Doebler is the prinicipal investigator of the Münster core ICAR team. Since finishing a math PhD in 2010, Philipp has been working in the statistics and quantitative methods group at the Institute of Psychology, at the University of Münster. Currently, Philipp serves as an interim professor at the University of Ulm. His research interests include automatic item generation, item response theory models and meta-analysis. Philipp contributes to ICAR generators for figural analogies, matrices and number sequences as well as item response theory analyses.

Luning Sun is Research Director of The Psychometrics Centre, University of Cambridge, UK. He completed his PhD at the University of Cambridge in 2014 with the support of a Gates Scholarship. His research focuses on the application of advanced psychometric techniques in neuropsychological assessment. Luning is working with his colleagues on the construction of item models for a range of measures, including face perception test, facial expression recognition test, executive function test, etc.

William Revelle is Professor of Psychology at Northwestern University where he studies the structure of temperament, ability, and interests using large scale, web based assessments taking advantage of the SAPA (Synthetic Aperture Personality Assessment) technique. His research includes models and data for personality and individual differences at three levels of analysis: within people, between people, and between groups of people. He is also the author of the general purpose psychometrics and data analysis package, psych, in the R statistical system.

the **contributors**

David Condon



Philipp Doebler

Luning Sun

William Revelle

Heinz Holling is a full professor at the Institute of Psychology of the University of Münster and head of the statistics and quantitative methods group. He works in the fields of optimal design, conjoint-analysis, adaptive testing, intelligence and automatic item generation. In a recent series of DFG funded projects and PhD theses, Heinz created automatic item generators for a wide range of cognitive abilities and is now contributing his expertise to ICAR.

Heinz Holling

John Rust is Director of The Psychometrics Centre at the University of Cambridge and Director of Research in the Department of Psychology, and also a Senior Member of Darwin College. John combines a huge academic and intellectual reputation in the field of testing and assessment with practical applications experience in a range of blue chips. His work ranges from the investigation of advanced statistical and computational techniques for use in test development, to the UK standardisations of widely used psychometric tests. He has authored several well-known tests, including Orpheus (a work based personality test), Giotto (an integrity test), RANRA (a test of numerical reasoning ability), GRIMS and GRISS (assessments of personal relationships), and RISC (an assessment of clinical state).

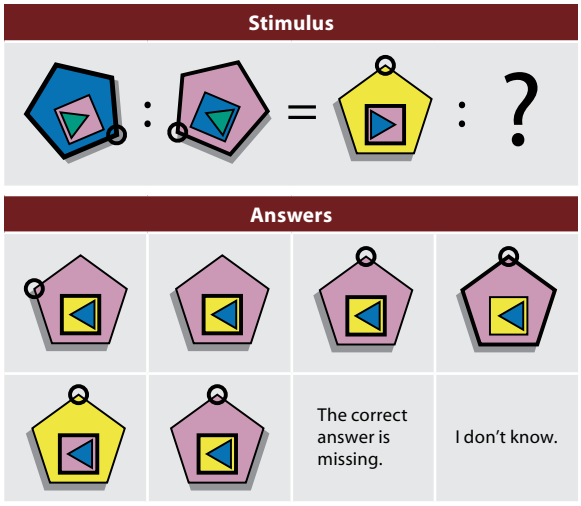
John Rust

The Figural Analogies Development Process

by Philipp Doebler

Figural analogies are classic reasoning tasks. The ICAR project chose figural analogies not only because of the established type of item format, but also because automated item generation (AIG) had been demonstrated before. In addition, figural analogies can be considered culture free, in the sense that neither cultural references nor verbal or semantic abilities are needed to solve those items. In this short article, I will give an overview of the design process of the figural analogies generator, focusing on the intricacies of the item generator design rather than standard procedures for validation of test material.

Figure 1



A typical figural analogy item produced by the ICAR generator. The shape is mirrored at the vertical and two colors are swapped and hence the third answer is correct.

Figure 1 shows a sample output of the ICAR item generator. Abstracting a bit, a typical analogical reasoning item is of the form:

A is to B as C is to D

where the test taker will have to pick D from a list. The As, Bs, Cs and Ds are geometric shapes that are inspired by graphical compositions of the Swiss architect and designer Max Bill. As a starting point, I conducted an **analysis of the cognitive process** behind analogical reasoning items. I radically reduced this analysis to a simplified two step process:

1. Identify the rule that leads from A to B.
2. Apply this rule to C mentally to obtain D.

Obviously real test takers will deviate from this strategy using heuristics (and maybe even meta-heuristics) to choose their answer. However, when designing and programming item generators, such simplified models are helpful, since at some point, a fully automated generator follows a very similar procedure to produce items.

Based on earlier work in our group, especially a series of research projects and a number of PhD theses written under the supervision of Heinz Holling, I identified rules (or radicals in the terminology of automatic item generation) that can govern the relationship of A and B. The rules shown in Table 1 were implemented.

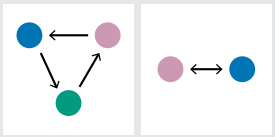
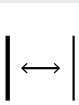
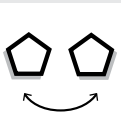
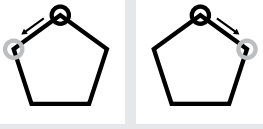
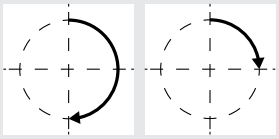
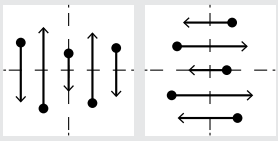
figural analogies **team**

Ehsan Masoudi

The Figural Analogies Generator has been developed by the Münster core ICAR Team. In particular, Ehsan Masoudi did most of the programming, while Philipp Doebler was responsible for concept, design and additional programming.

Contact the Team

Table 1: Radicals for figural analogy items

Radicals	Graphical Cue(s)
Swap colors	
Swap line width	
Swap shadow	
Wandering circle	
Rotation	
Mirroring	

Programming was mostly done by Ehsan Masoudi in R, since R provides a relatively easy to use graphical system along with statistical tools. In addition, R is the backbone of the **Concerto platform** that the Cambridge ICAR core team actively develops. Also, R features an informal **object oriented programming** (OOP) system (the S3 class system), which allowed us to structure the representations of items in R. Our aim was to produce a generator that could be employed to make booklets as well as online tests. The generator allows (almost) arbitrary combinations of radicals, though it is not advisable to administer any items that use more than three rules.

An automatic item generator combines radicals with **incidentals**, which could be labelled surface features of the items, to create stimuli, attractors and distractors. In our case, the incidentals were the geometric Bill shapes. These were represented in R as objects in the sense

Find out more about the Concerto Platform here:

Concerto Platform

of OOP. After writing helper functions to plot the Bill shapes with a **color-blind friendly palette**, we wrote functions that would take a radical (or a combination of radicals) and a Bill shape as input and would apply the radical(s) to the shape to produce a new shape. For example, the leftmost shape in Figure 1 might serve as an input, together with the combination of radicals *vertical mirroring* and *swap the two outer colors*, to produce the second leftmost shape.

Combinations of radicals form **item families**. In the context of AIG the radicals are the central component of an items, and the incidentals are needed to produce many members of an item family. If a member of an item family is to be generated, the ICAR figural analogies generator will proceed as follows: After randomly generating shapes A and C, the combination of radicals will be applied to A to generate B and the attractor D. The attractor will then be mixed with a set of distractors. Occasionally, one might want to not present an attractor. Whether the attractor is shown or not can be regarded as an additional radical, as this clearly influences the psychometric properties of the items.

Distractor generation deserves special attention in AIG, since psychometric features will crucially depend on the quality of the distractors. A naïve strategy might be to systematically create all possible answers and randomly choose from them a set of distractors. However, this is prone to creating very easy items. In the figural analogy design process we came back to the simplified cognitive analysis to create distractors: Assuming a test taker is not able to identify the rule that governs the change from shape A to shape B, she or he might have nevertheless identified part of the correct rule. Starting from a combination of radicals, the ICAR generator adds, deletes or swaps rules to create proximate combinations of rules. These are applied to shape C to create distractors. For example, in Figure 1 the fifth distractor is produced by omitting the color swap rule.

The ICAR figural analogies generator is currently being validated. Readers of the ICAR news that are interested to see the generator in action can find it in the sidebar.

Wrapping up, the generator, given a set of rules, will produce items that can be useful in many contexts. One or two rule items are generally easier than more complex combinations, so the generator can cater to a wide audience of test takers. Since the generation process starts from random shapes, the generator will yield many different members for each combination of rules. This makes it a tool to produce “google-safe” items, that are also suitable to create parallel tests for repeated measurement.

Read more on color-blind friendly functionality here (courtesy of j*fly):

➲ **Color-Blind Friendly Palette**

the figural analogies **test**

Readers of the ICAR news that are interested to see the generator in action can find it here:

➲ **The ICAR Figural Analogies Test (EN)**

The implementation is multilingual and a german version also exists:

➲ **The ICAR Figural Analogies Test (GER)**

The ICAR core team consists of:

- Prof. William Revelle and Dr. David Condon from Northwestern University, United States
- Dr. Philipp Doebler and Prof. Heinz Holling from University of Münster, Germany
- Prof. John Rust, Dr. Michal Kosinski, Dr. David Stillwell, Dr. Luning Sun, Fiona Chan and Aiden Loe from University of Cambridge, United Kingdom

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