

# Intelligence: a matter of (re)copying ?

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# Intelligence versus G

- no global agreement
- no clear definition
- G-factor, (G)eneral intelligence, (G)eneral mental ability, (G)..., etc.
- due to [Charles Spearman](#)

Nevertheless...

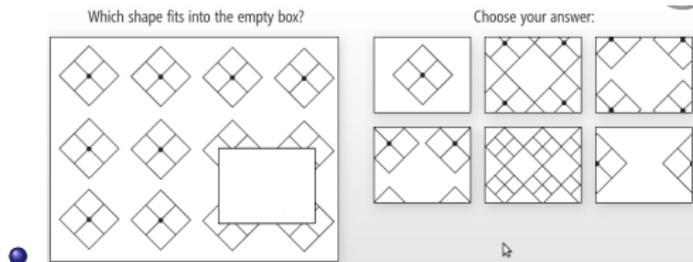
- numerous attempts to measure intelligence or G for an individual
- IQ tests
- large varieties of tests

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# IQ tests examples

Vocabulary based:

1) Which same three-letter word can be placed in front of the following words to make a new word?

SIGN, DONE, DUCT, FOUND, FIRM, TRACT, DENSE

2) ABC ABD IJJKK ?

Numerical tests:

# IQ tests examples

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Which number fits instead of a question mark?

Choose your answer:

451	125	154
104	54	87

52 25 77 77 ? 451 605

# From IQ tests to Raven matrices

Graphic-based tests:

If you disassemble the block, which piece would be missing?

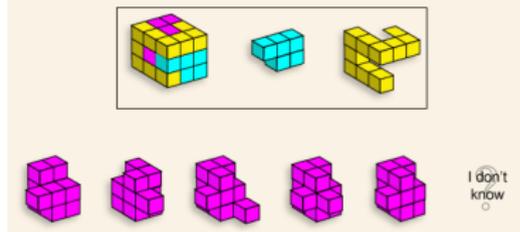


I don't know

# From IQ tests to Raven matrices

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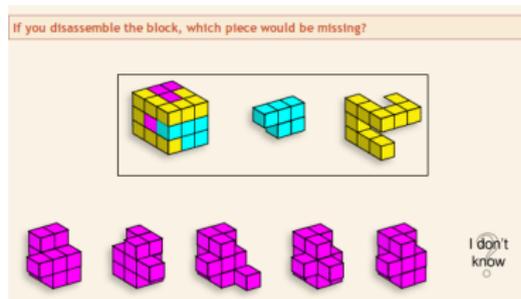


“Exotic tests”

- [www.test-my-iq.co.uk](http://www.test-my-iq.co.uk)
- Brad Pitt 126
- First: Hong Kong (110) Last: Zambia (60)

# From IQ tests to Raven matrices

Graphic-based tests:



“Exotic tests”

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Lessons learned ...

- avoid cultural bias → no vocabulary-based or numerical tests
- avoid color → black and white tests
- something is missing !

# Raven matrices

General pattern to be followed:

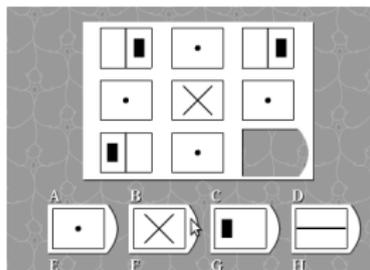
- a sequence to be completed
- the solution has to be chosen among a set of candidates
  - John Raven (1936)
  - 3 batteries of visual tests: standard - colored - advanced
  - previous rules adopted
  - each test = matrice of 8 pictures to be completed with a 9th one
  - the solution to be chosen among a set of 8 candidate pictures
  - increasing difficulty (Raven's Progressive Matrices)

# Raven matrices

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Example of Raven test (modified)



# To complete a sequence ?

- how ? LOGICALLY ;-)
- abc abd ijk ?
- ijk ? no way !
- ijl ... better

the main idea:

## ANALOGY MAKING !

- build up an analogical proportion starting from 3 items  $a, b, c$
- pb to be solved: “find the 4th element  $d$  such that  $a : b :: c : d$ ”
- ability to build up/discover analogy: essential skill of human intelligence !

# Analogical proportions: Boolean view

- 4 items  $a, b, c, d$
- informally: dissimilarity of  $(a, b) =$  dissimilarity of  $(c, d)$ .
- Boolean view: **dissimilarity** indicators:  $a \wedge \bar{b}$  and  $\bar{a} \wedge b$

$$a : b :: c : d$$

iff

$$a \wedge \bar{b} = c \wedge \bar{d} \text{ and } \bar{a} \wedge b = \bar{a} \wedge b$$

- Standard properties :
  - 1 basic patterns  $a : b :: a : b$  and  $a : a : b : b$
  - 2 symmetry  $a : b :: c : d \rightarrow c : d :: a : b$
  - 3 central permutation  $a : b :: c : d \rightarrow a : c :: b : d$
  - 4 transitivity  $a : b :: c : d$  and  $c : d :: e : f \rightarrow a : b :: e : f$
  - 5 equivalent to:  $a \wedge d = b \wedge c$  and  $a \vee d = b \vee c$
  - 6 and a lot more...

# Analogical proportion: other patterns

- Truth table (**6 lines** (among  $2^4 = 16$ ) lead to truth value 1 )

0	0	0	0
1	1	1	1
0	0	1	1
1	1	0	0
<b>0</b>	<b>1</b>	<b>0</b>	<b>1</b>
<b>1</b>	<b>0</b>	<b>1</b>	<b>0</b>

- Equation solving: we have 3, find the 4th one (if you can !)
- $110? \rightarrow 0$ ,  $010? \rightarrow 1$ ,  $100? \rightarrow$  **no solution**
- Boolean vector extension:

$$\vec{a} : \vec{b} :: \vec{c} : \vec{d} \text{ iff } \forall i \in [1, n], a_i : b_i : c_i : d_i$$

- Functional extension :  $a : f(a) :: b : f(b)$

# Raven test: a Boolean analysis

Raven matrix: 8 known pictures - 1 unknown picture  $pic[3,3]$

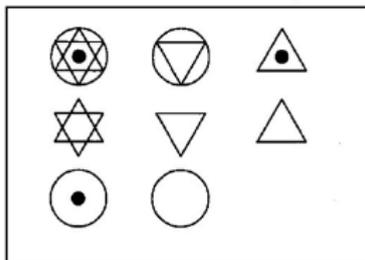
$pic[1, 1]$	$pic[1, 2]$	$pic[1, 3]$
$pic[2, 1]$	$pic[2, 2]$	$pic[2, 3]$
$pic[3, 1]$	$pic[3, 2]$	$pic[1, 3]$

- Working hypothesis 1:** rows/columns = samples of (unknown) functional dependencies
  - $\forall i \in [1, 2], \exists f$  tel que  $pic[i, 3] = f(pic[i, 1], pic[i, 2])$  (row)
  - $\forall j \in [1, 2], \exists g$  tel que  $pic[3, j] = g(pic[1, j], pic[2, j])$  (column)
- Working hypothesis 2:** extended analogical proportion to solve  
 $(a,b):f(a,b)::(c,d):f(c,d)$  for row  
 $(a,b):g(a,b)::(c,d):g(c,d)$  for column

$$(pic[1, 1], pic[1, 2]) : pic[1, 3] :: (pic[2, 1], pic[2, 2]) : pic[2, 3]$$
$$(pic[2, 1], pic[2, 2]) : pic[2, 3] :: (pic[3, 1], pic[3, 2]) : pic[3, 3]$$

# A complete example

- 1 Boolean coding  
Raven test

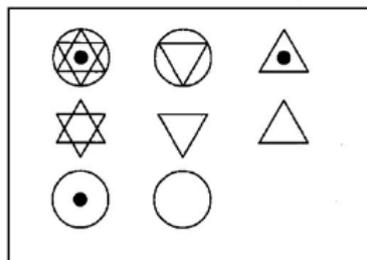


# A complete example

## 1 Boolean coding

Raven test

Features



- Black dot

- STriangle

- RTriangle

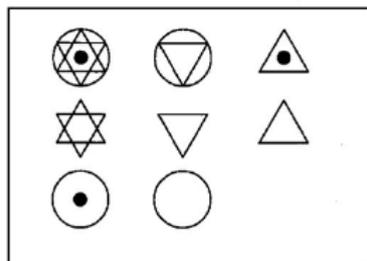
- Circle

# A complete example

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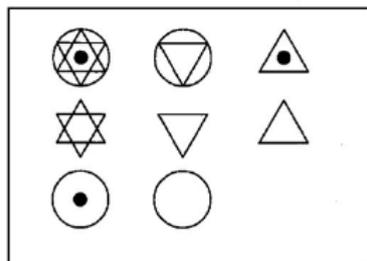
Coding

1111	0011	1100
0110	0010	0100
1001	0001	????

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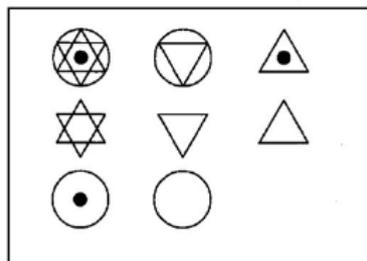
## 2 Equation solving process solution 1st feature →

# A complete example

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- Black dot

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Coding

1111 0011 1100

0110 0010 0100

1001 0001 **????**

## 2 Equation solving process

solution 1st feature → **1**

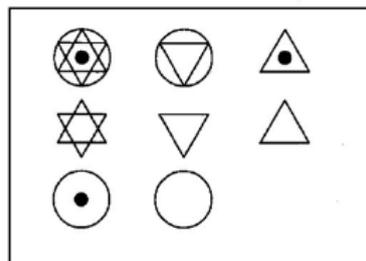
solution 2nd feature →

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Coding

1111 0011 1100

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1001 0001 **????**

## 2 Equation solving process

solution 1st feature → **1**

solution 2nd feature → **0**

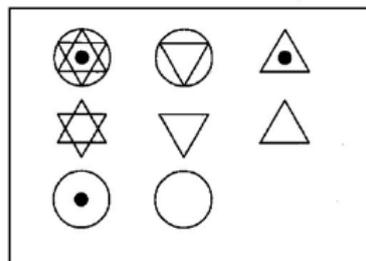
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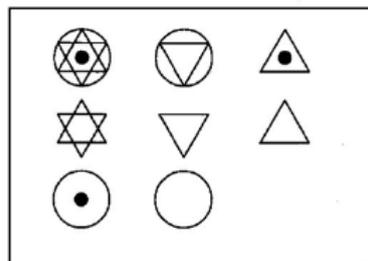
solution 3rd feature →

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1111	0011	1100
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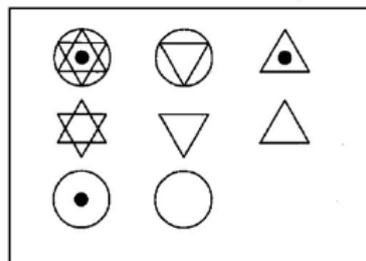
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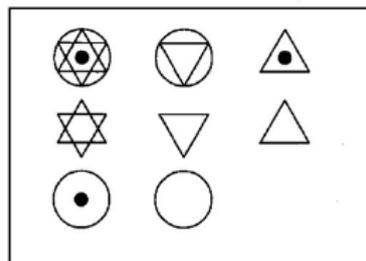
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# Algorithm...

- Immediate translation of the previous ideas
- Equation solving process
- With suitable Boolean encoding 32 / 36 automatically solved
- Solution build up from scratch ...

Drawbacks:

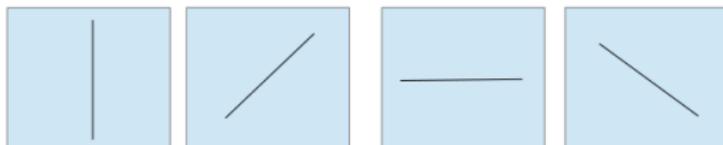
- We fail to solve 4 tests ... Why ?

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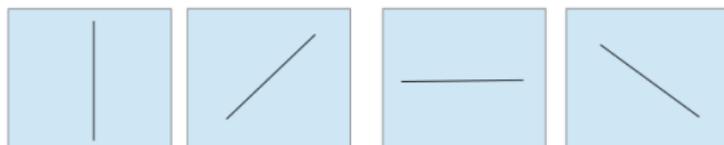


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- Manual encoding !

# Iphone encoding?

- Can we do it automatically ? **Yes we can ...**
- How? **Using a mobile phone ;-)** i.e. a camera
- Picture = matrix of pixel = BMP file
- Matrix of pixel = Boolean encoding ! (very,... very low level...)
- Algorithm still valid:  
input: **8 BMP files** - output: **the 9th BMP file !**
- 16 tests solved (among the 32 previously solved)!
- Constraints: same size - B&W - no compression

## Concluding remarks

- Simple, homogeneous and robust process to solve 32 / 36 Raven tests (except 4)
- Mainly (re)-copying previously seen solutions (Polya/CBR?)
- Constructive method
- Mix with SMT... and CogSketch to get automatic encoding ?
- Tested in classification problems, gives surprisingly good results !

Thank you !

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