The language of geometry: Fast comprehension of geometrical primitives and rules in human adults and preschoolers

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Introduction

The child's acquisition of language has been suggested to rely on the ability to build hierarchically structured representations from sequential inputs.

Research question: Does a similar mechanism underlie the acquisition of geometrical rules?

Why is this interesting? Might reveal a fundamental aspect of human cognition

Method

A formal language capable of describing, in a compact manner, all sequences of movements on a regular octagon.

0: stays in same location

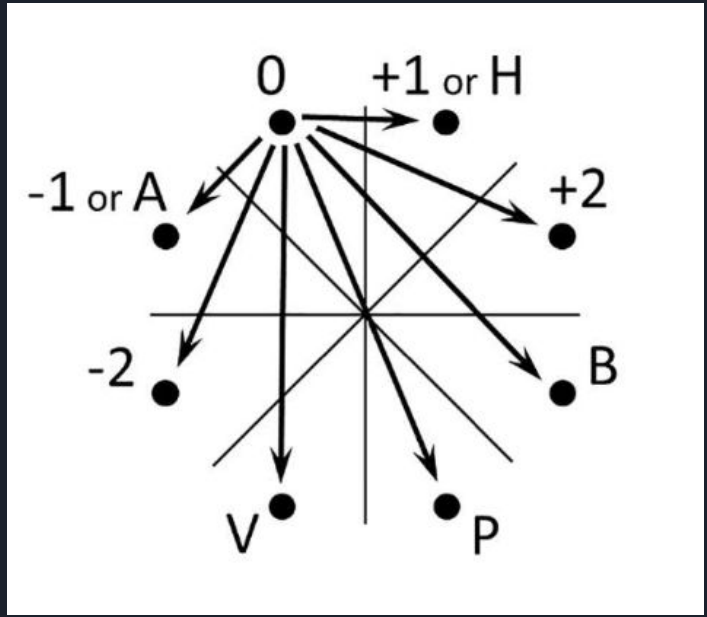
+1,+2: next element clockwise

-1,-2: next element counterclockwise

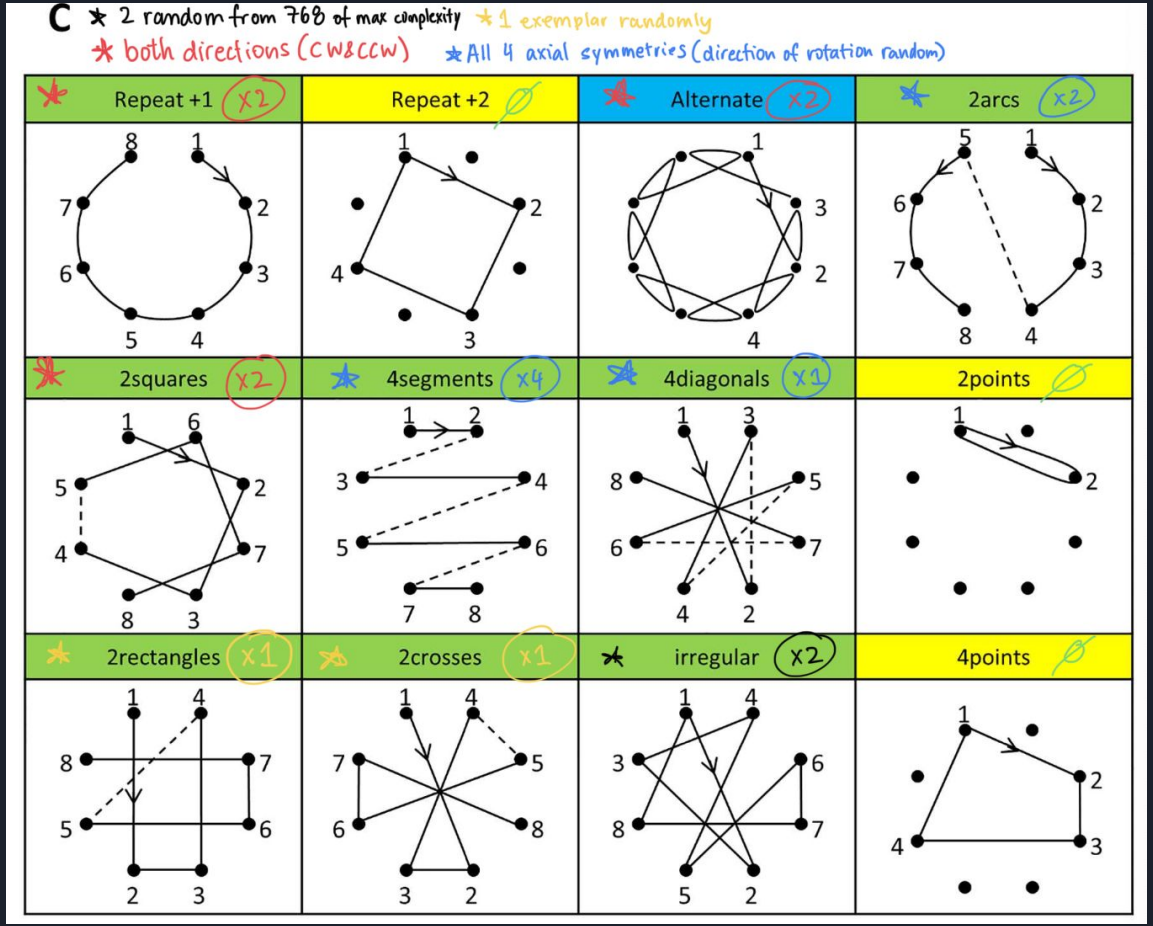
H,V: horizontal & vertical symmetry

P: rotational symmetry (+4)

A,B:symmetries around diagonal



Method

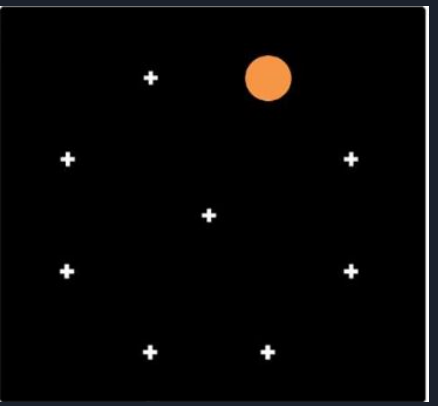


Total of 17 sequences

Experiment 1

Participants: 23 French adults (12 female; mean age 26.6; range 20–46)

1. The 8 dots of the octagon are always visible
2. First a simple CW or CCW “repeat +1”
3. For each participant the sequences are in a random order
4. First two elements of sequence are flashed (location 3)
5. Participant must guess the next location,
6. If incorrect, sequence is flashed again (1-3) with correct answer and participant must guess the following location (location 4)
7. Errors tracked from 3rd and 16th element of sequence
8. 17 sequences in total



Results

- Errors decrease over time (due to rote memory + anticipation)
- Error rate increases with sequence complexity
- Regular sequences learned better than irregular ones
- Quickly detected geometric regularities and generalized from few items

Results were different for preschoolers and uneducated adults

Experimental Environment and Static Stimuli

```
NUM_OF_DOT = 8
EXP_RADIUS = 150
DOT_RADIUS = 10
DOT_COLOR = "grey"
TRIGGERED_DOT_RADIUS = 15
TRIGGERED_DOT_COLOR = "yellow"

dot_positions = [
    (EXP_RADIUS * m.cos((t*2*m.pi/NUM_OF_DOT)+(m.pi/NUM_OF_DOT)),
     EXP_RADIUS * m.sin((t*2*m.pi/NUM_OF_DOT)+(m.pi/NUM_OF_DOT)))
    for t in range(NUM_OF_DOT)]

dots = [stimuli.Circle(radius = DOT_RADIUS, colour = DOT_COLOR,
                       position = p) for p in dot_positions]
```

- **Octagon Definition**

- **Visual Stimuli** : The `dots` list generates the 8 circles that are always visible

- **Feedback/Movement :** The `triggered_dots` list creates the dynamic elements used to flash successive locations during the sequence presentation, using `TRIGGERED_DOT_COLOR` ("yellow") and a larger radius (`TRIGGERED_DOT_RADIUS = 15`) to highlight the current position.

Sequences

Simple Sequences

```
C_sequences_ez = [(np.asarray([i for i in range(NUM_OF_DOT)]), "repeat cw"),
                  (np.asarray([NUM_OF_DOT-i-1 for i in range(NUM_OF_DOT)]), "repeat ccw")]
```

Regular Sequences

```
C_sequences = [(np.asarray([0,2,4,6,1,3,5,7]), "2squares cw"),
               (np.asarray([0,6,4,2,1,7,5,3]), "2squares ccw"),
               (np.asarray([0,2,1,3,2,4,3,5,4,6,5,7,6,0,7,1]), "alternate cw"),
               (np.asarray([0,6,7,5,6,4,5,3,4,2,3,1,2,0,1,6]), "alternate ccw"),
               (np.asarray([0,4,1,5,2,6,3,7]), "4diagonales cw"),
               (np.asarray([0,4,7,3,6,2,5,1]), "4diagonales ccw"),
               (np.asarray([1,2,3,4,0,7,6,5]), "2arcs cw"),
               (np.asarray([0,7,6,5,1,2,3,4]), "2arcs ccw"),
               (np.asarray([0,1,7,2,6,3,5,4]), "4segments cw"),
               (np.asarray([1,0,2,7,3,6,4,5]), "4segment ccw"),
               (np.asarray([0,5,4,1,6,3,2,7]), "2rectangles"),
               (np.asarray([0,4,5,1,2,6,7,3]), "2crosses")
               ]
```

Irregular sequence

- Makes sure it is not a simple or regular sequence
- Makes sure there is no repetition
- Makes sure there is no distinguished pattern

Trials

```
def run_trial(sequence_name, sequence):
    present_instructions(FIRST_INSTRUCTION)

    present_for(*dots)
    present_for(*dots + [triggered_dots[sequence[0]]])
    present_for(*dots + [triggered_dots[sequence[1]]])
    timed_draw(*dots)
    good_dot = wait_for_dot_click(sequence[2], dot_positions)
    i = 2
    while good_dot and i <= MAX_SEQ_SIZE :
        timed_draw(*dots + [clicked_dots[sequence[i%NUM_OF_DOT]]])
        i+=1
        good_dot = wait_for_dot_click(sequence[i%NUM_OF_DOT], dot_positions)
    i+=1

    while not(good_dot) and i <= MAX_SEQ_SIZE :
        present_for(*dots)
        for j in range(i):
            present_for(*dots + [triggered_dots[sequence[j%NUM_OF_DOT]]])
        timed_draw(*dots)
        good_dot = wait_for_dot_click(sequence[i%NUM_OF_DOT], dot_positions)
        while good_dot and i <= MAX_SEQ_SIZE :
            timed_draw(*dots + [clicked_dots[sequence[i%NUM_OF_DOT]]])
            i+=1
            good_dot = wait_for_dot_click(sequence[i%NUM_OF_DOT], dot_positions)
        i += 1
    # exp.data.add([sequence_name,sequence[0], i - 3])
    present_instructions(END_INSTRUCTION_SEQUENCE)
```

Click function

```
def wait_for_dot_click(correct_dot_idx, dot_positions, radius=DOT_RADIUS):
    mouse = io.Mouse(show_cursor=True)
    while True:
        _, (x, y), _ = mouse.wait_press()
        clicked_dot = None
        for idx, (dot_x, dot_y) in enumerate(dot_positions):
            dist = m.sqrt((x - dot_x) ** 2 + (y - dot_y) ** 2)
            if dist <= radius:
                clicked_dot = idx
                break
        if clicked_dot is not None:
            return clicked_dot == correct_dot_idx
```