

RESEARCH OPPORTUNITIES IN COMPUTER SCIENCE

Computational Social Choice

An Introduction

ROCS
2017

RESEARCH OPPORTUNITIES IN COMPUTER SCIENCE

Summer 2017 at IITGN

ROCS
2017

RESEARCH OPPORTUNITIES IN COMPUTER SCIENCE

Summer Research Internship
Programme - SRIP
(MAY 8 – JULY 14)

ROCS
2017

RESEARCH OPPORTUNITIES IN COMPUTER SCIENCE

ACM-India Summer School on Graph Theory and Graph Algorithms **26 JUNE – 15 JULY**

**ROCS
2017**

RESEARCH OPPORTUNITIES IN COMPUTER SCIENCE

Workshop on Algorithms Engineering

**5 JUNE – 15 JUNE
(TENTATIVE)**

**ROCS
2017**

RESEARCH OPPORTUNITIES IN COMPUTER SCIENCE

CSE Seminar Series

MONDAYS 3PM AT 7/109

<http://cs.iitgn.ac.in/videos/>

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2017**

RESEARCH OPPORTUNITIES IN COMPUTER SCIENCE

Stay Tuned: <http://cs.iitgn.ac.in>

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2017

THE STANDARD VOTING SETUP

A typical voting scenario involves
a set of alternatives, and
a set of voters.

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Voters have preferences over the alternatives,
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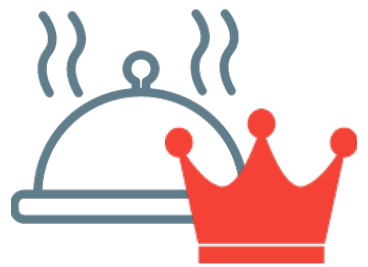
In this talk, we'll think of preferences as
linear orders over the rankings.

A group of friends have an evening to spend.









(Plurality)





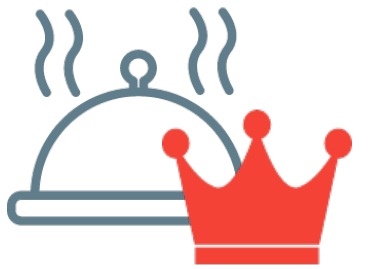
(Plurality)



We say that a voter (or a group of voters) can manipulate if they can obtain a more desirable outcome by misreporting their preferences.

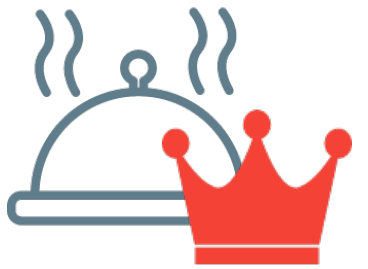
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We'll see that plurality is vulnerable to this behaviour.



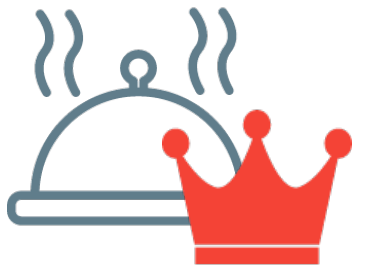
(Plurality)





(Plurality)





(Plurality)





(Plurality)



Manipulation



(Plurality)



This scheme is intended only for honest men.



















An alternative that beats all the others
in pairwise comparisons.



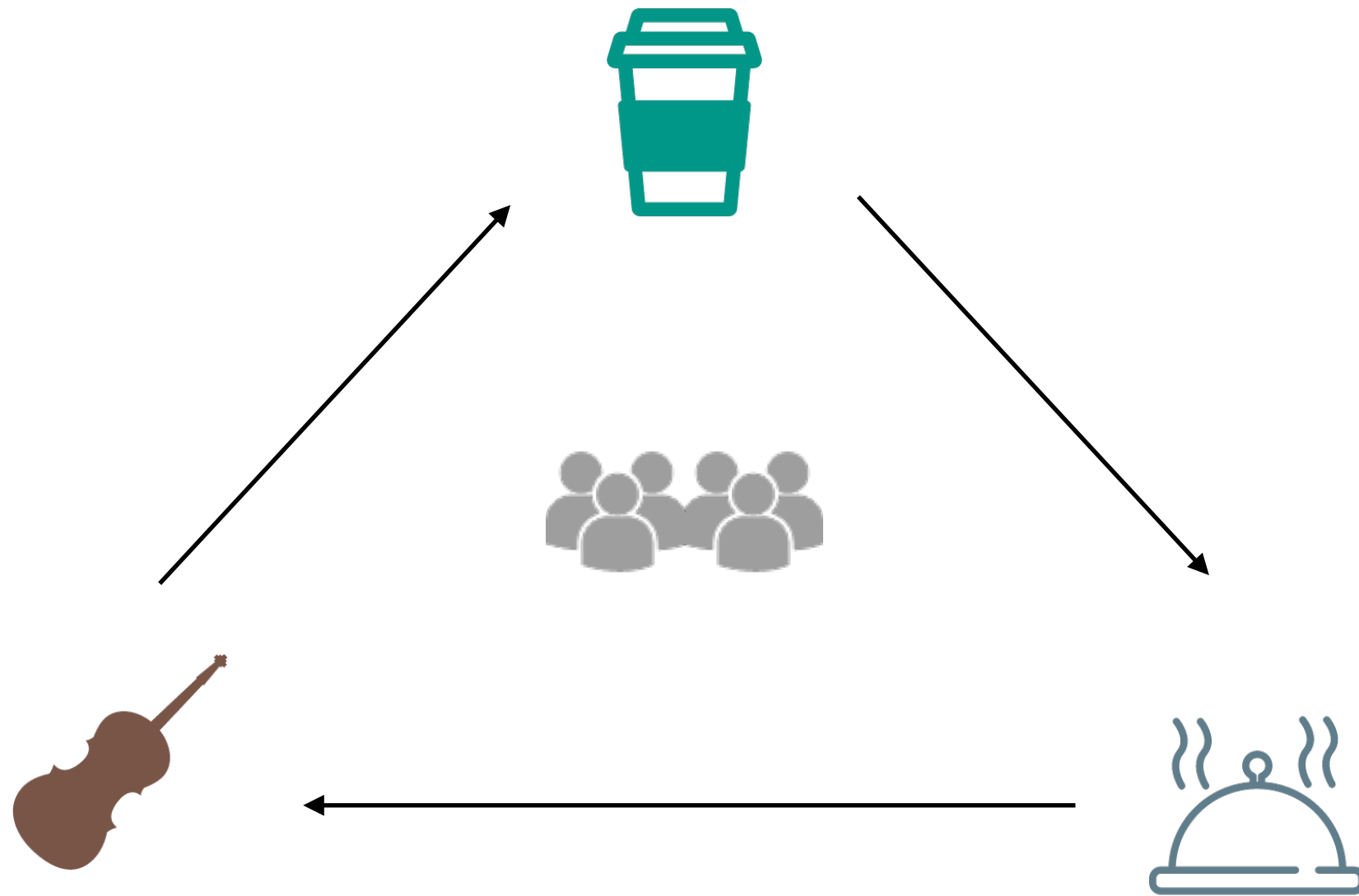
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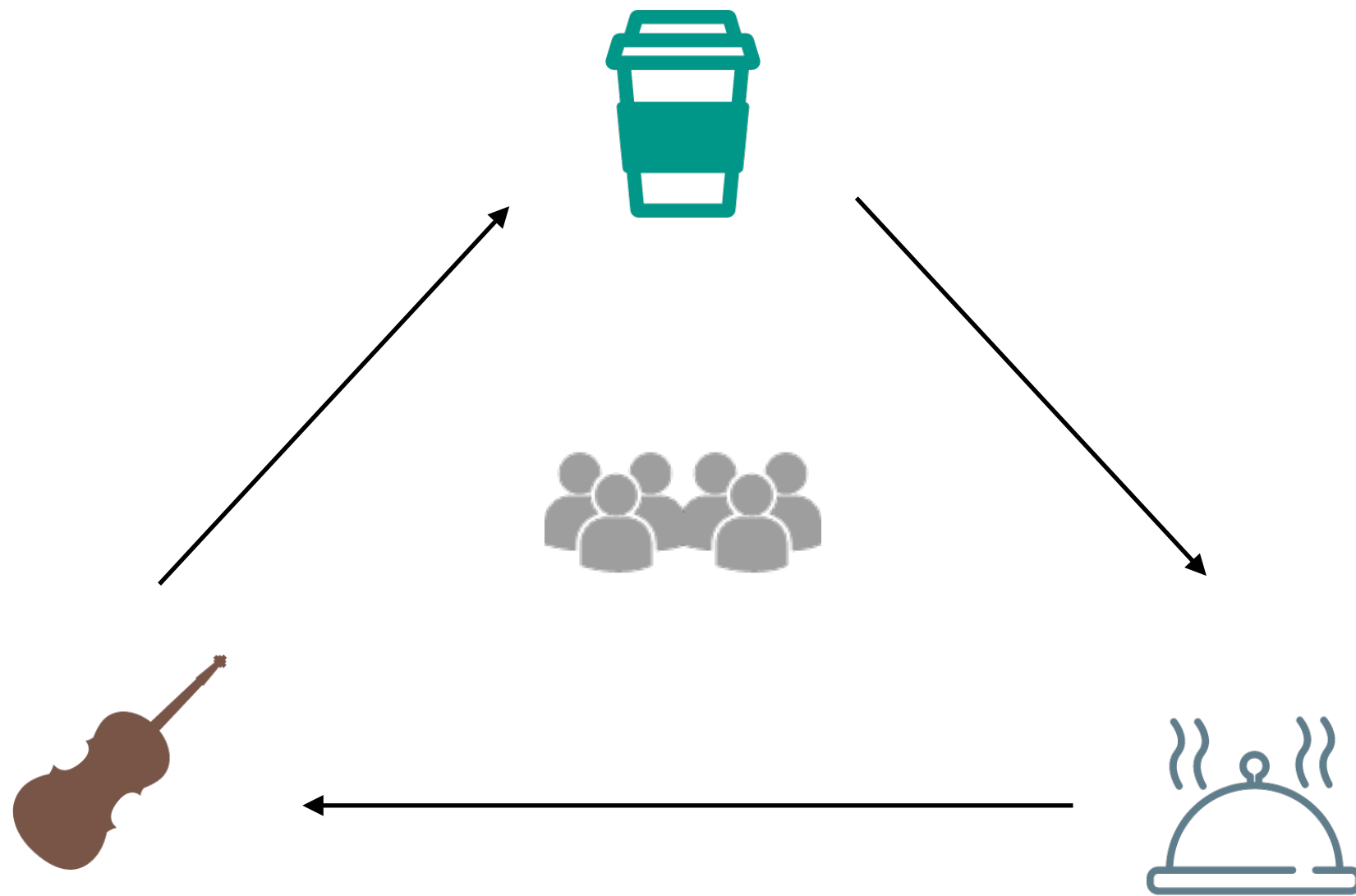
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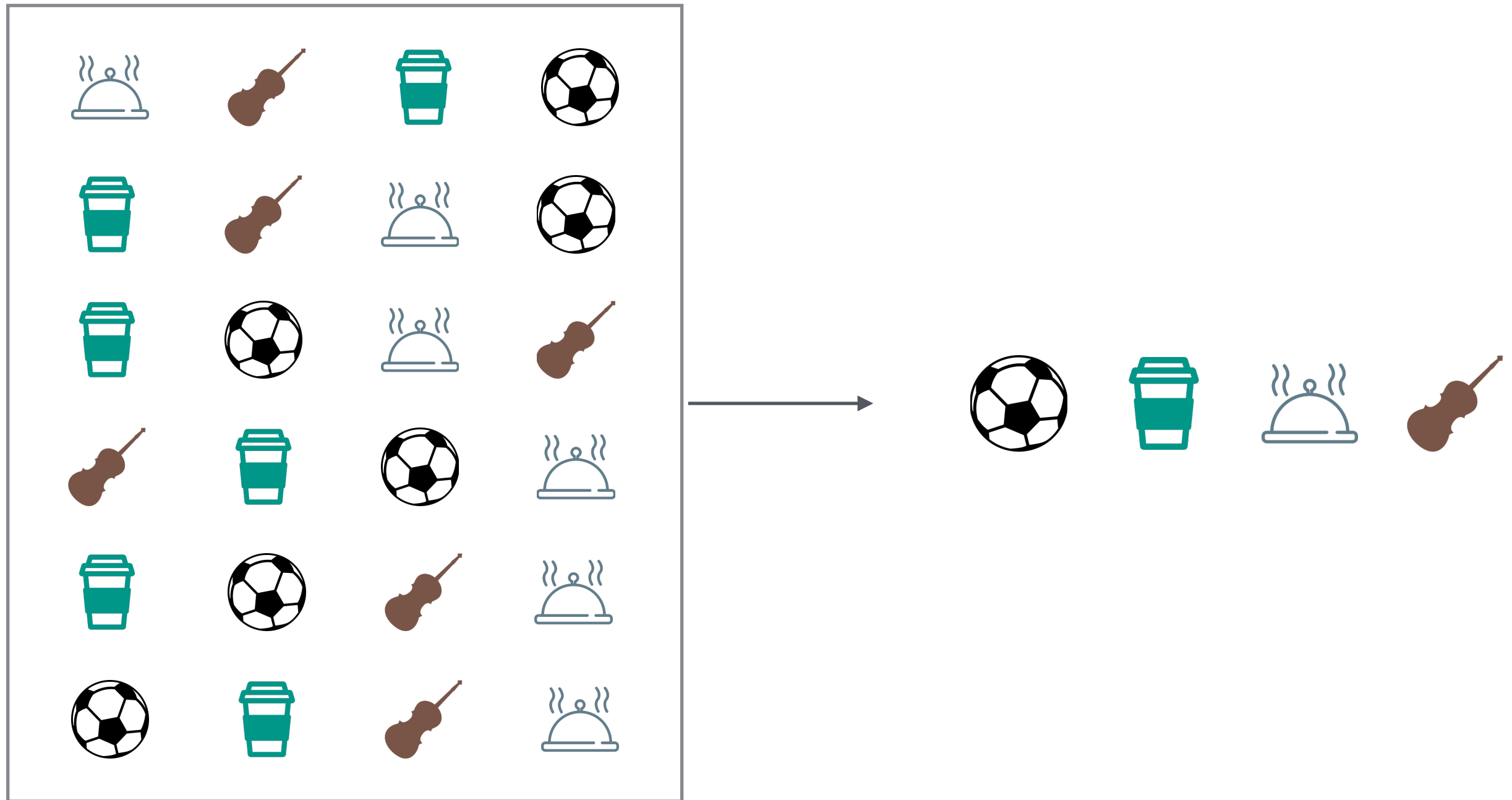
may not exist!

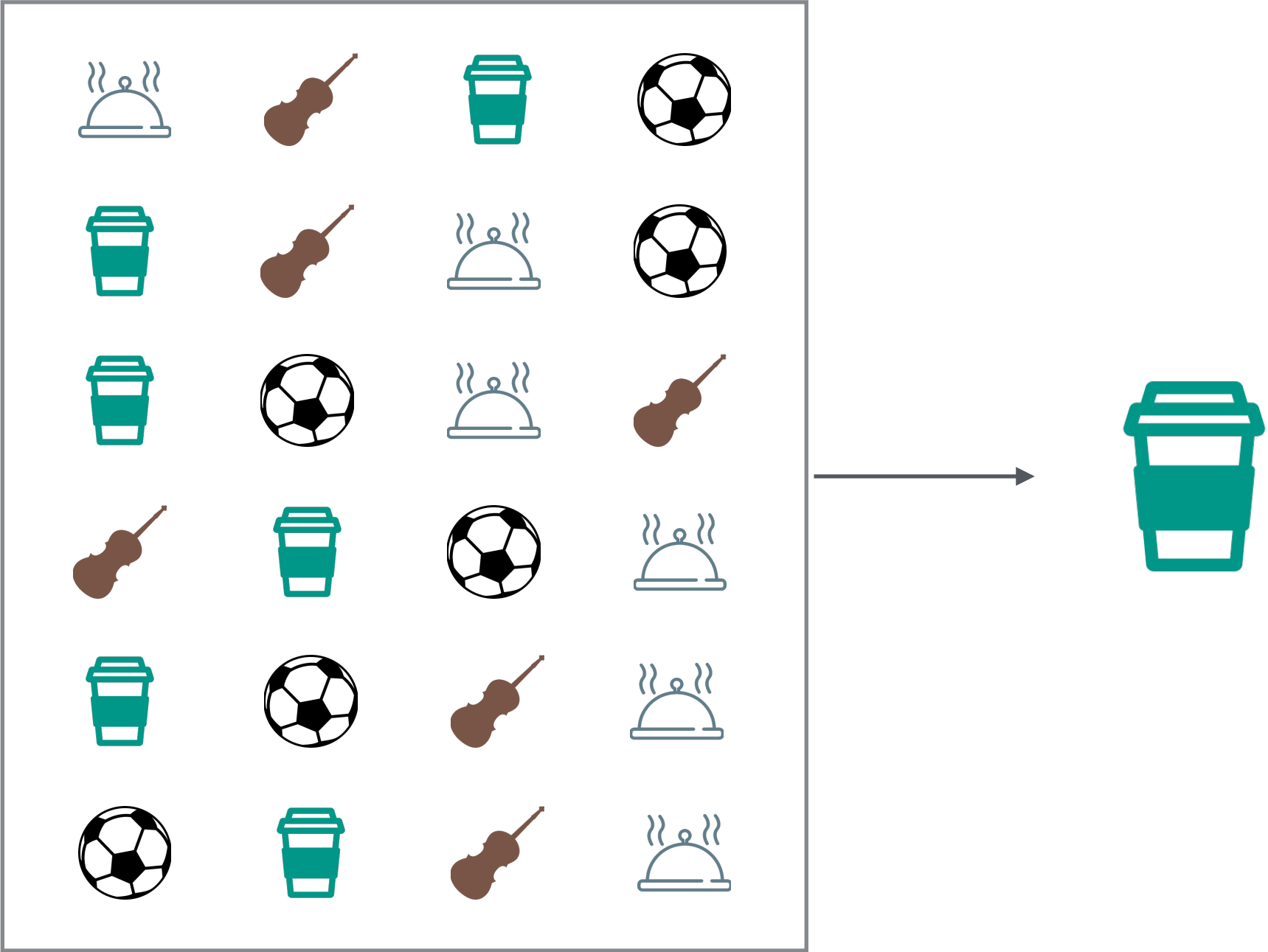
Desirable properties of voting rules.

We'll now pause to formally define
social choice functions and
social welfare functions.

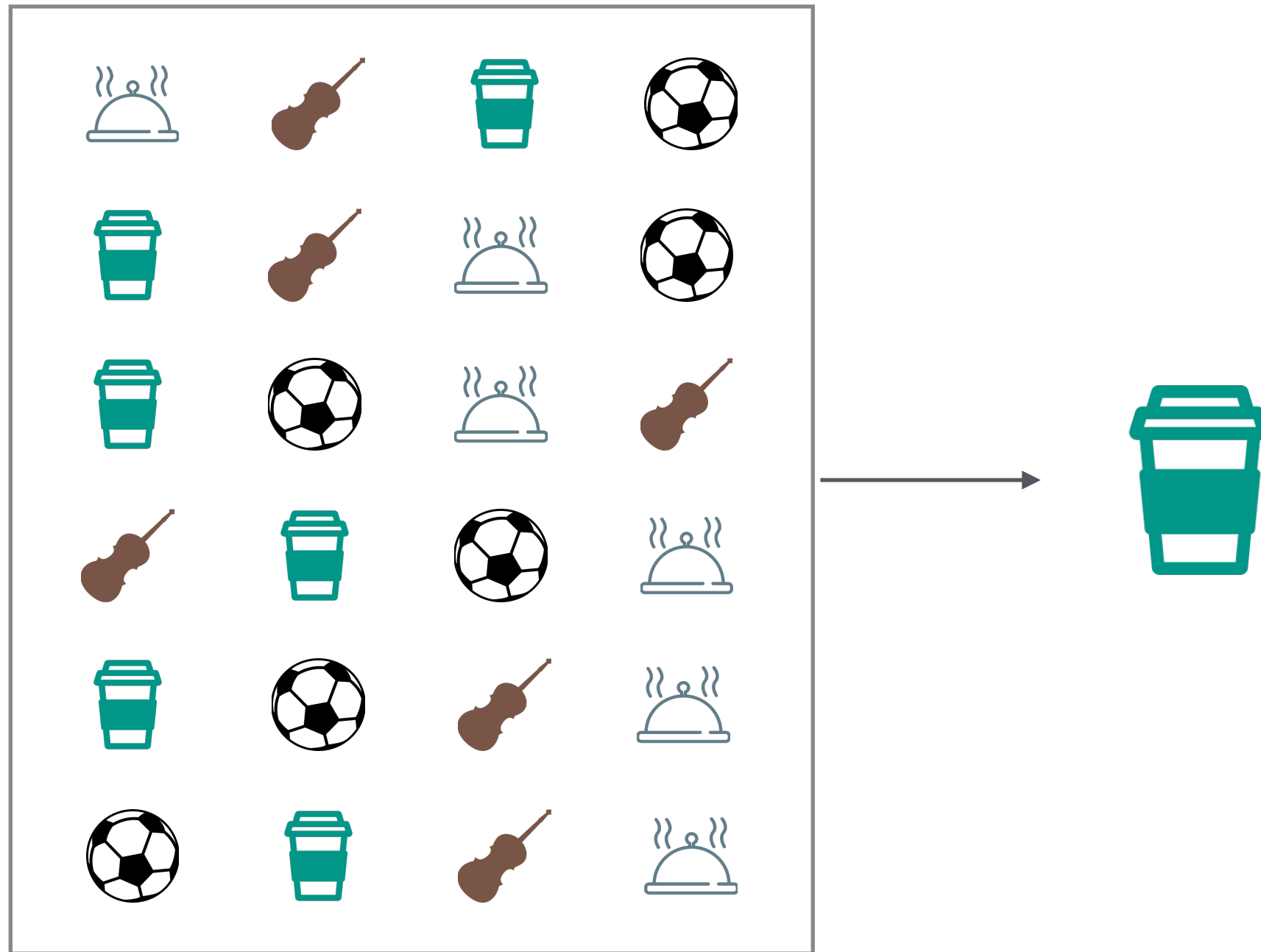


Social Welfare Functions (SWF)





Social Choice Functions (SCF)





Unanimity



Unanimity



Unanimity

If everyone prefers A to B then
the consensus ranking also prefers
A over B.





Independence of Irrelevant Alternatives



Independence of Irrelevant Alternatives



Independence of Irrelevant Alternatives



Independence of Irrelevant Alternatives

Suppose a SWF prefers A over B in the consensus ranking for a profile P.

Let Q be a profile that is the same as P when projected on the candidates A and B.

Then the SWF must prefer A over B in the consensus ranking that it determines for Q as well.



Arrow (1949)

Arrow (1949)

When voters have three or more alternatives,
any social welfare function which respects
unanimity and
independence of irrelevant alternatives
is a dictatorship.

Gibbard-Satterthwaite (1973/75)

Gibbard-Satterthwaite (1973/75)

Any **strategy-proof** SCF where at least three candidates have some chance of being selected must be a **dictatorship**.

Workarounds

Workarounds

Domain Restrictions

Workarounds

Domain Restrictions

Randomised Voting Rules

Workarounds

Domain Restrictions

Randomised Voting Rules

Computational Hardness

Workarounds

Domain Restrictions

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Computational Hardness

SINGLE PEAKED PREFERENCES

definition, recognition, strategy-proofness

SINGLE PEAKED PREFERENCES

Definition



The Theory of Committees and Elections.
Black, D., New York: Cambridge University Press, 1958

A

B

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Left

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Left

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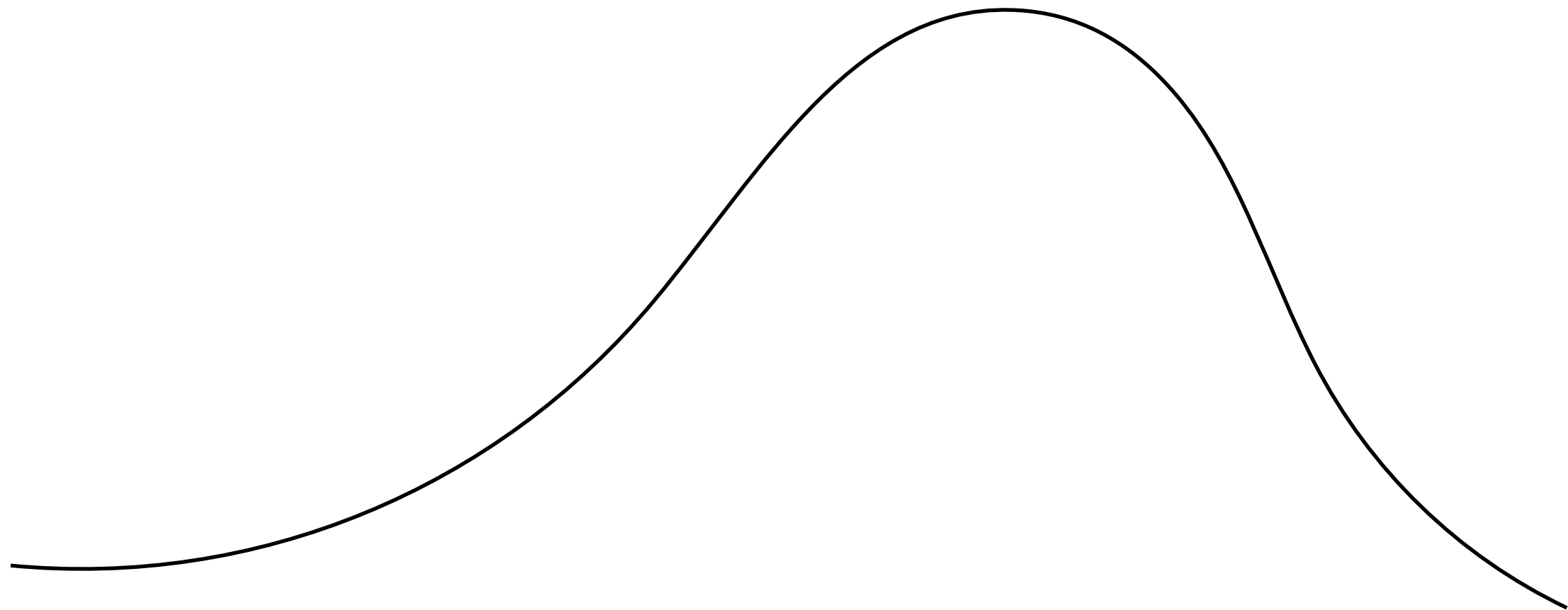
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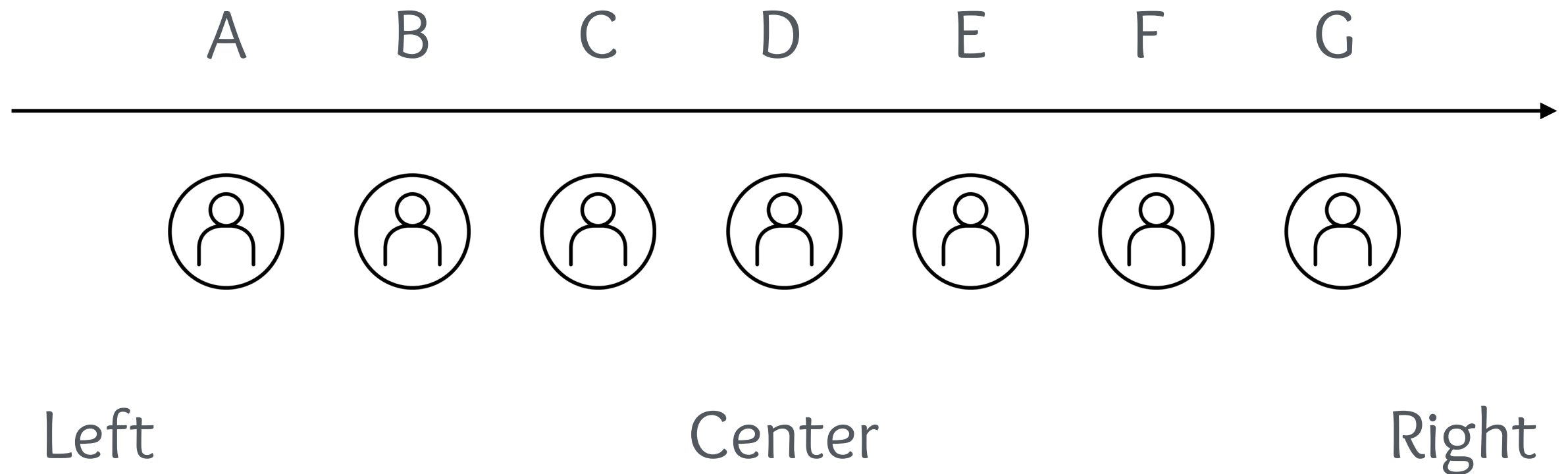
G



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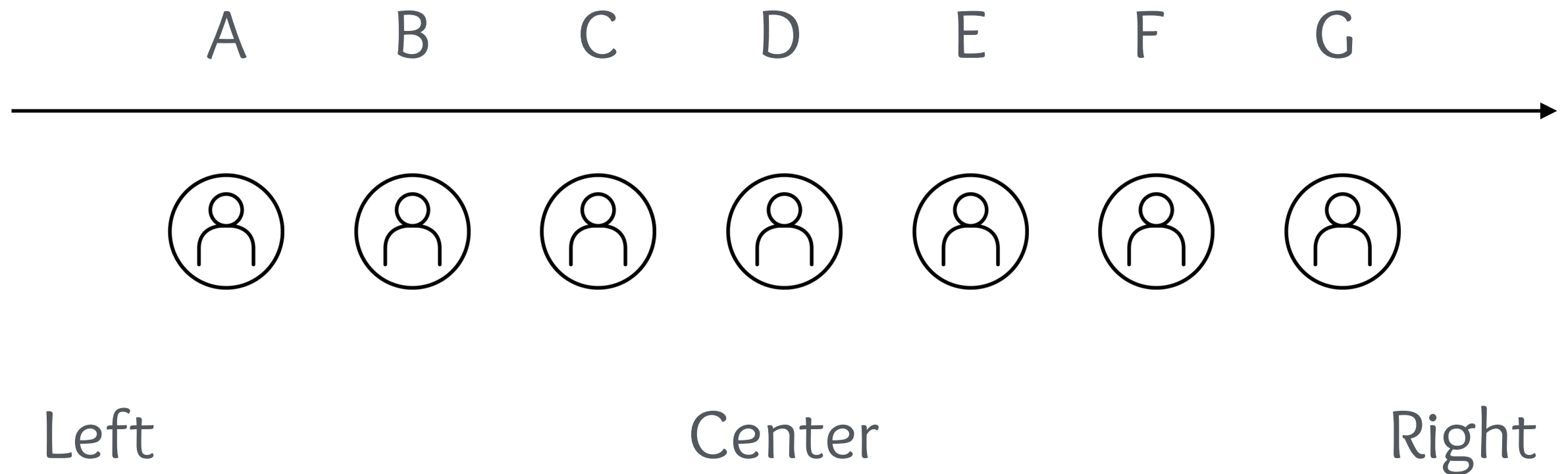
Center

Right



If an agent with single-peaked preferences prefers x to y , one of the following must be true:

- x is the agent's peak,
- x and y are on opposite sides of the agent's peak, or
- x is closer to the peak than y .



The notion is popular for several reasons:

- No Condorcet Cycles.
- No incentive for an agent to misreport its preferences.
- Identifiable in polynomial time.
- Reasonable (?) model of actual elections.

SINGLE PEAKED PREFERENCES

Recognition



Stable Matching with Preferences Derived from a Psychological Model
Bartholdi and Trick, Operations Research Letters, 1986

Recognising if a given profile is single-peaked with respect to some preference ordering.



Checking if a 0/1 matrix has the **consecutive-ones property**.



$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{pmatrix}$$



$$\begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \end{pmatrix}$$



the single
peaked order

0	1	0	0
1	1	0	0
1	1	1	0
1	1	1	1

SINGLE PEAKED PREFERENCES

Strategyproofness



The Theory of Committees and Elections.
Black, D., New York: Cambridge University Press, 1958

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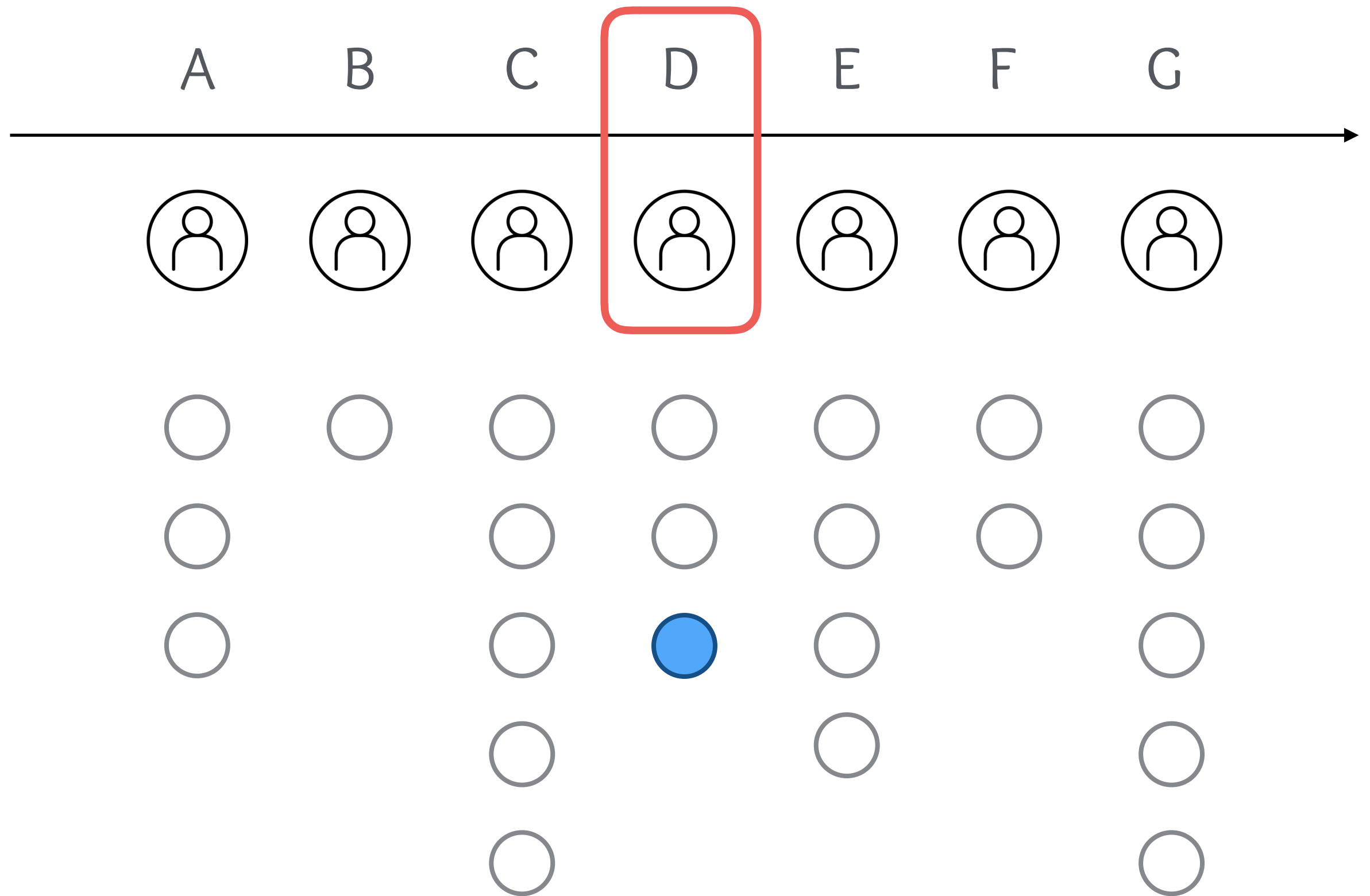
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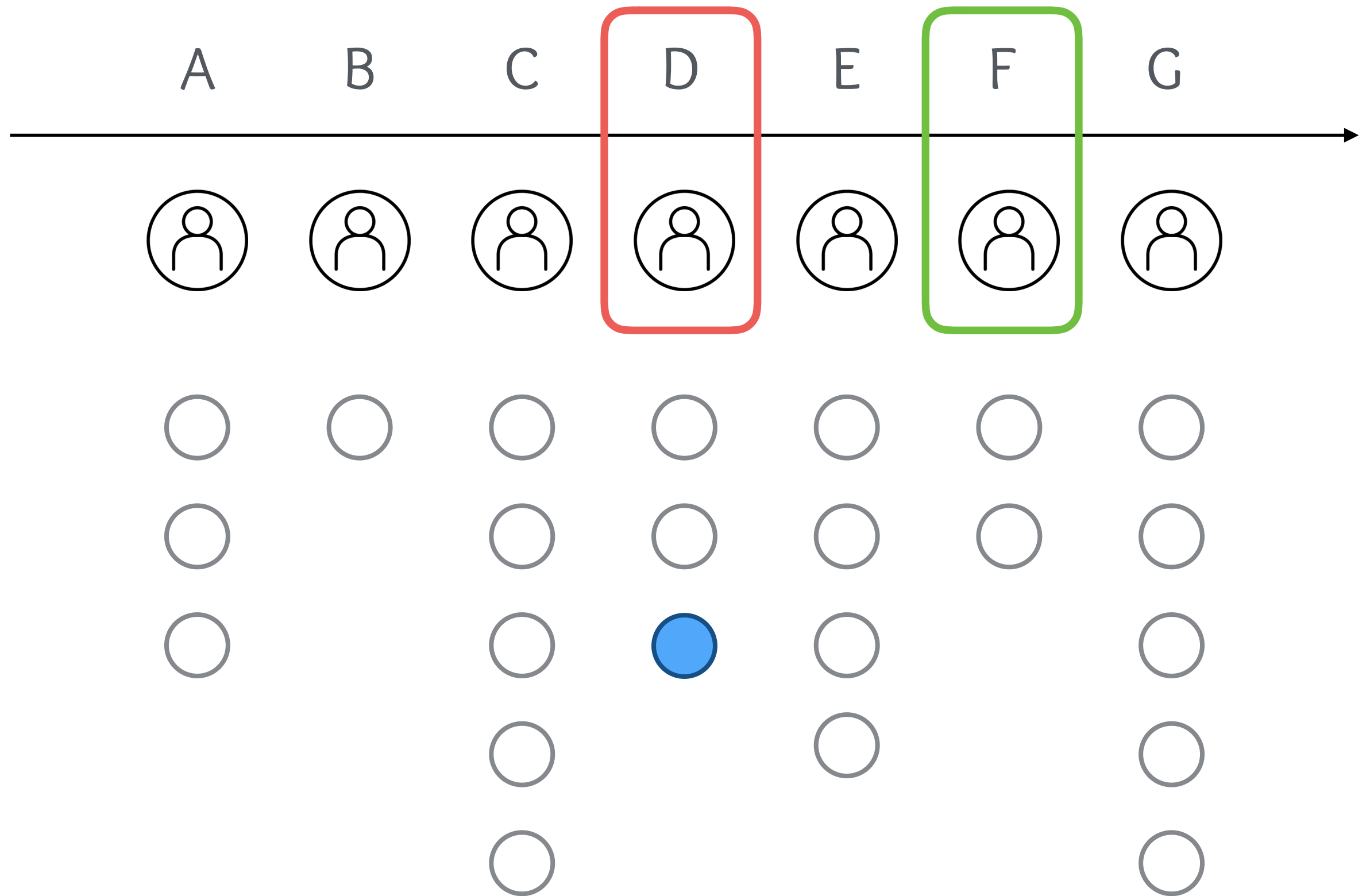
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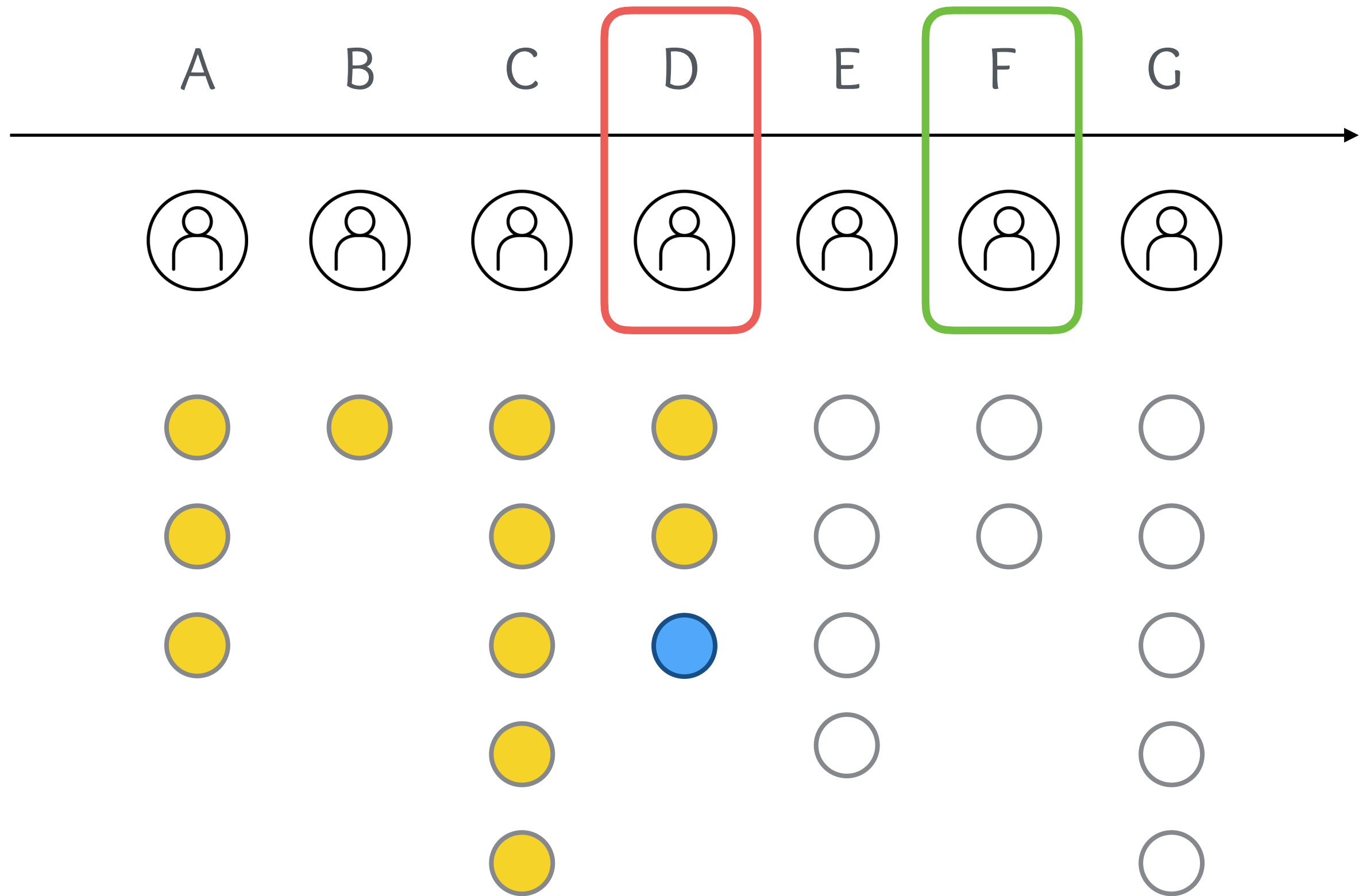




Claim: D beats all other candidates in pairwise elections.



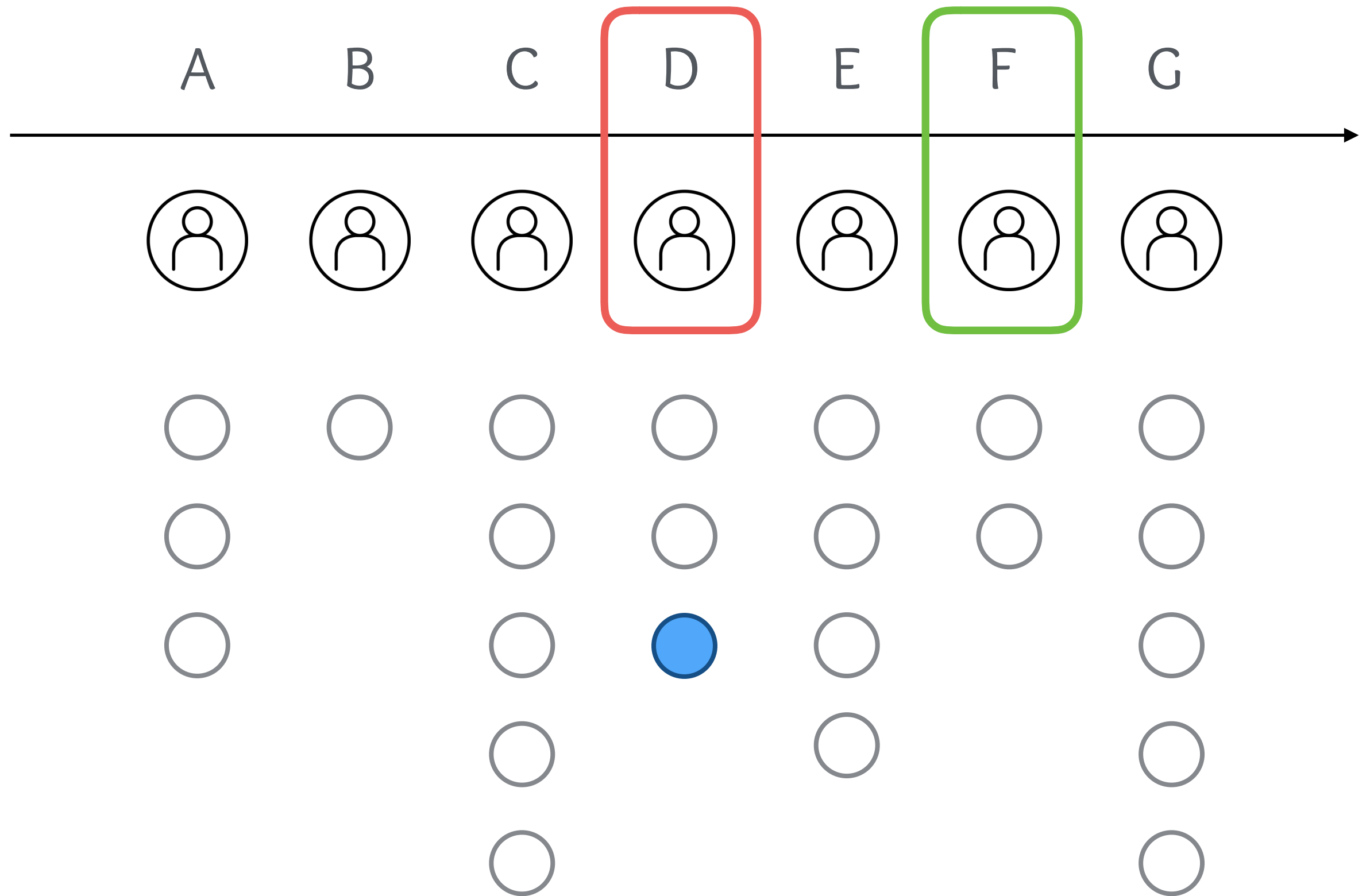
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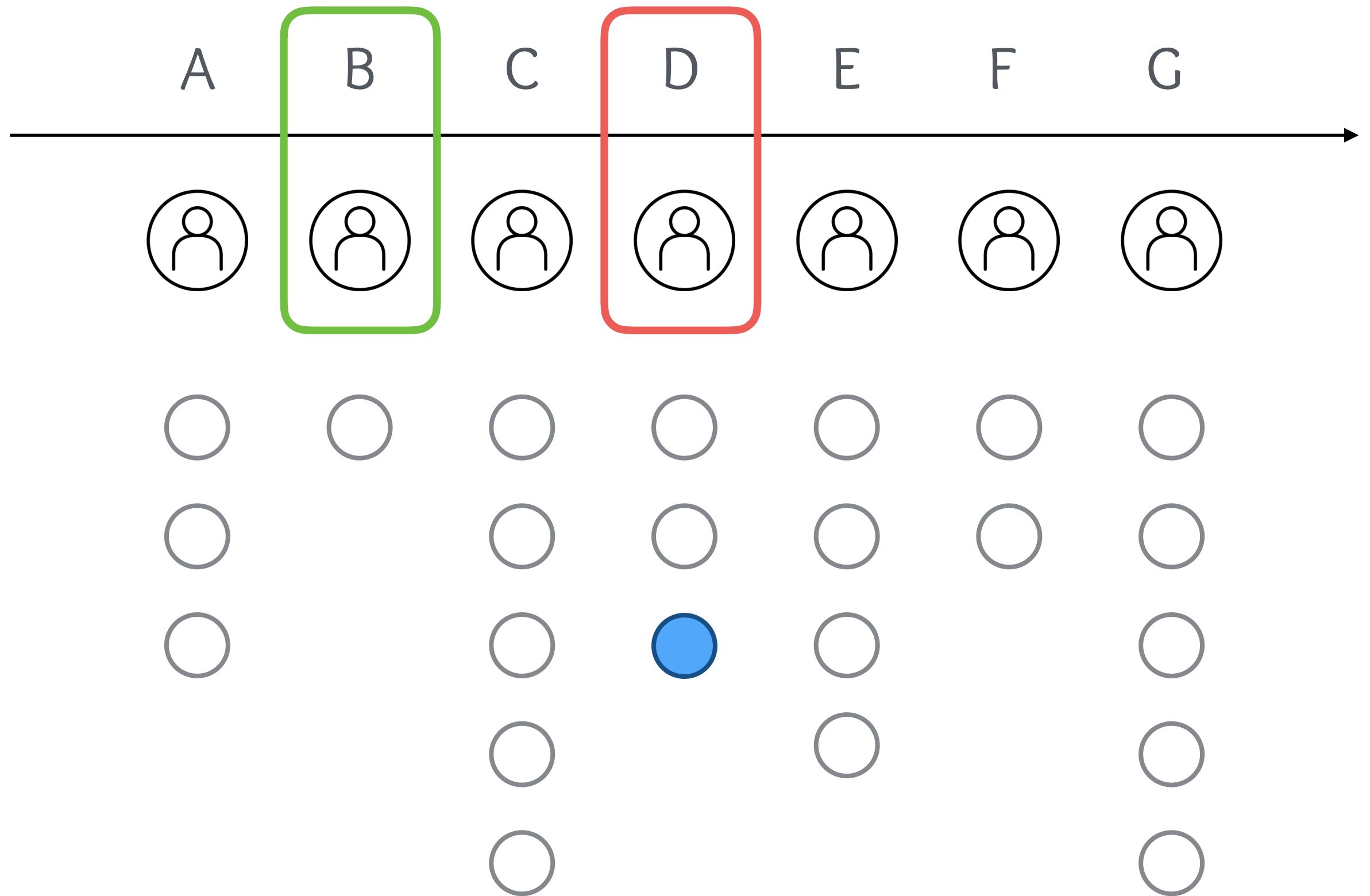
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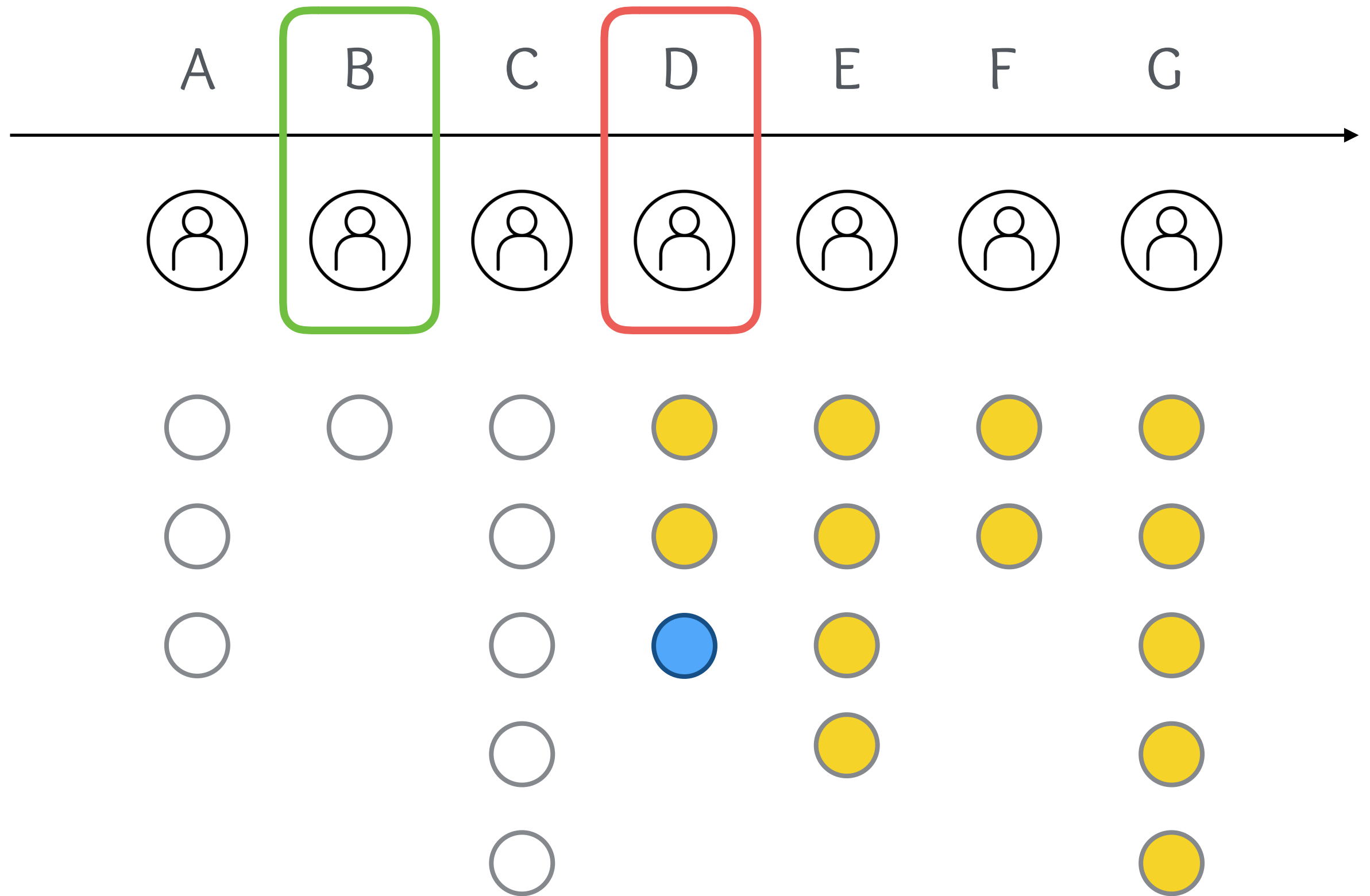
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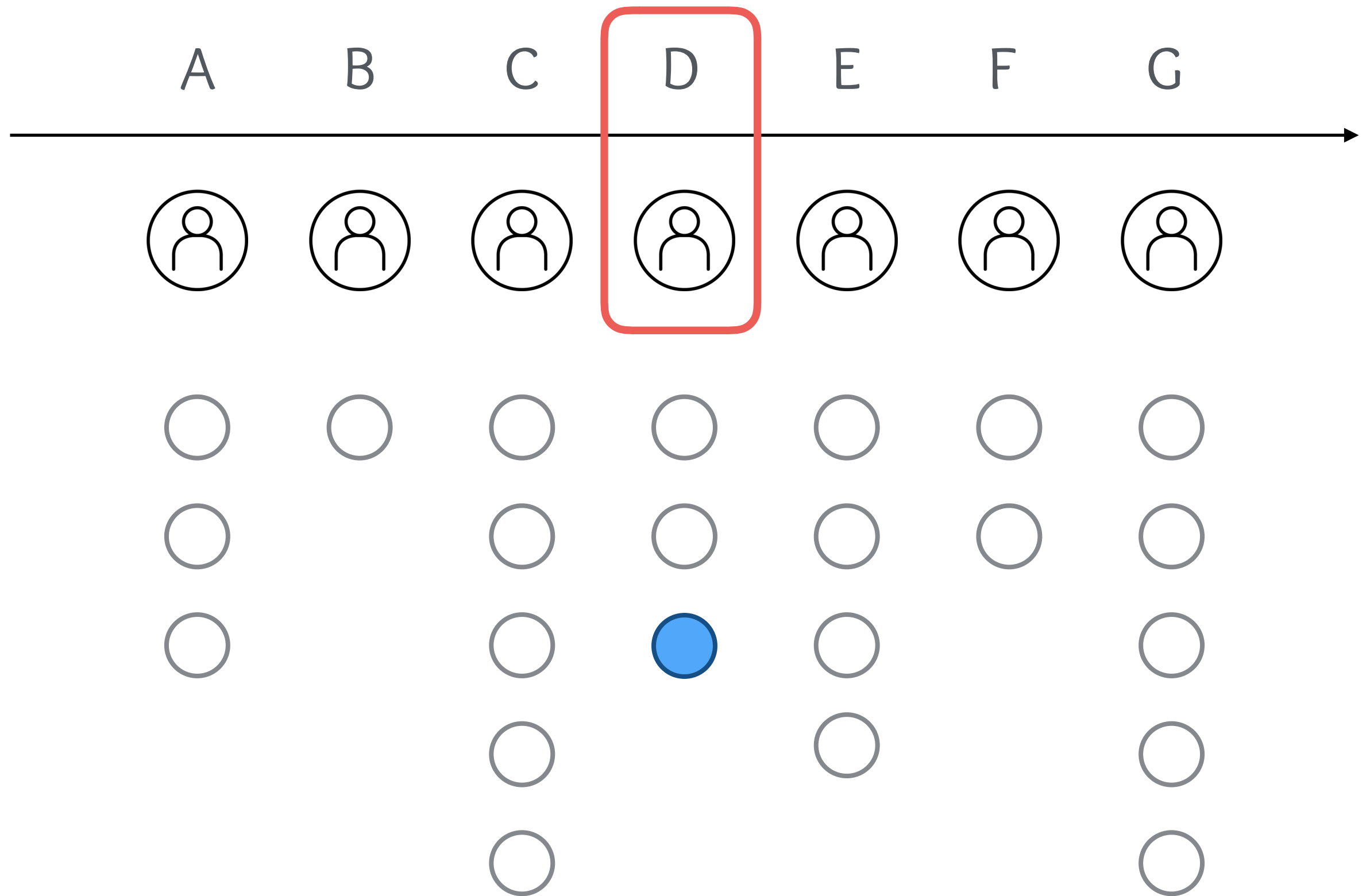
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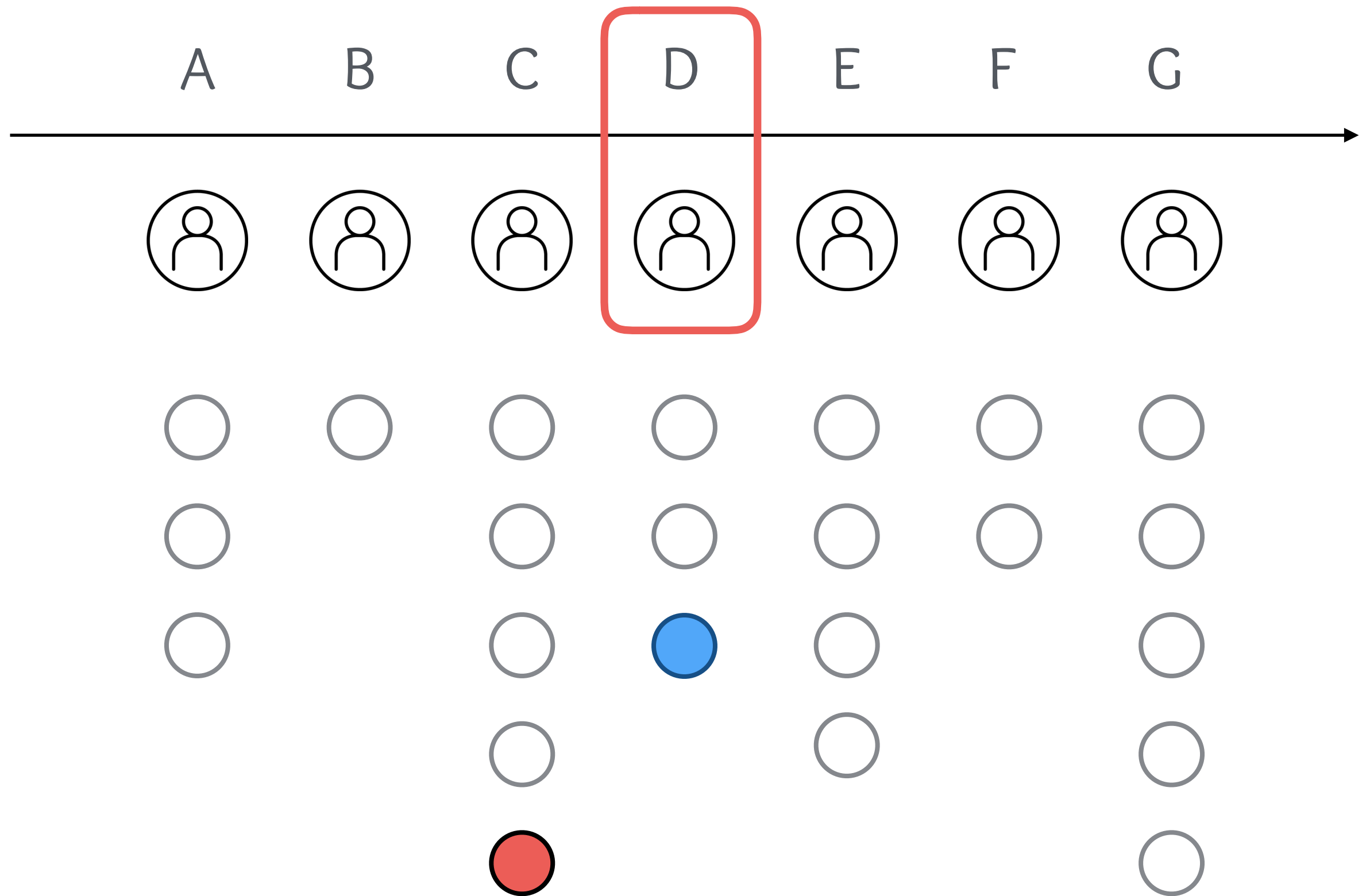
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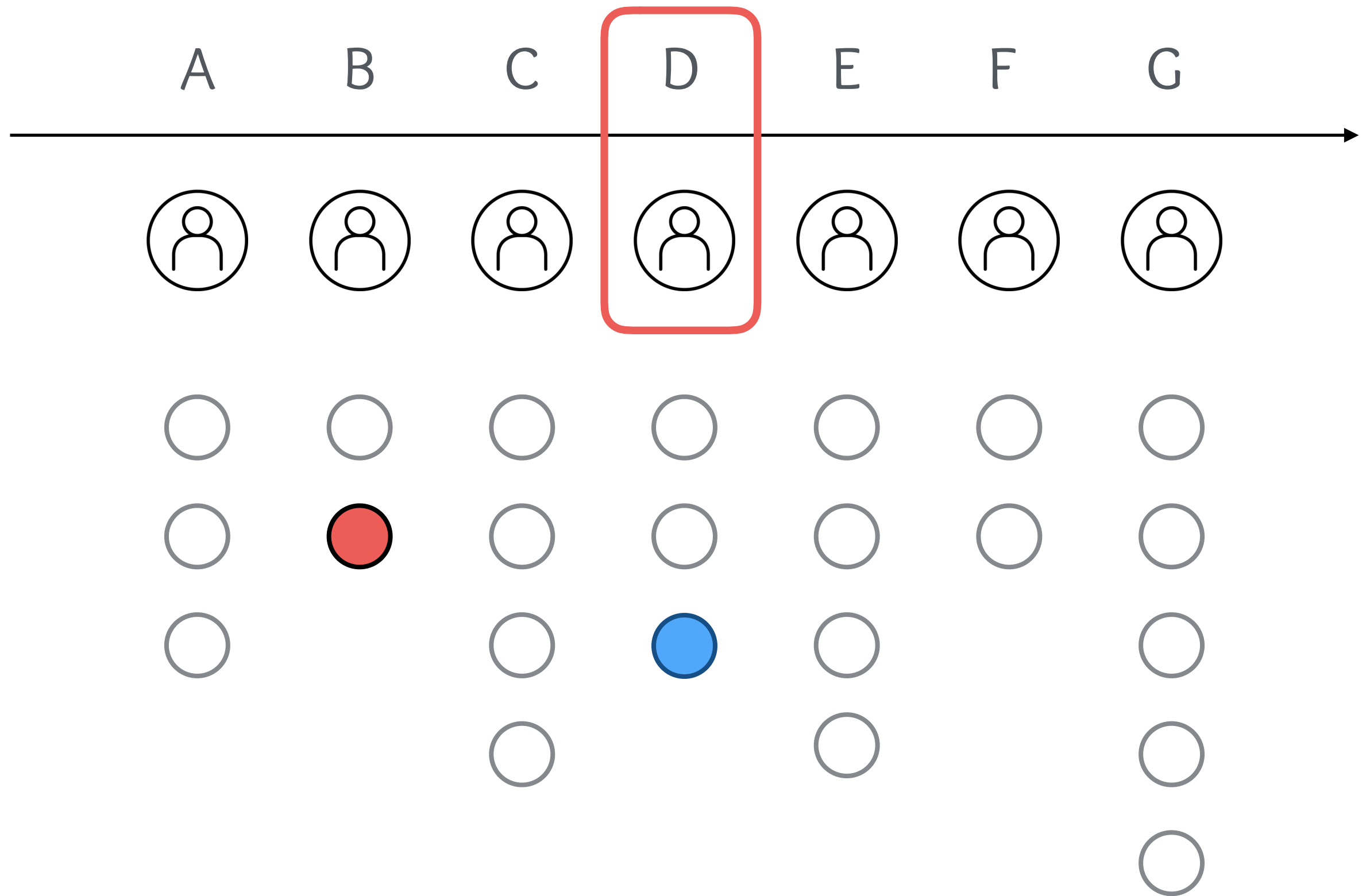
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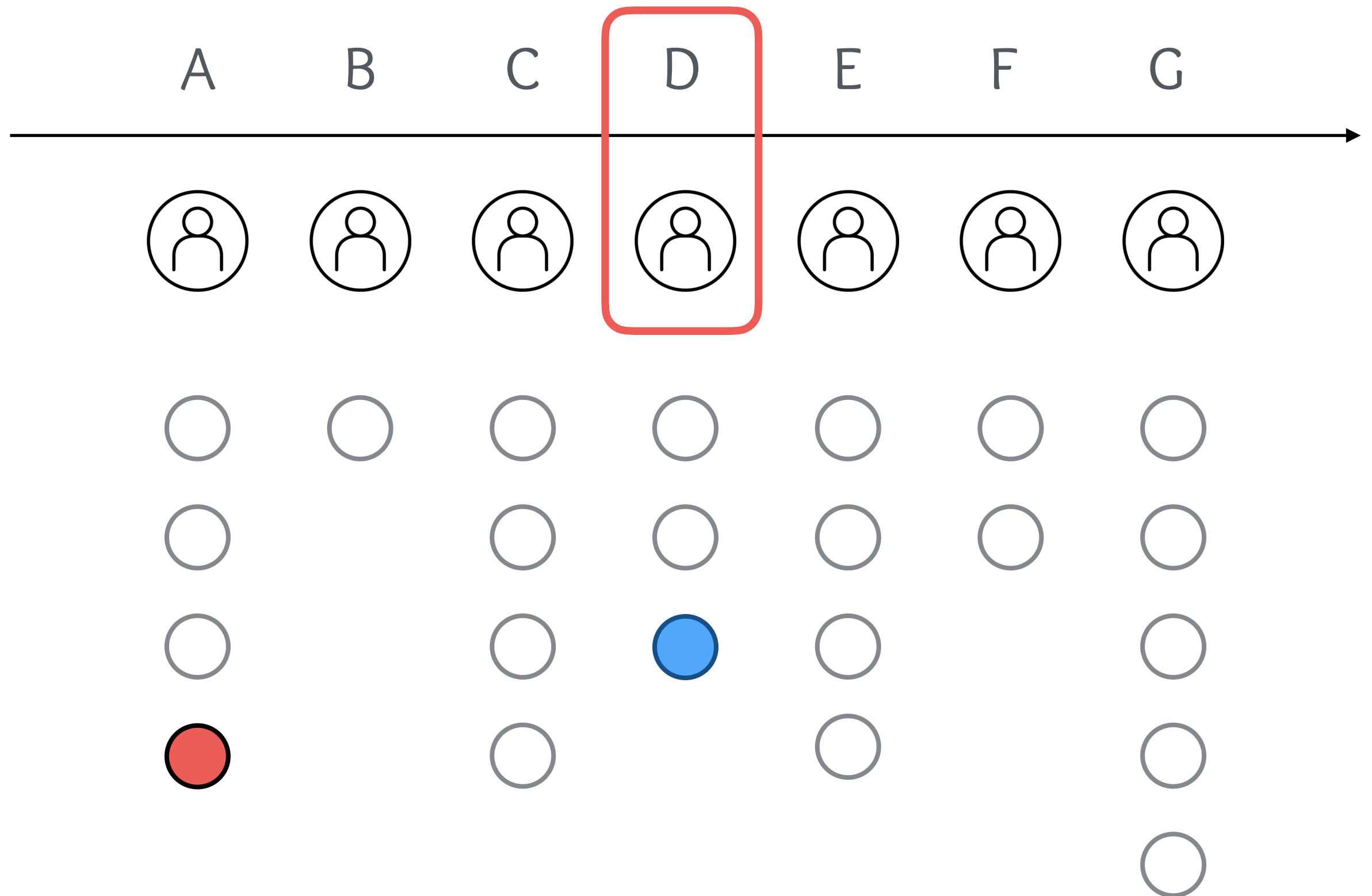
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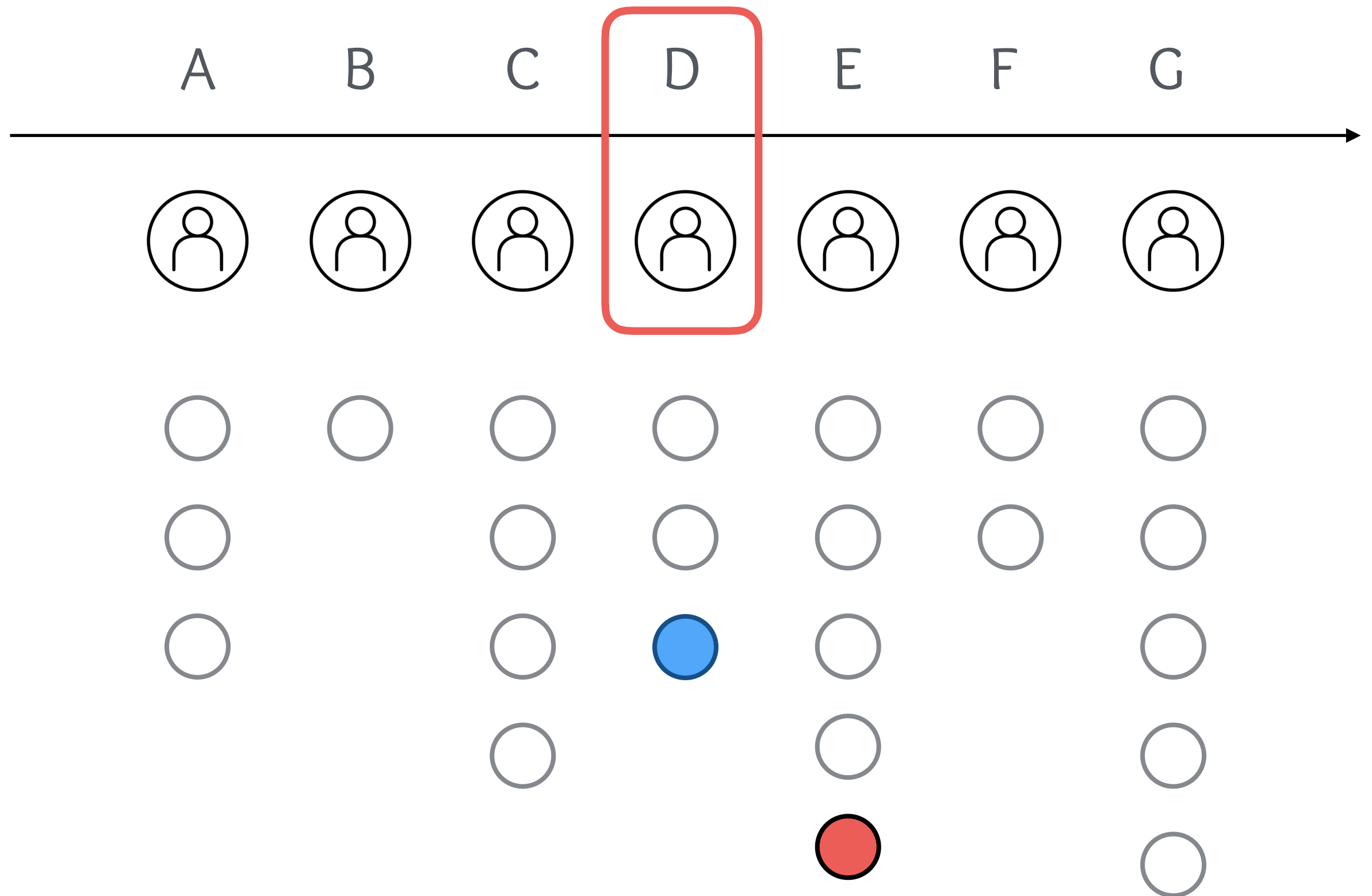
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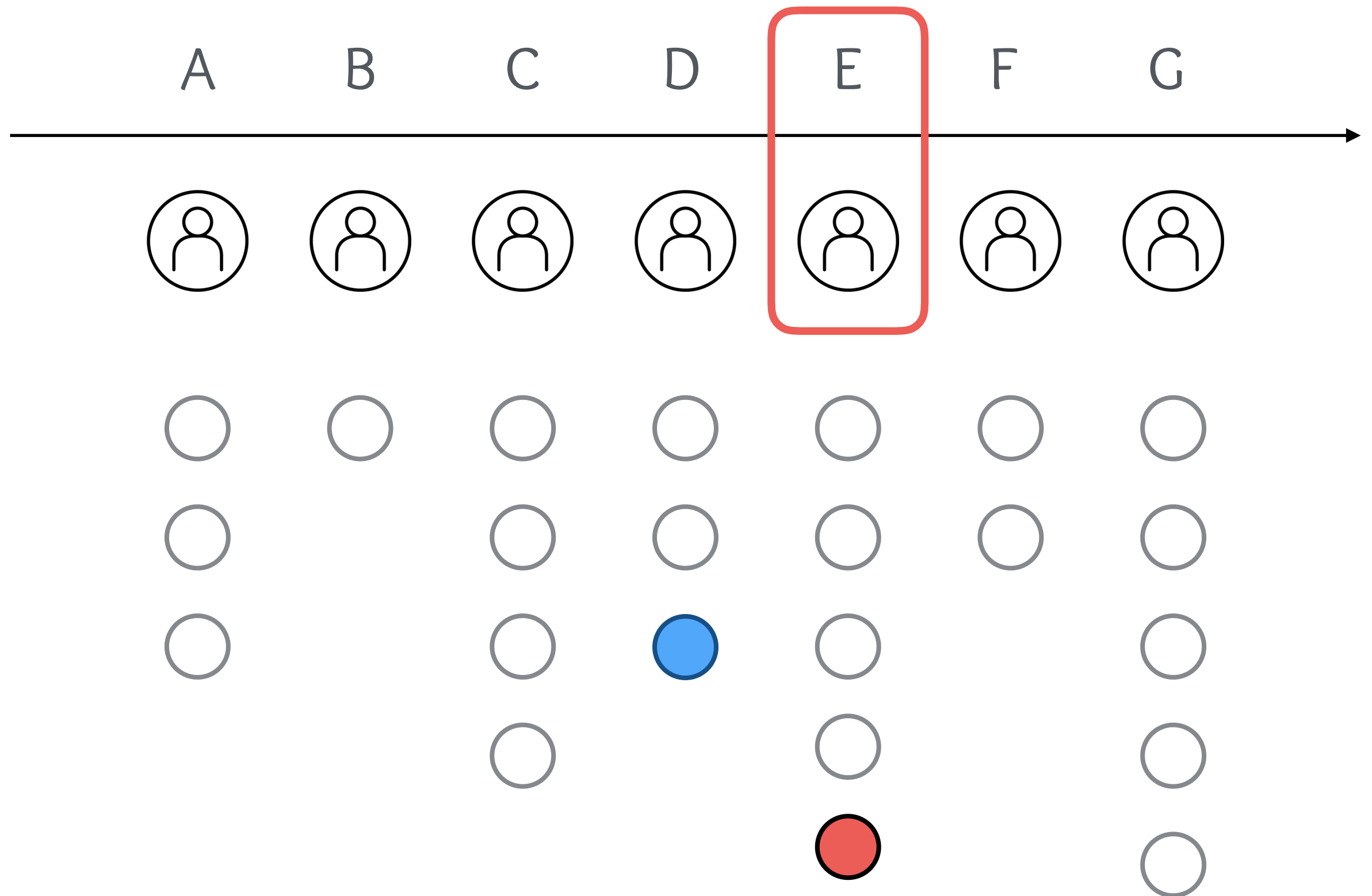
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THE GOLDEN TICKET:
P, NP, AND
THE SEARCH FOR THE IMPOSSIBLE

Lance Fortnow

1.00

Beyond Computation: The P vs NP Problem

by Michael Sipser
Professor of Applied
Mathematics
MIT



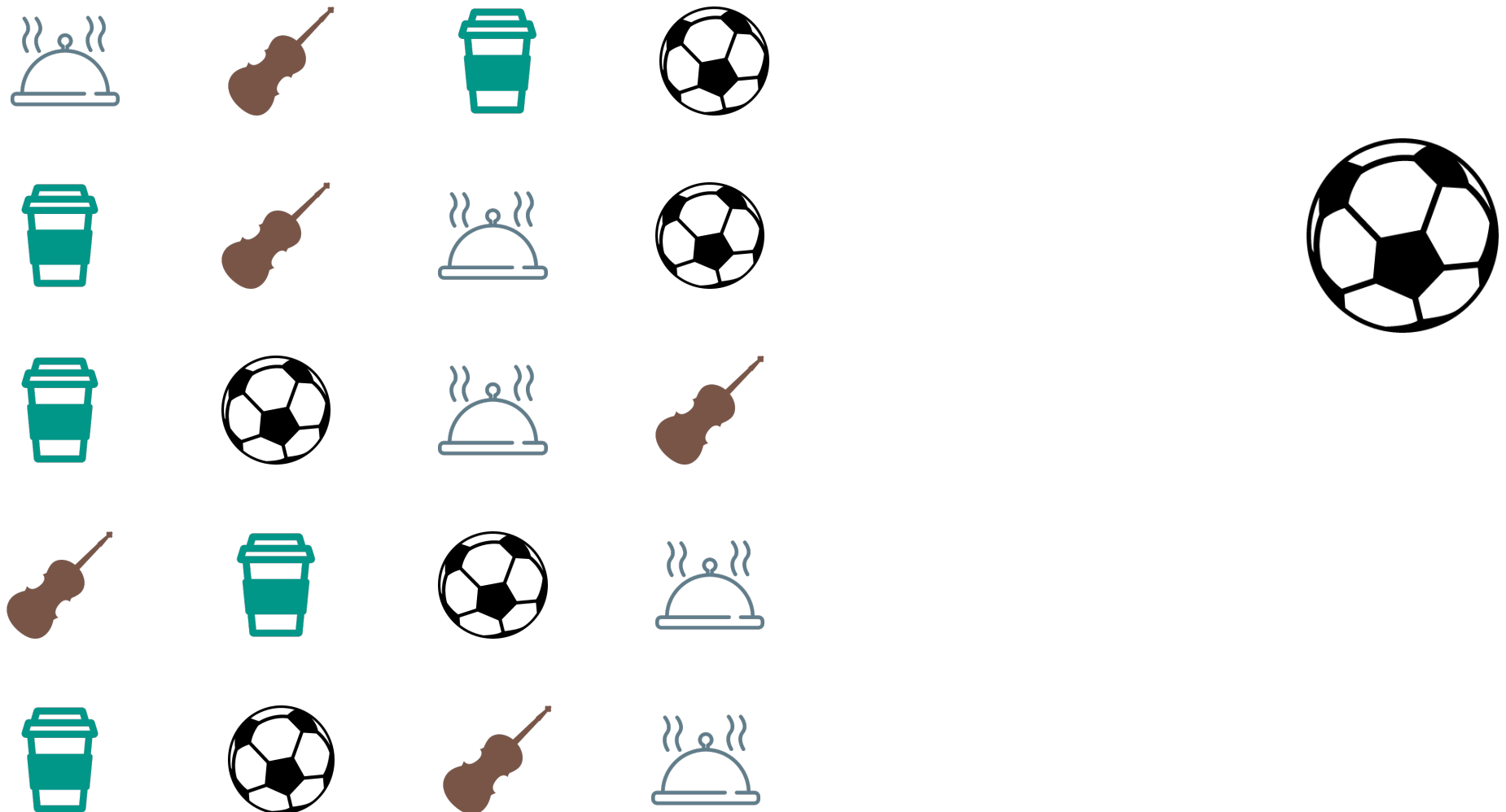
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Beyond Computation: The P vs NP Problem -
Michael Sipser

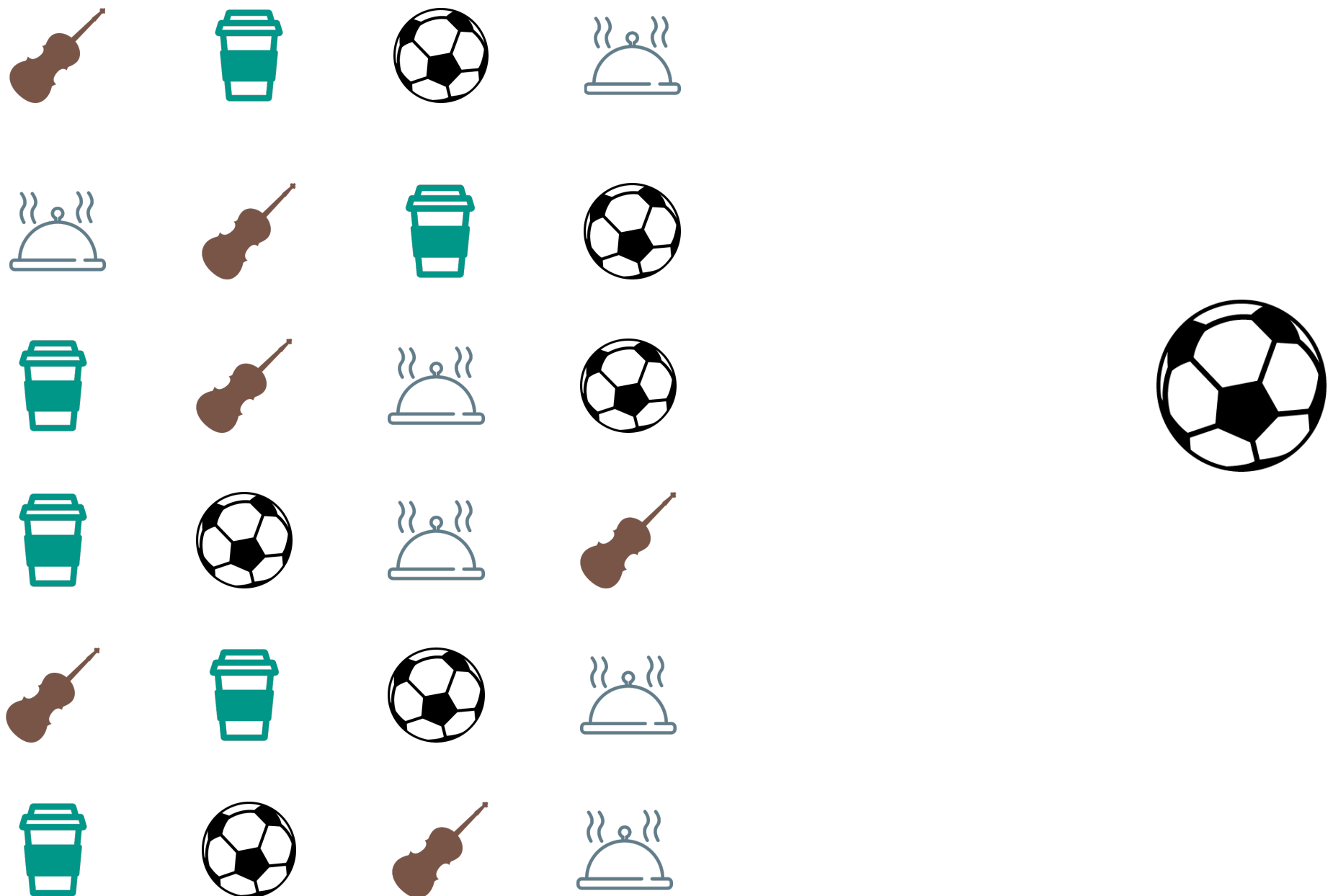
Manipulation: The Computational Problem

Input: Voting rule, profile, & a favourite candidate.



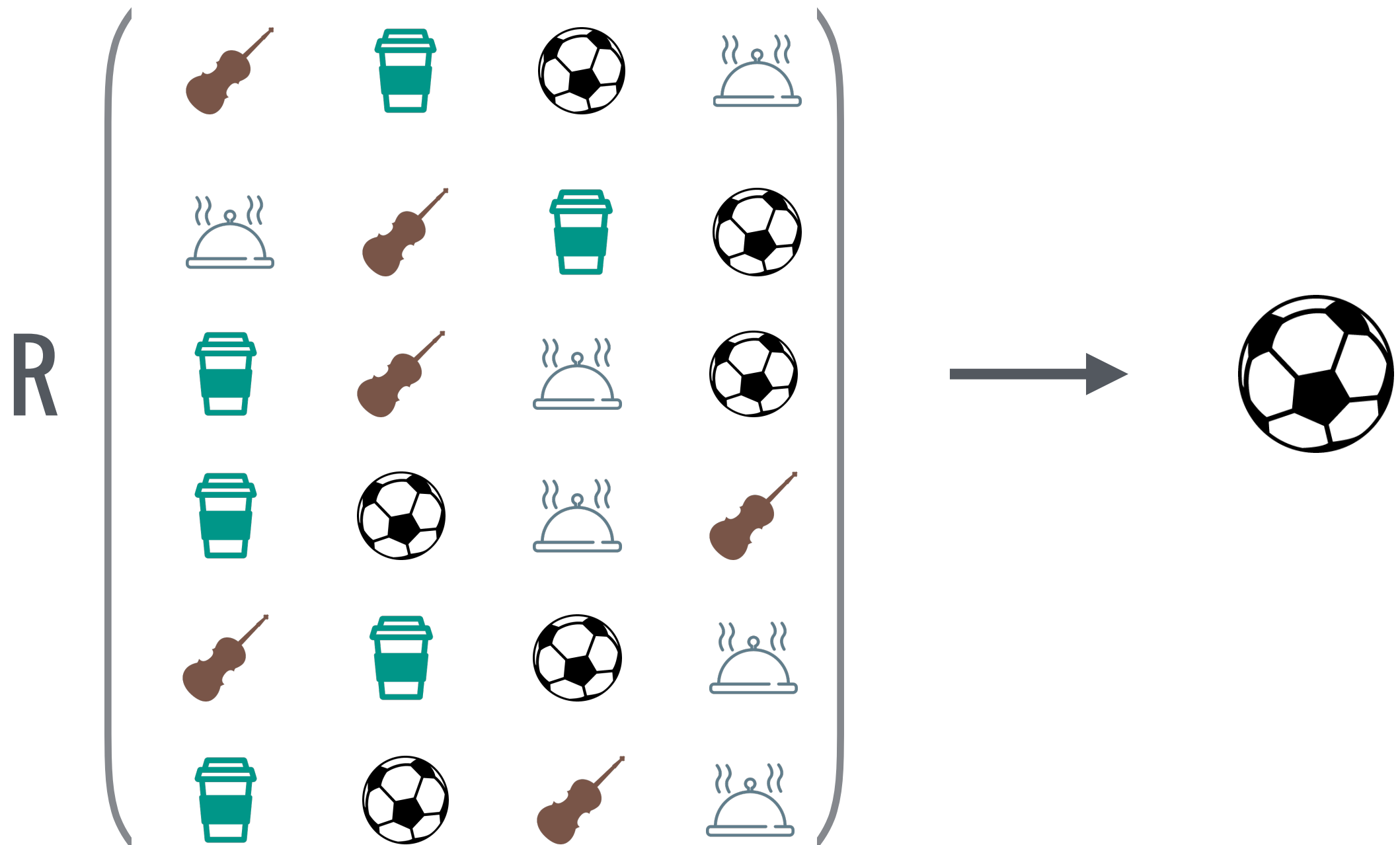
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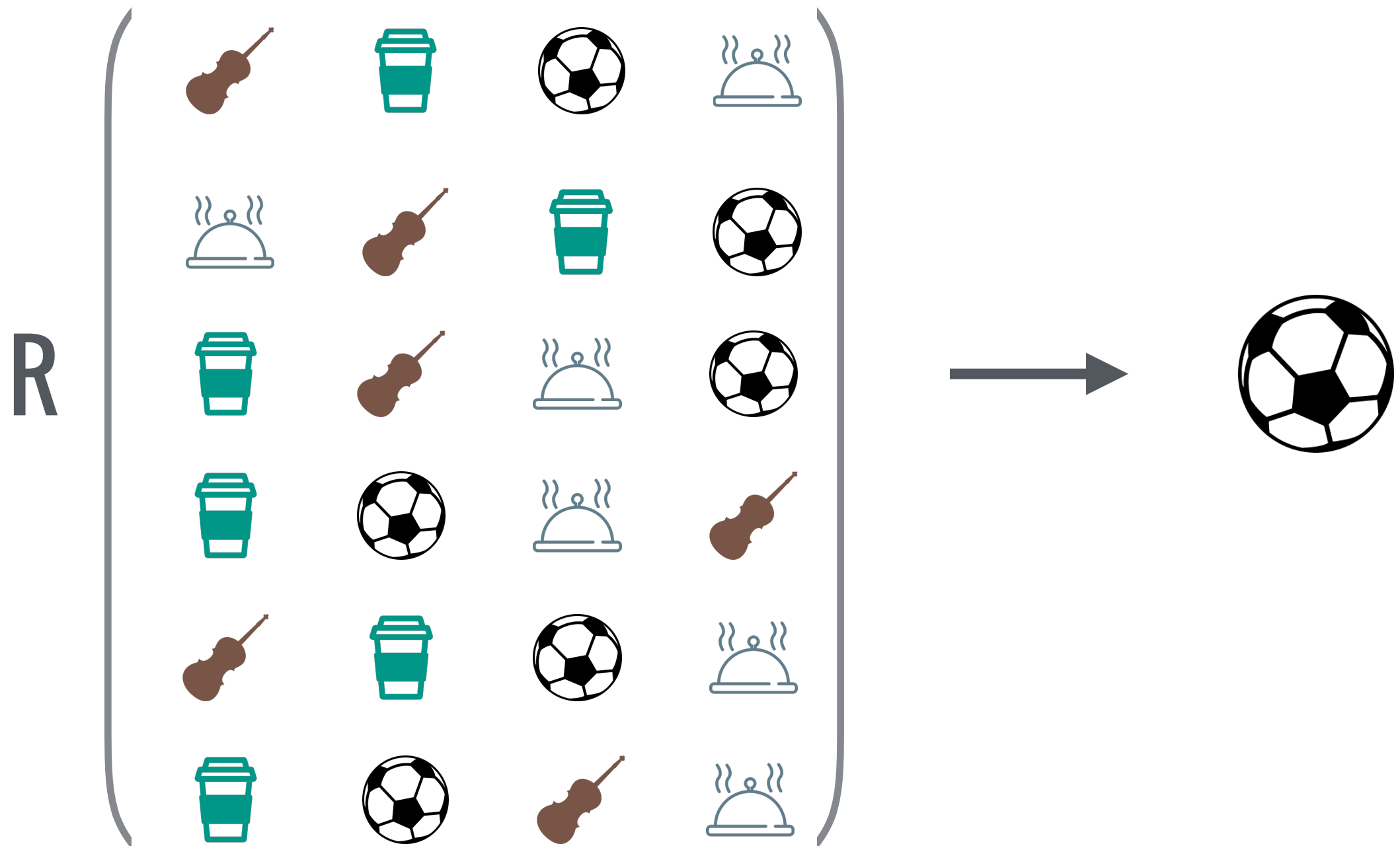
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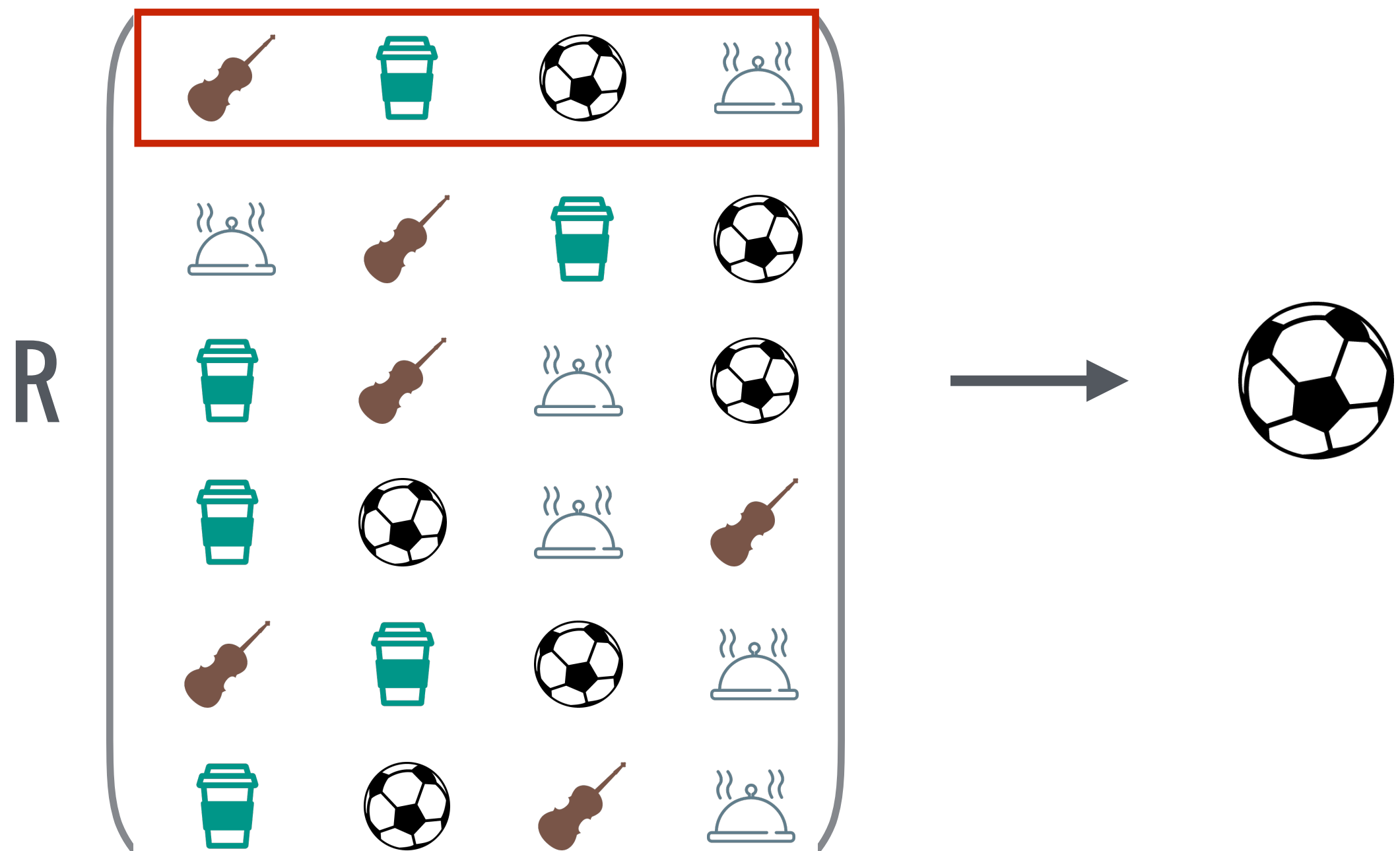
Manipulation: The Computational Problem

Output: A vote that makes the favourite win wrt the rule.



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The Computational Difficulty of Manipulating an Election*

J. J. Bartholdi III, C. A. Tovey, and M. A. Trick**

School of Industrial and Systems Engineering, Georgia Institute of Technology,
Atlanta, GA 30332, USA

Received June 9, 1987 / Accepted July 29, 1988

Abstract. We show how computational complexity might protect the integrity of social choice. We exhibit a voting rule that efficiently computes winners but is computationally resistant to strategic manipulation. It is *NP*-complete for a manipulative voter to determine how to exploit knowledge of the preferences of others. In contrast, many standard voting schemes can be manipulated with only polynomial computational effort.

Manipulation: Hardness Results

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Manipulating some voting rules (STV, Second Order Copeland) is NP-hard even for a single manipulator.

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For many common voting rules, manipulation is NP-hard when there are **two or more manipulators** involved.

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For many common voting rules, manipulation is NP-hard when there are **two or more manipulators** involved.

For **weighted elections**, the manipulation problem is frequently NP-hard, even when there are a constant number of candidates.

Manipulation: Objections to NP-hardness

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It is only worst-case hardness, and random choices of manipulative votes have a high probability of success.

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It is only worst-case hardness, and random choices of manipulative votes have a high probability of success.



AI's War on Manipulation: Are We Winning?

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HANDBOOK *of*
COMPUTATIONAL
SOCIAL CHOICE

Felix Brandt • Vincent Conitzer • Ulle Endriss
Jérôme Lang • Ariel D. Procaccia

