Australasian Mathematical Psychology Conference (2026)

The Effect of Price Signals on Effort and Productivity in a ‘Hard’ Task

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Incentives inform behaviour

Imagine you are the pole-vaulting prodigy, Armand “Mondo” Duplantis

You are **clearly** capable of jumping higher than anyone else on earth.

World Athletics pays you ~$100,000 USD prize money for each new world record.

Incentives inform behaviour

The current WR is 6.16m.

You know you can jump at least 6.30m.

How would you structure your career?

A. Try to jump as high as physically possible?

B. Try to jump *just barely* high enough to beat the world record?

Incentives inform behaviour

Effort is shaped by incentives.
Jenkins, et al., (1998); Camerer, et al., (1999)

Seemingly innocuous incentives can have unintended (and often adverse) effects.
Deci, et al., (1999); Ariely, et al., (2009); Titmuss (1970)

The institutions we use to incentivise collective discovery (i.e., patents) have some well-documented criticisms.
Fritz (1958); Usher (1964); Hall, et al., (2012)

Research question

How do we incentivise groups of individuals to commit the effort necessary to solve hard problems?

↓

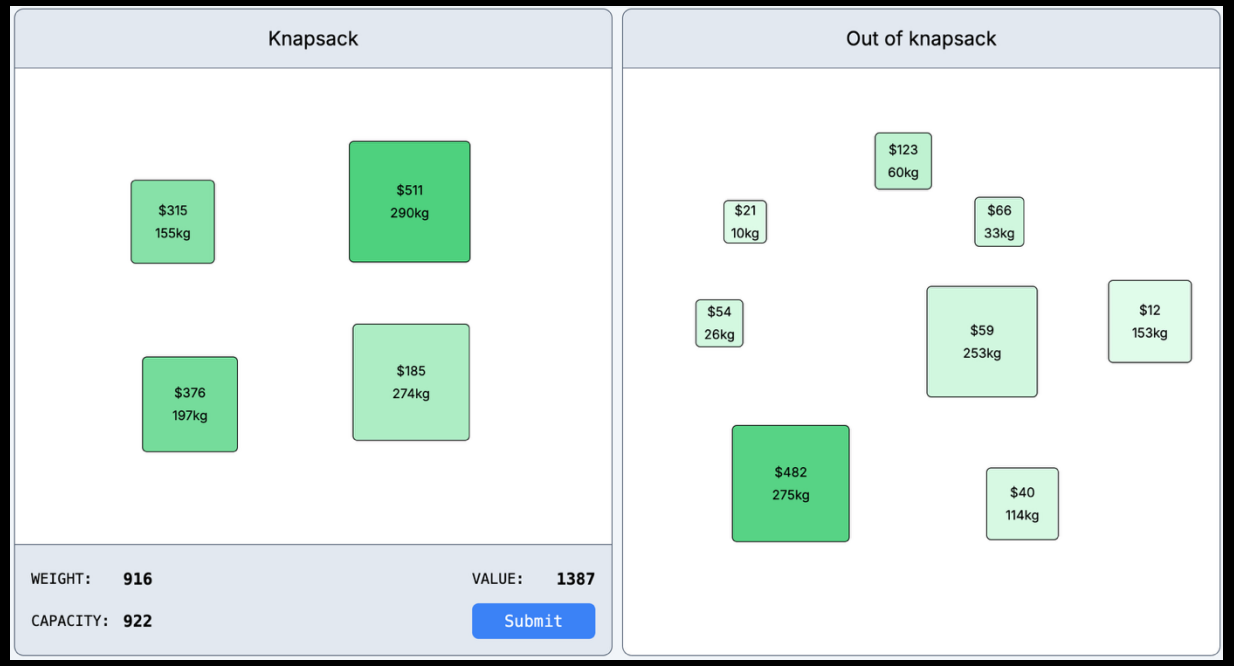
How should we (as a society) design our institutions?

Operationalising intellectual discovery

We analogise the process of intellectual discovery using the knapsack problem:

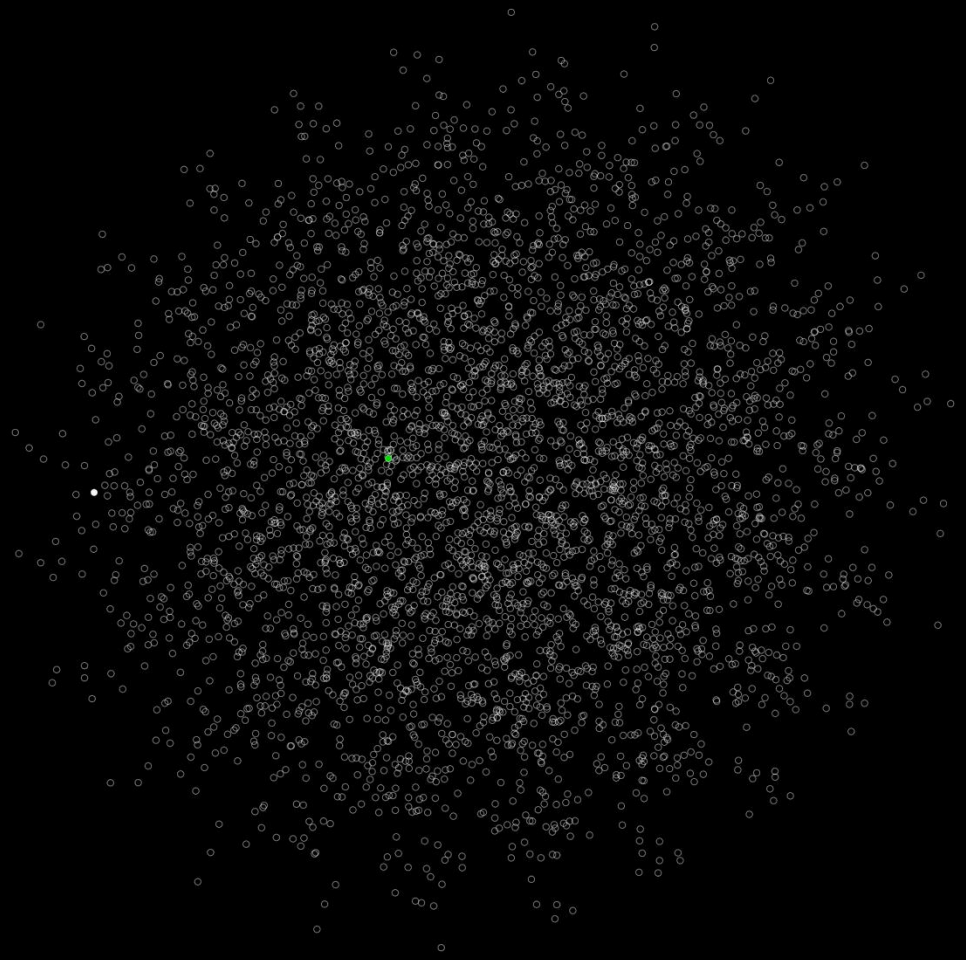
$$\max \sum_{i=1}^{n} v_i x_i \qquad \text{s.t.} \qquad \sum_{i=1}^{n} w_i x_i \leq C$$

- $W = \{w_1, \ldots, w_n\}$, weight vector
- $V = \{v_1, \ldots, v_n\}$, value vector
- $C =$ capacity constraint



Scan to try the KP yourself:
kme.research.cbmm.ai/demo/

Approximation



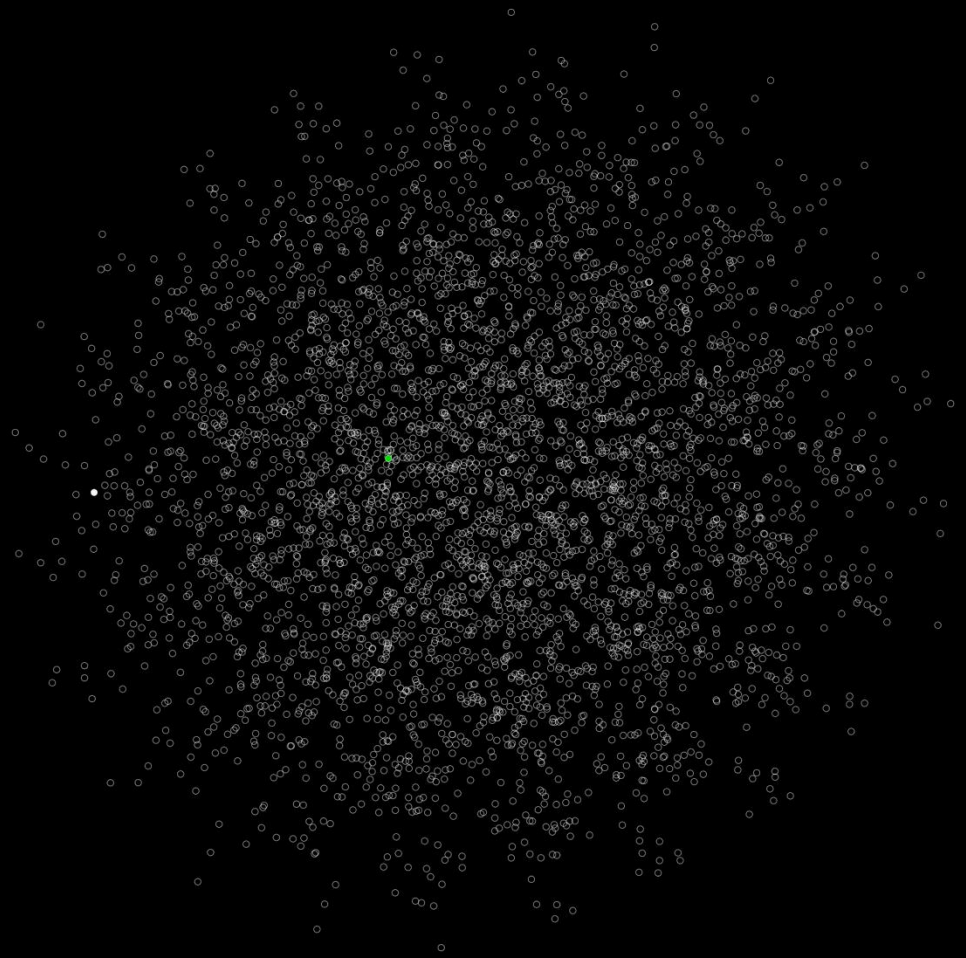
Problem: The total solution space is too vast to exhaustively explore.

Compromise: Individuals try to strike a balance between:

- **Solution quality** – the resulting solution should be within ϵ of the optimum.
- **Frugality** – computational cost should be minimised.

Result: Search over constrained subset of total solution space.

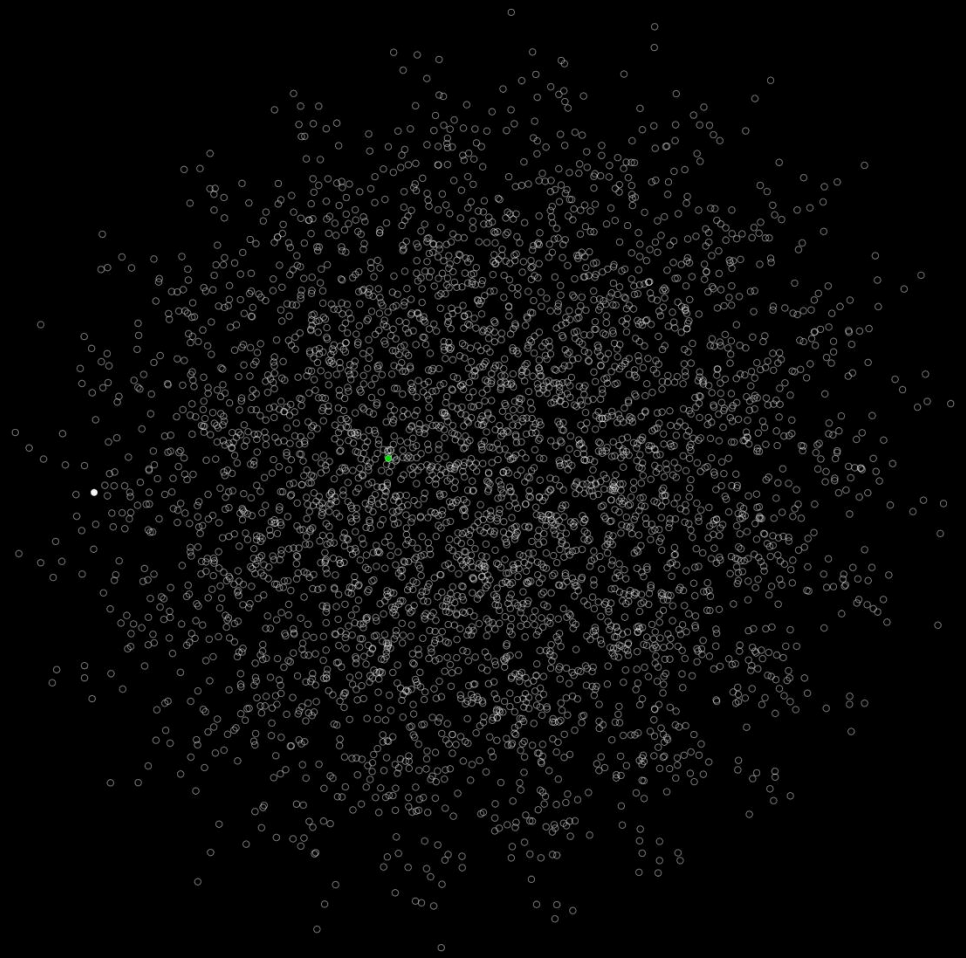
Collective problem-solving



A single individual explores a small subset of the solution space.

A group of individuals collectively explore a large portion of the solution space.

Collective problem-solving



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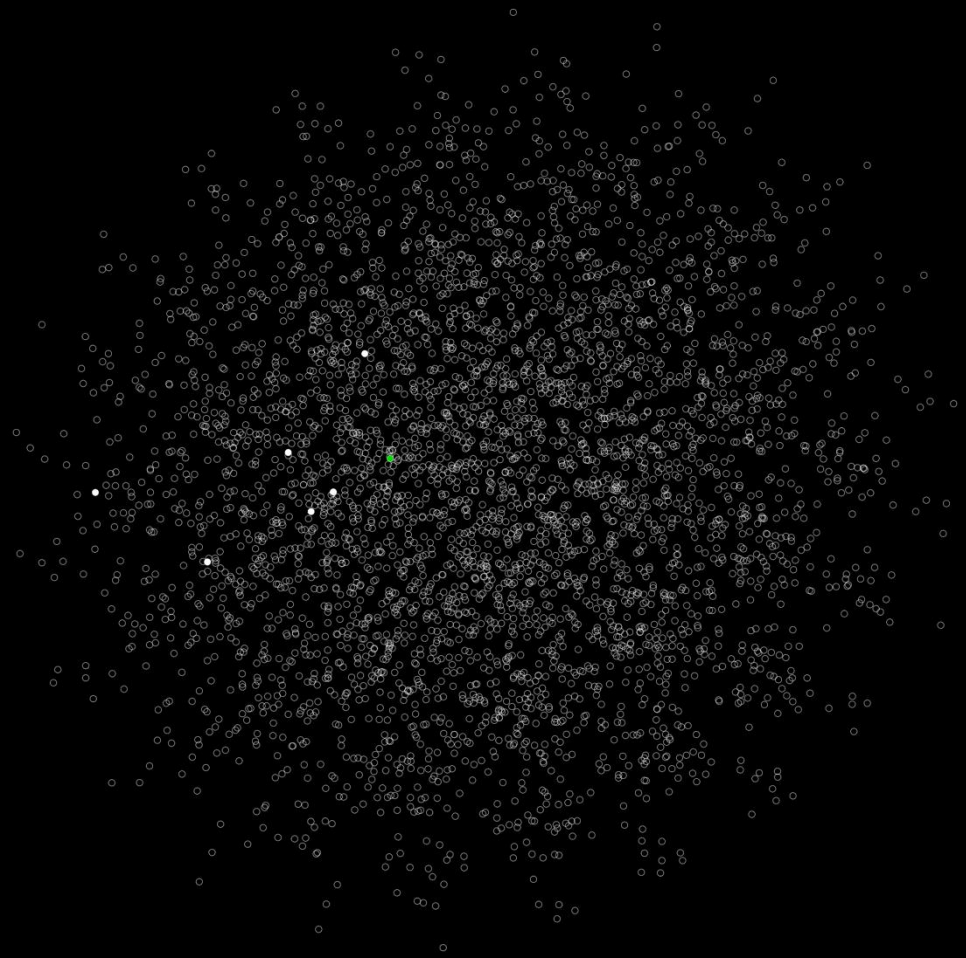

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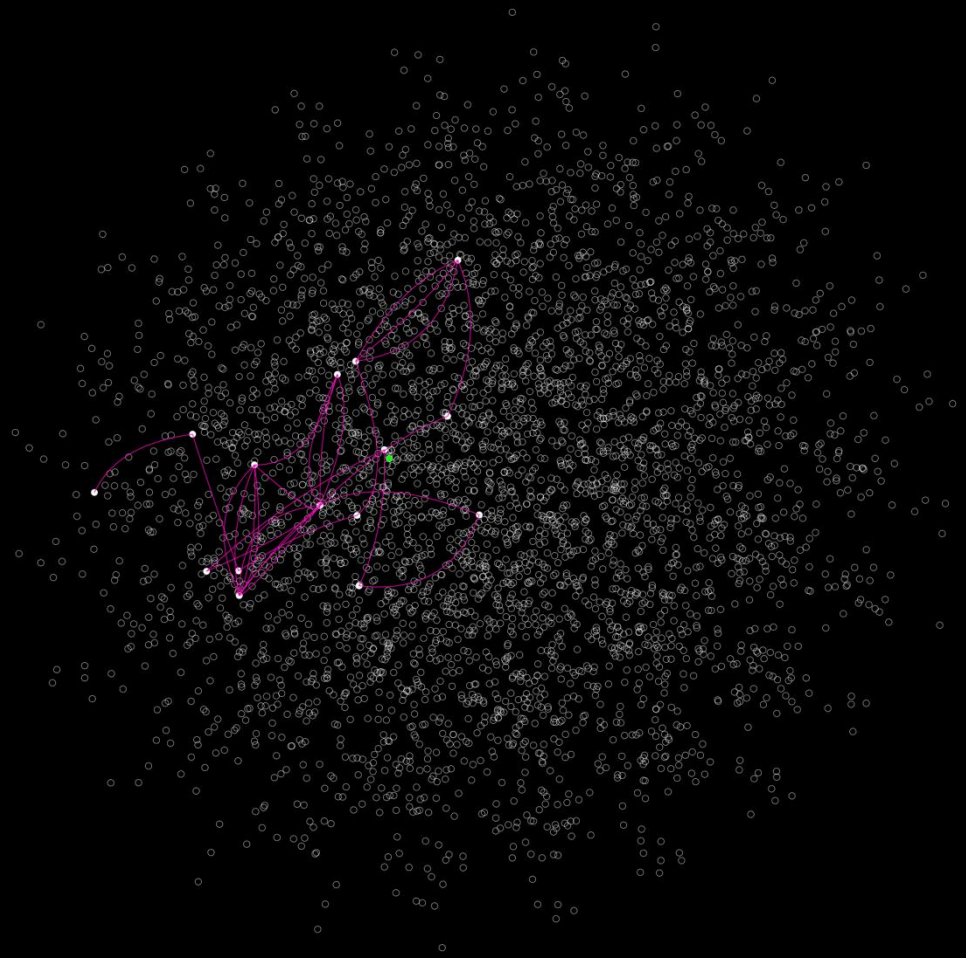
Collective problem-solving



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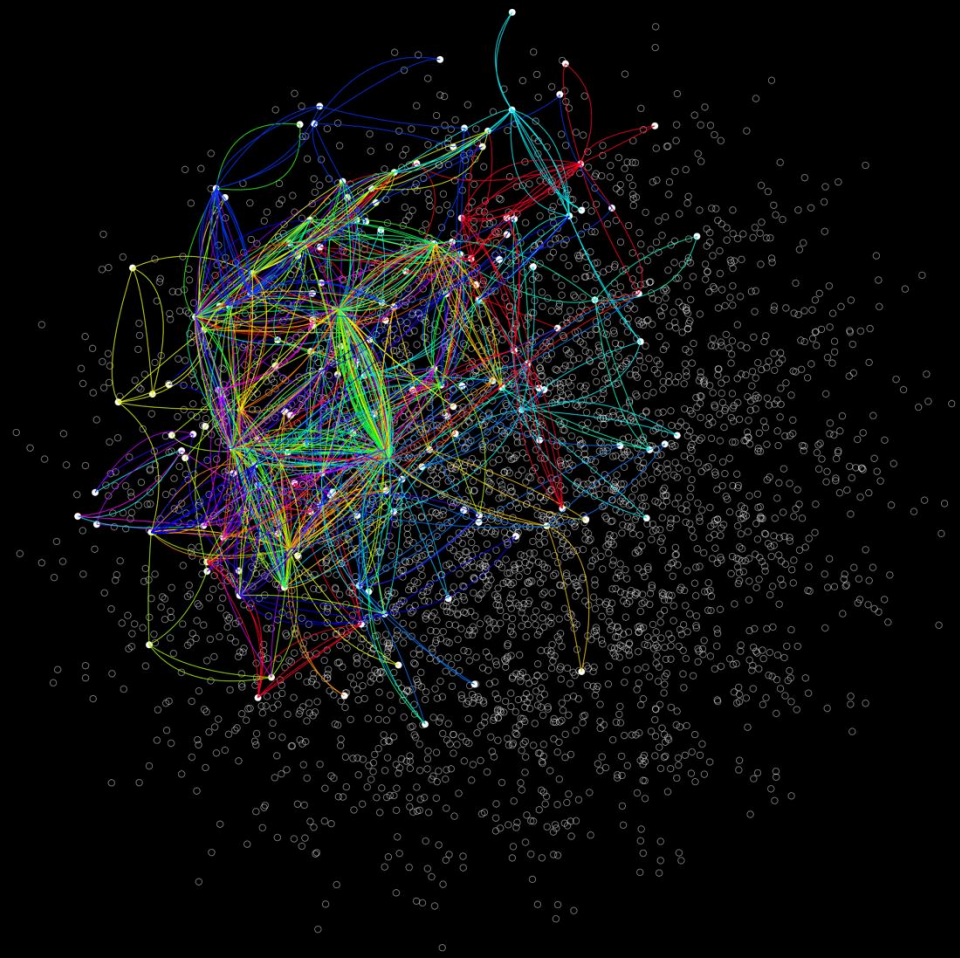


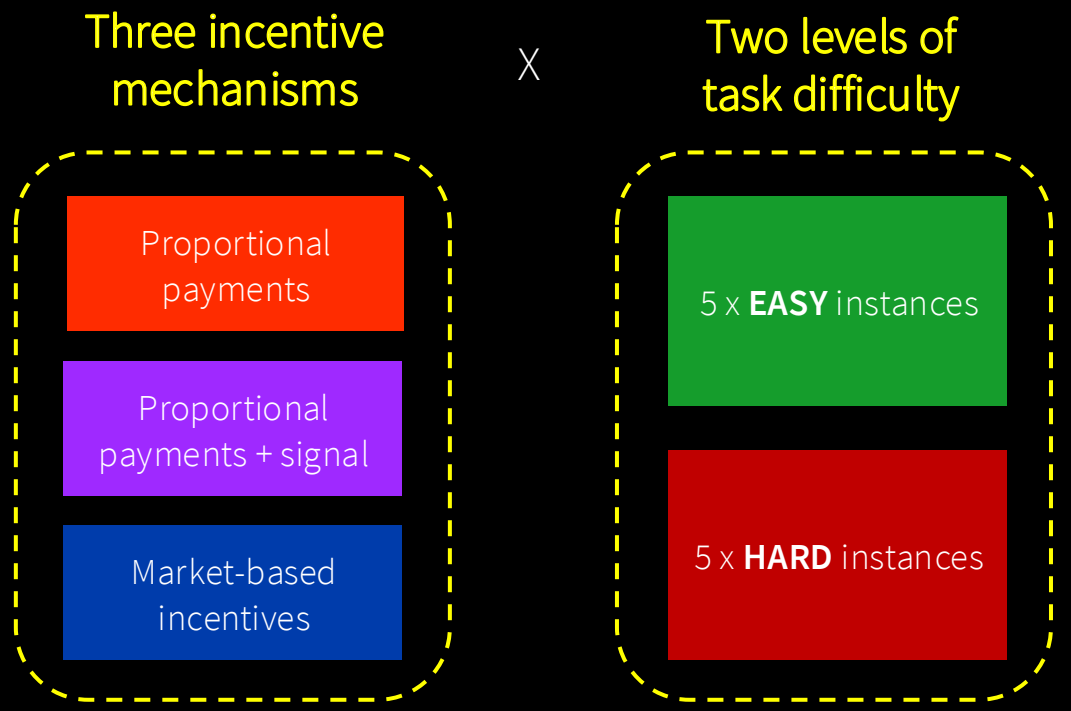
A group of individuals collectively explore a large portion of the solution space.

Experiment design

- **Sample of N = 120**
  Recruited from the University of Melbourne community, aged between 18 - 50. Mean age: 26; Gender: 78F, 41M, 1 prefer not to say.

- **3 (treatments) x 2 (difficulty)**
  In each treatment, participants solved 10 instances of the knapsack problem (5 easy, 5 hard)

- **Within-subject design**
  Six blocks of ~20 participants completed each treatment. Order of treatments was perfectly counterbalanced.



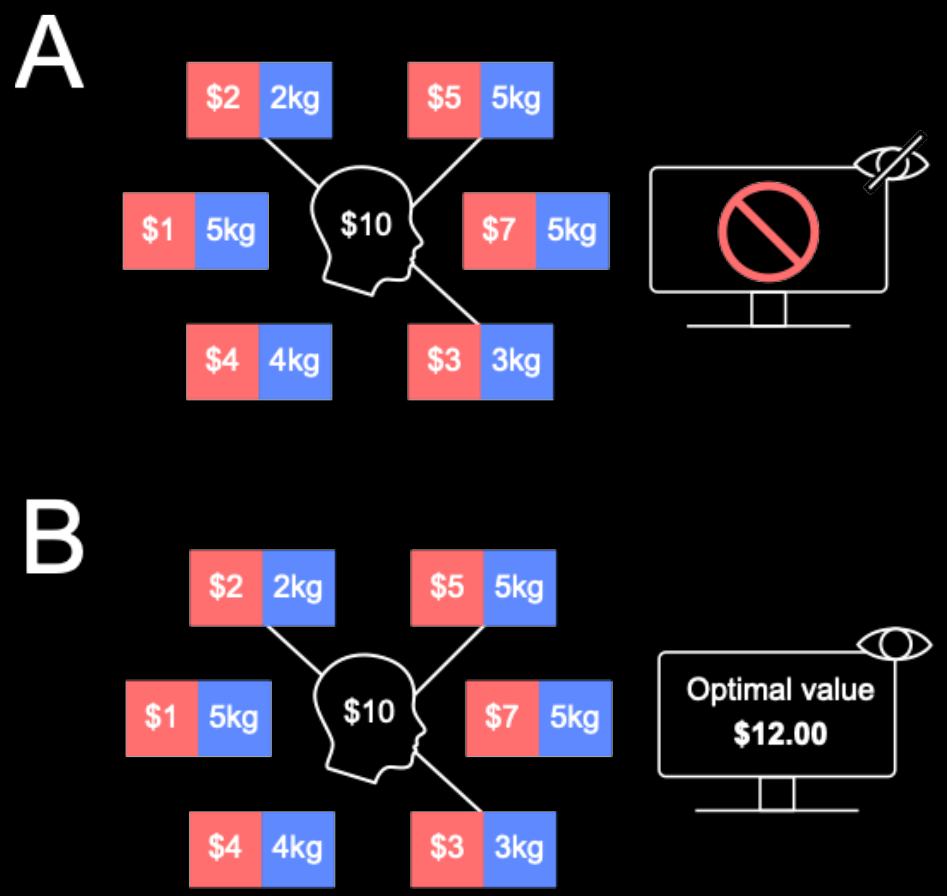
Treatments

- **Proportional payments**
  Participants paid in proportion to their effort.

  $1.50 in proportion to submitted value
  $1.50 bonus for finding the optimal solution

- **Proportional payments + signal (signal)**
  Identical to proportional payment treatment.

  Except that participants were told the optimal value before attempting to solve the instance.



- **Market treatment**[1]

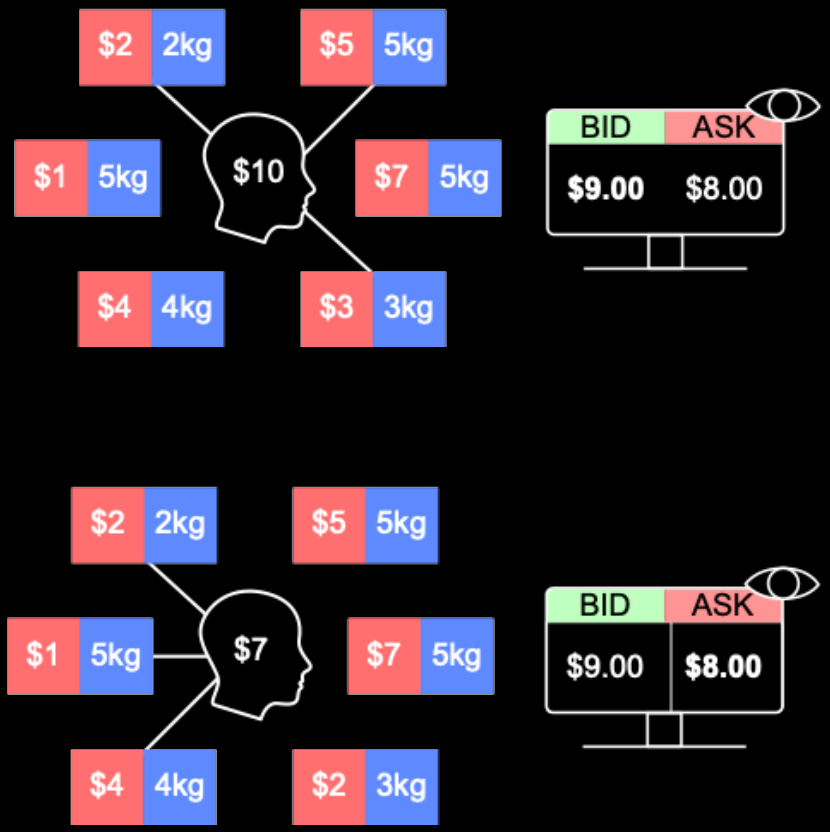
Participants trade experimental assets (“stocks”), while solving the knapsack problem.

The stock’s value equals the highest solution discovered by anyone.

Profit comes from:

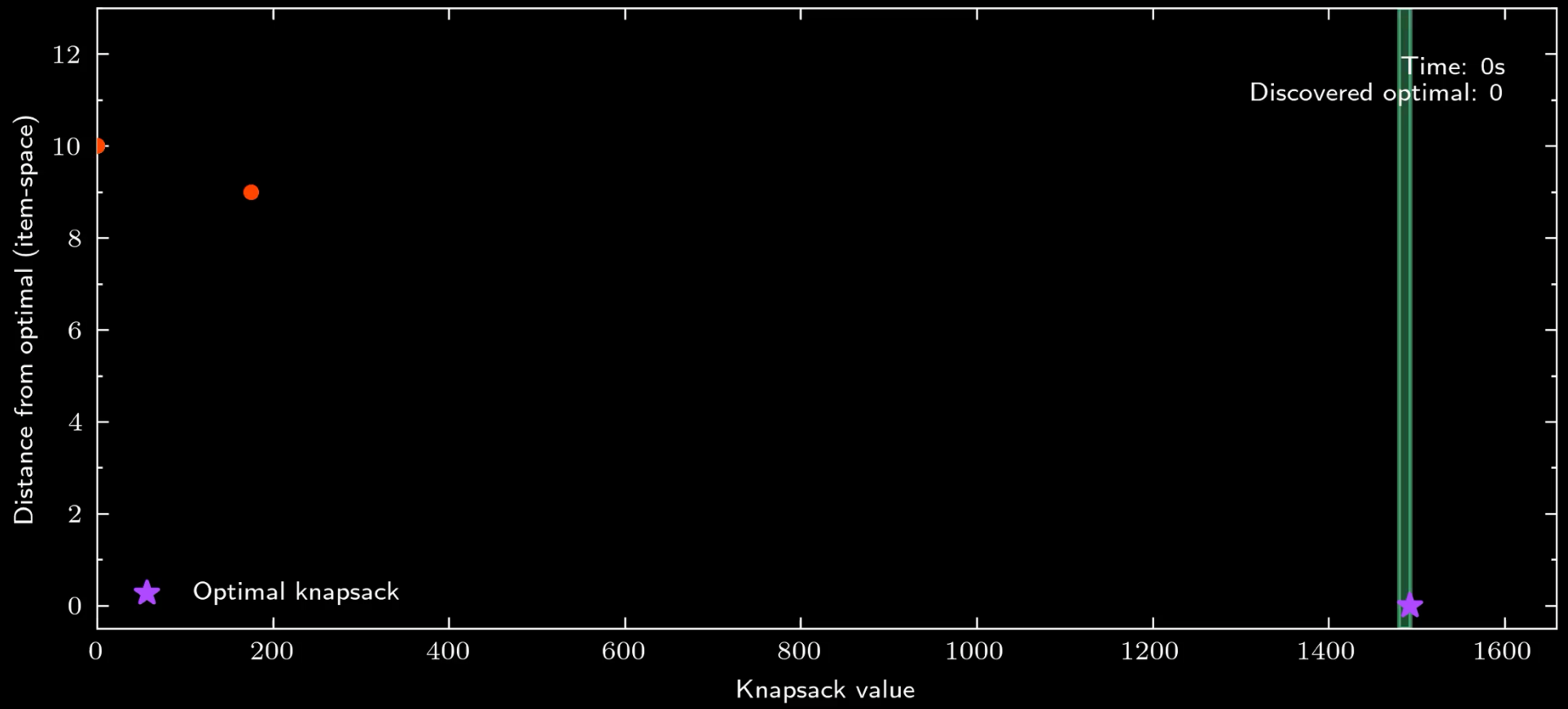
- Buying stocks at prices below the final best solution, and
- Selling stocks at prices above the final best solution.

C



1. Adapted from experiment two in Bossaerts, Peter, et al. "Resource allocation, computational complexity, and market design." Journal of Behavioral and Experimental Finance 42 (2024): 100906.

Market condition



Outcome measures

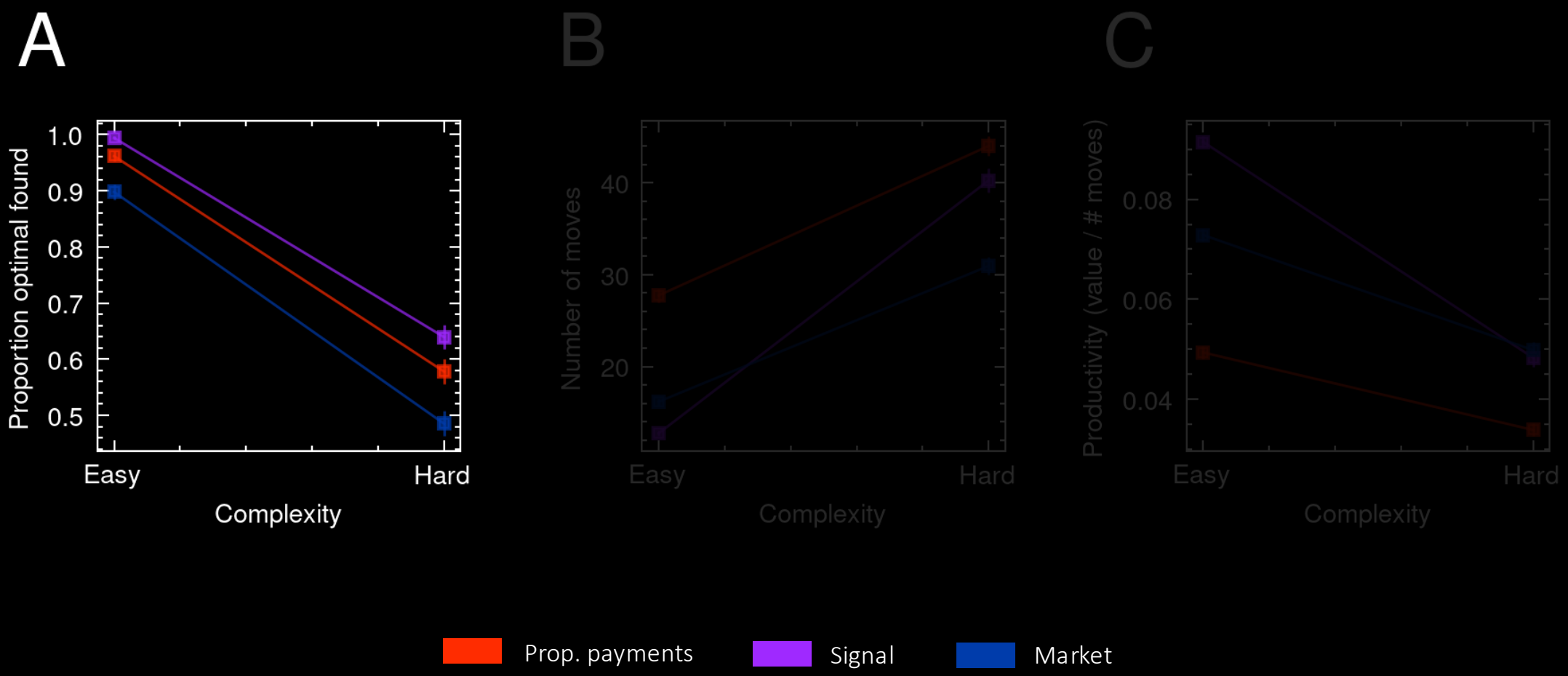
1. **Quality**
   Probability optimal solution attained

2. **Effort**
   Number of ‘item moves’

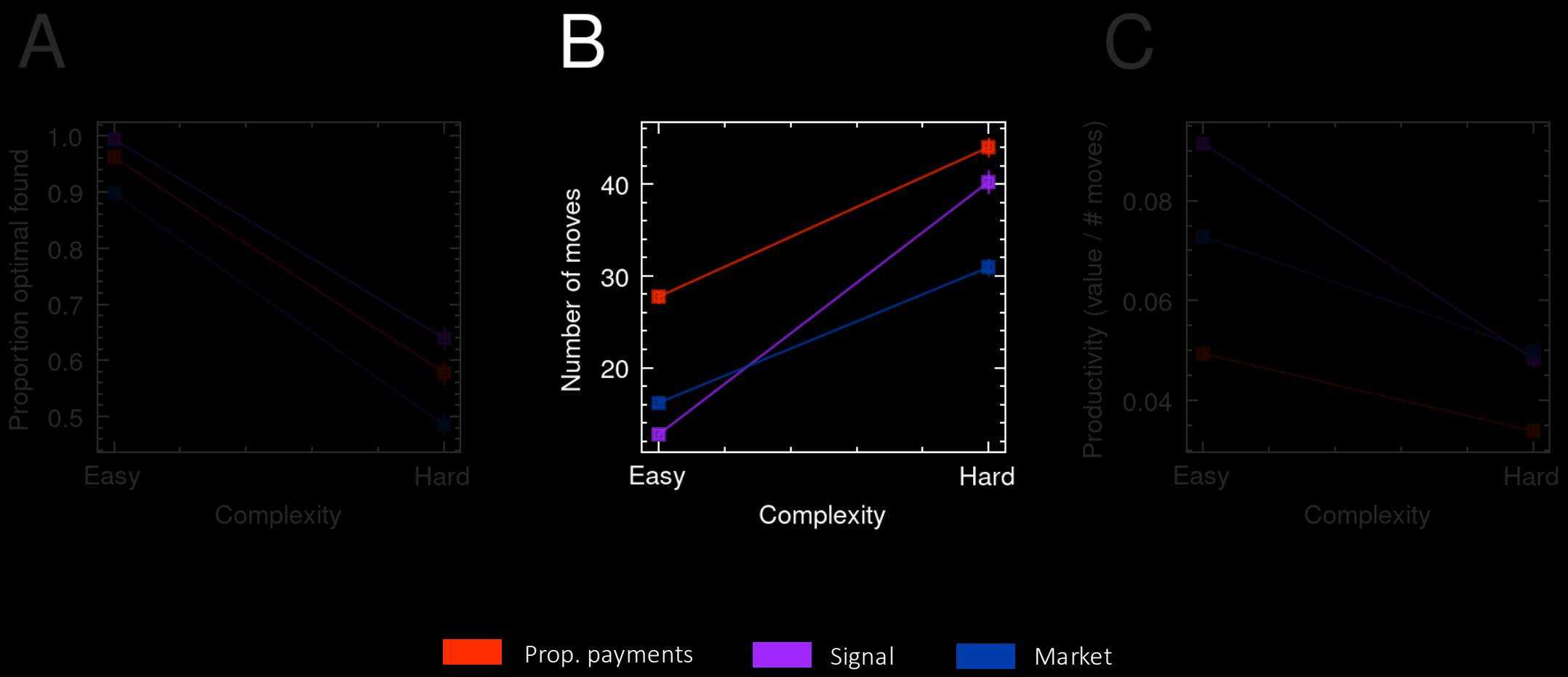
3. **Productivity**
   Submitted value / number of moves

4. **Speed of discovery**
   How long it takes for the optimal solution to be discovered

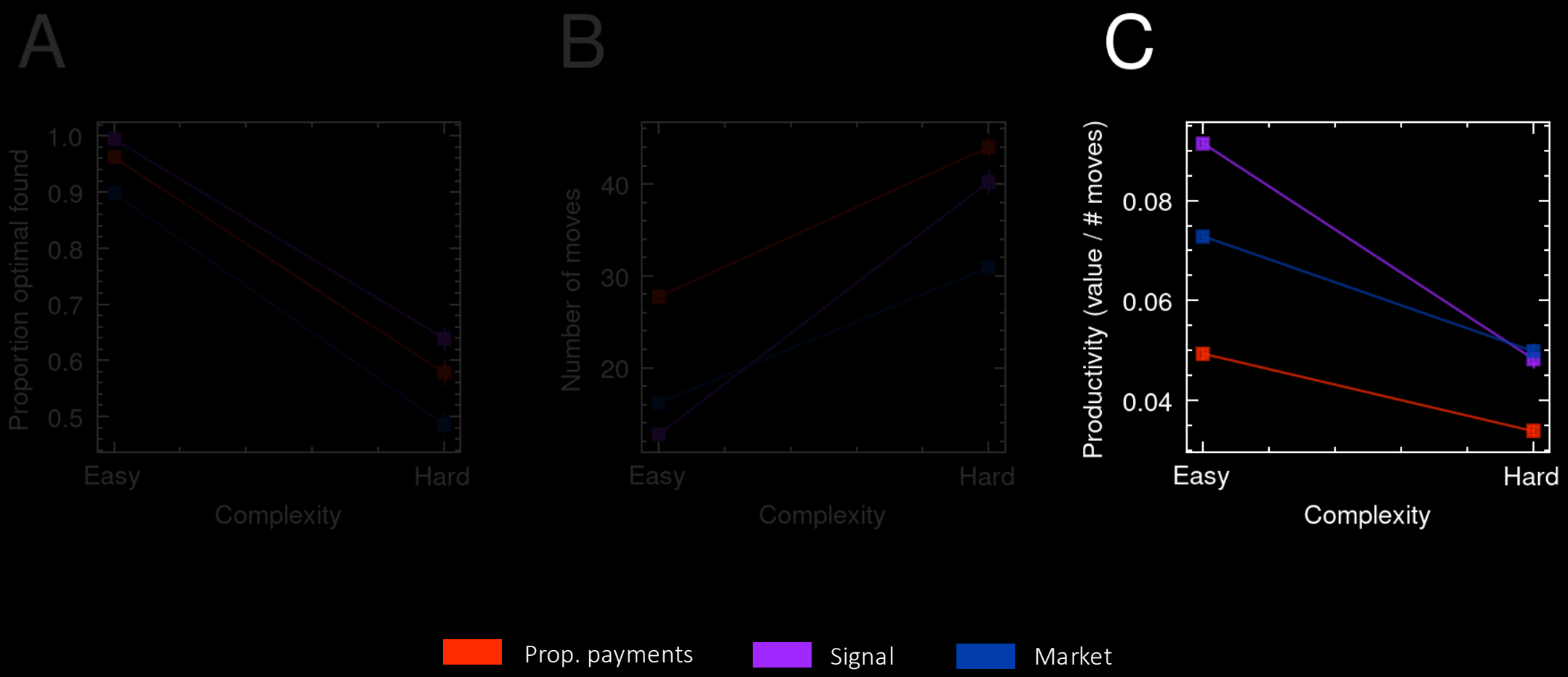
Quality, effort, productivity



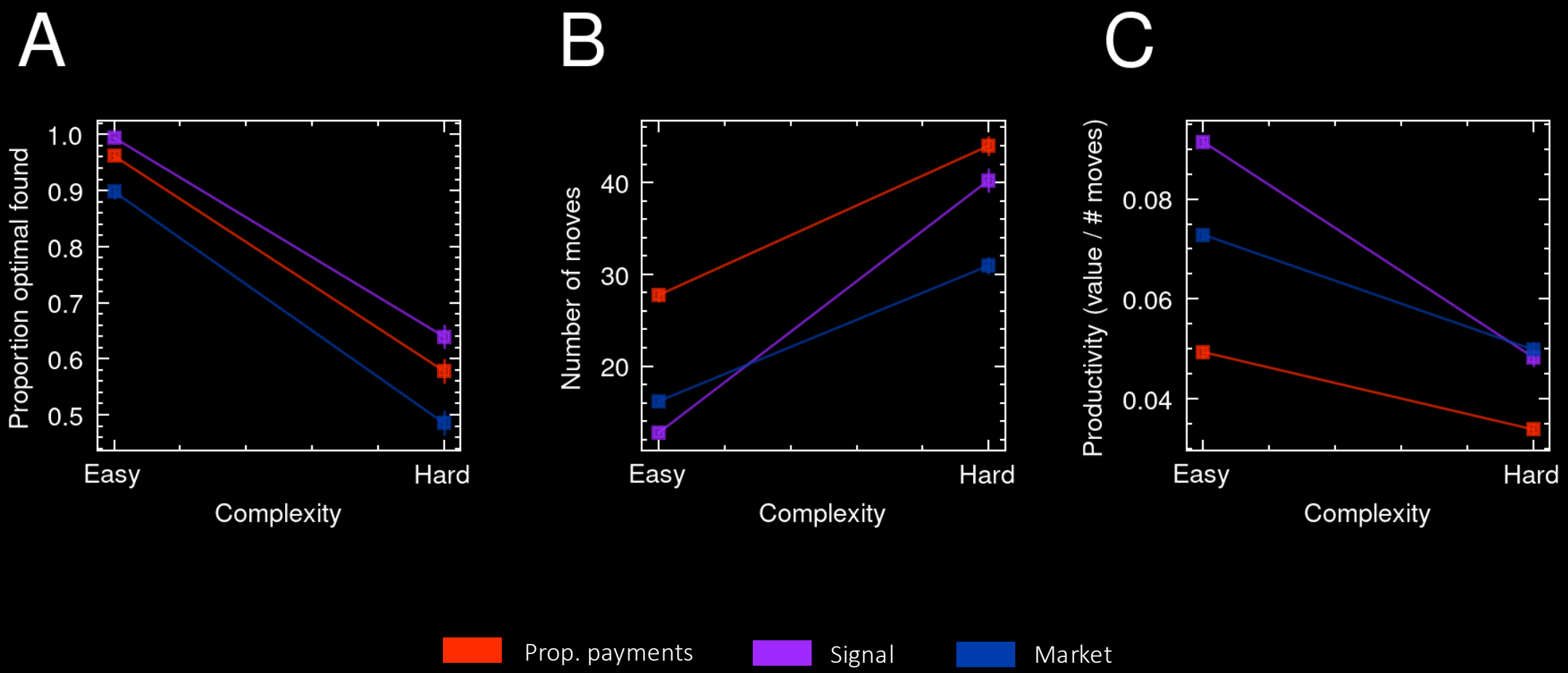
Quality, effort, productivity



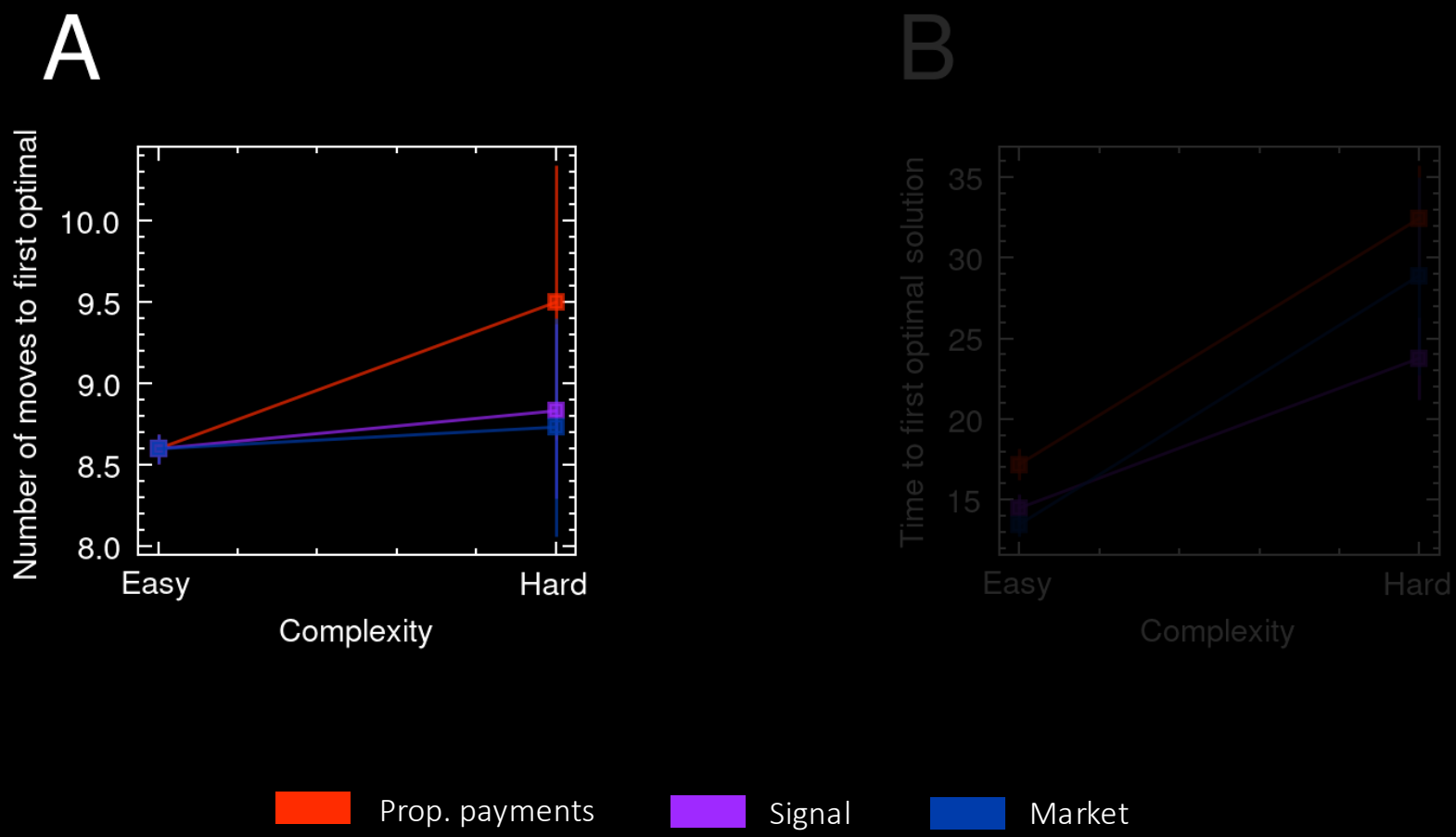
Quality, effort, productivity



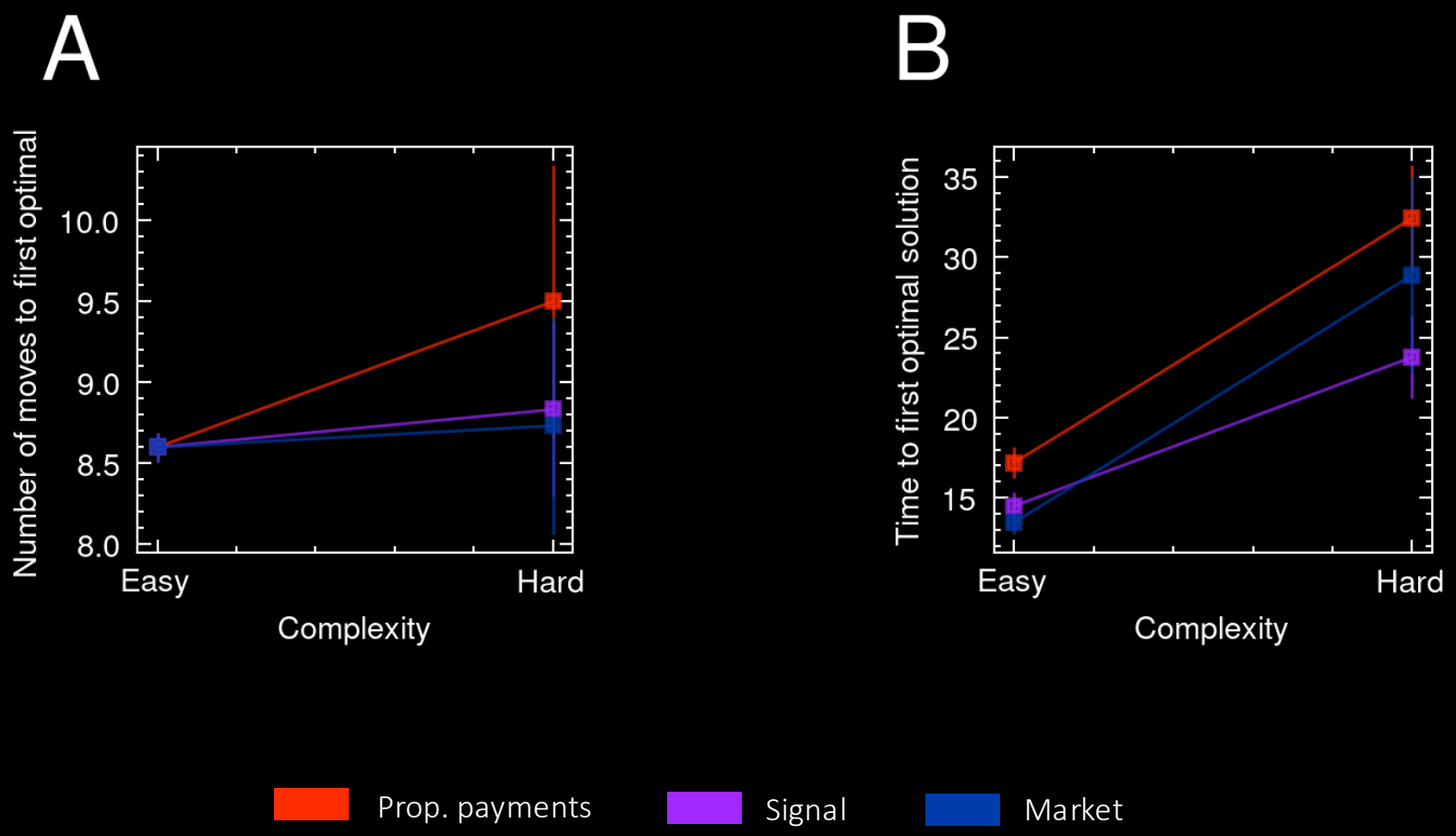
Quality, effort, productivity



Speed of discovery



Speed of discovery



Summary

1. **Complexity matters**
   Higher problems reduce performance but markets and signals can mitigate this.

2. **Markets enable collective intelligence**
   Groups explore larger portions of the solution space, trading shares information and reduces redundant effort.

3. **Payment ∝ effort → highest quality outcomes**
   Direct individual incentives maximise average solution quality at the expense of duplicated effort.

4. **Information sharing → speed of discovery (?)**
   Institutions that share information accelerate discovery on average (but large error bars)

Thank you

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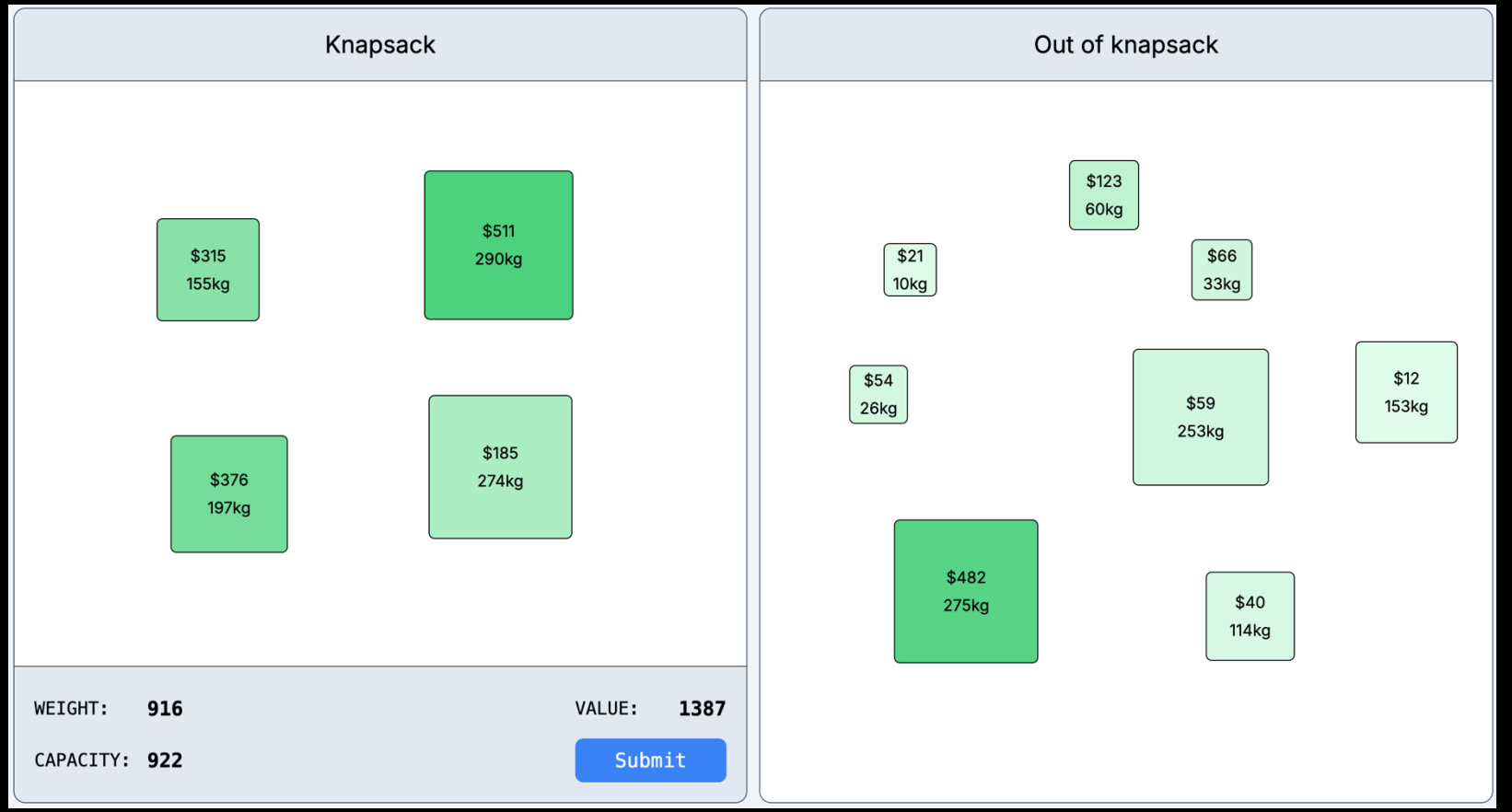
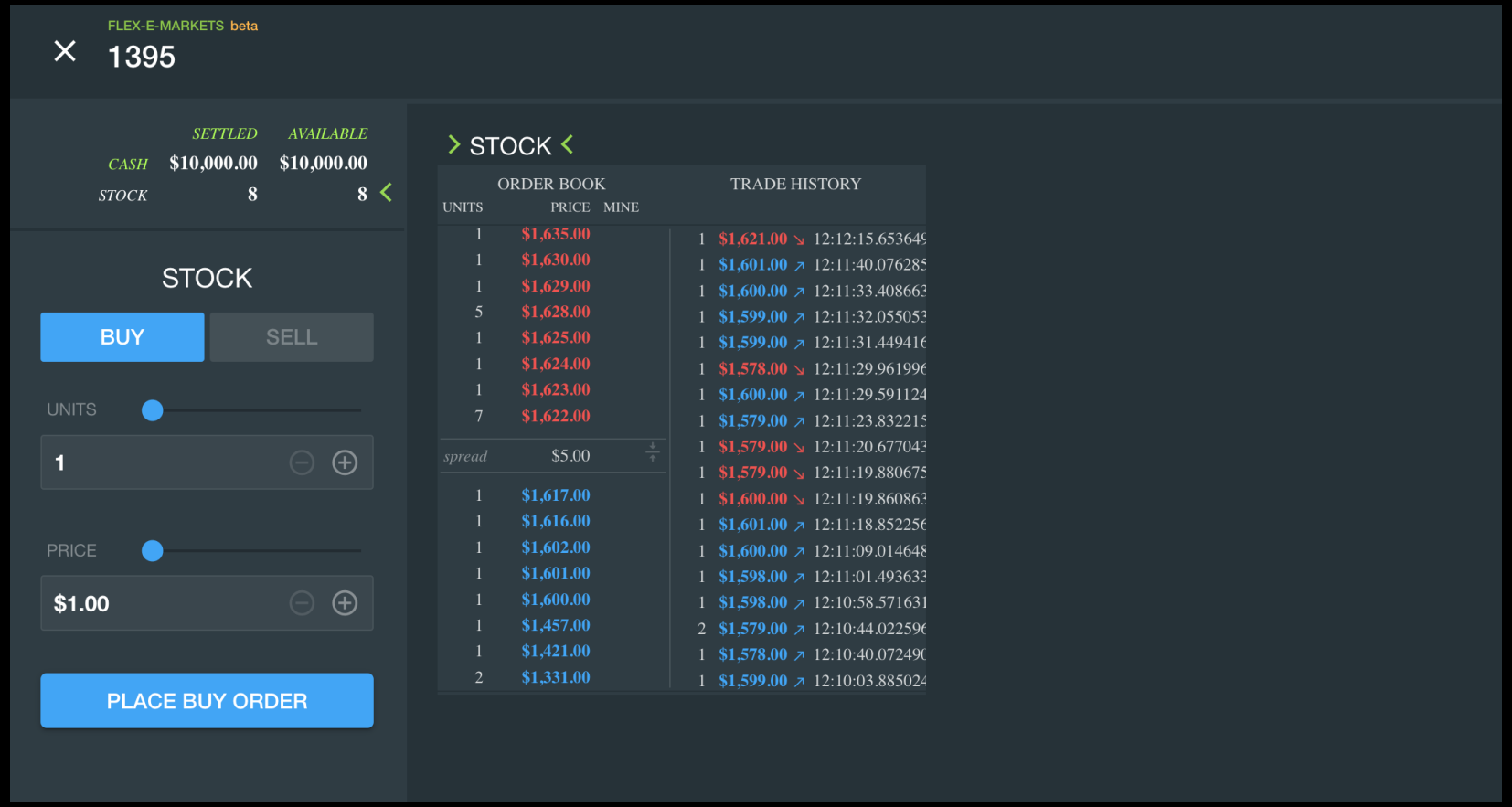
Knapsack Interface



Trading interface

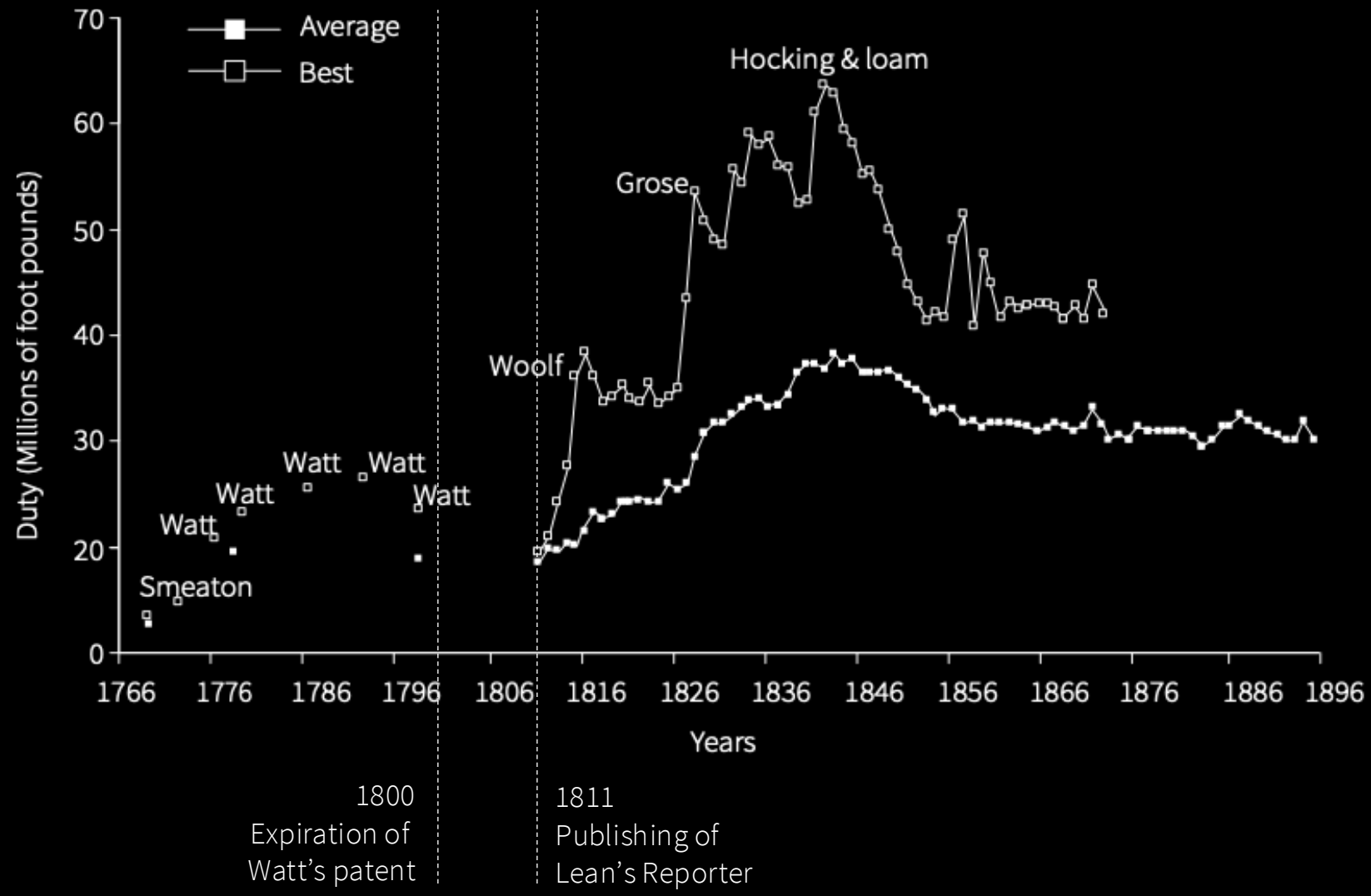


“If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. **But since we have had a patent system for a long time**, it would be irresponsible . . . to recommend abolishing it.”

An Economic Review of the Patent System

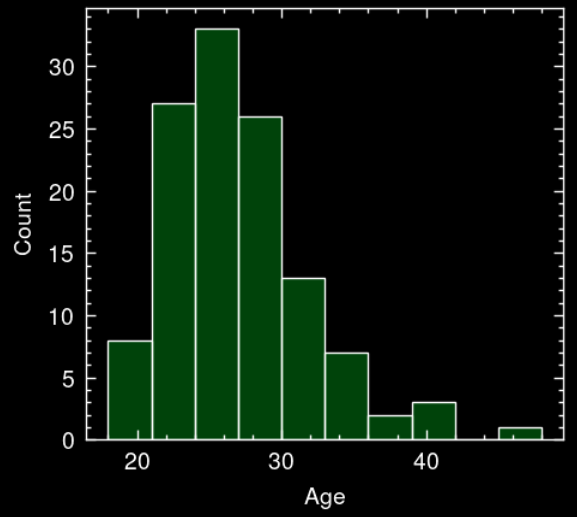
Fritz Machlup, 1958

Historical case study: Cornwall

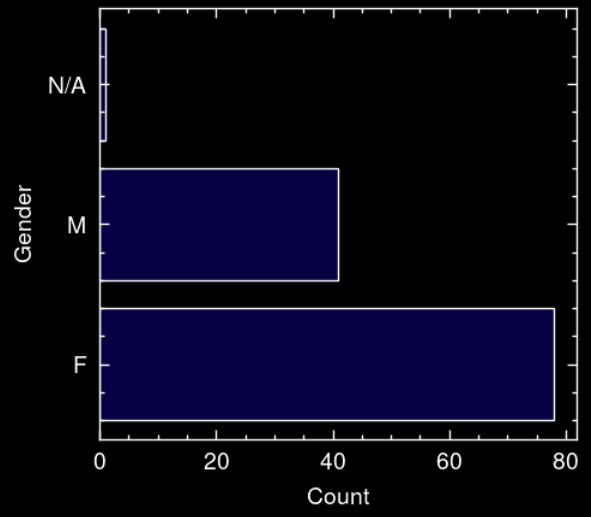


Demographics

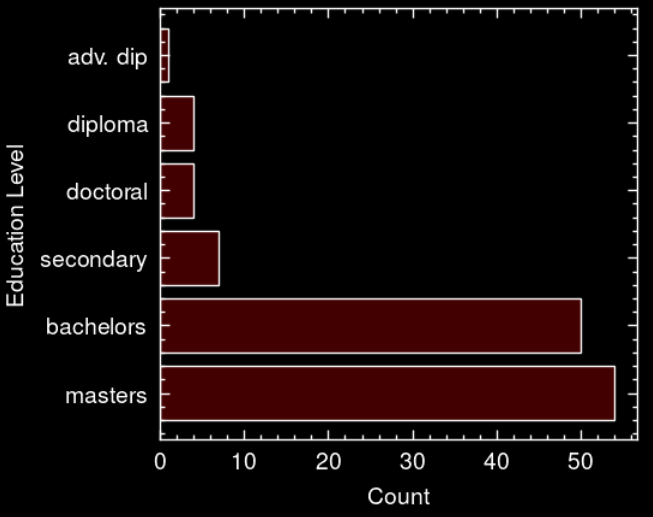
A



B

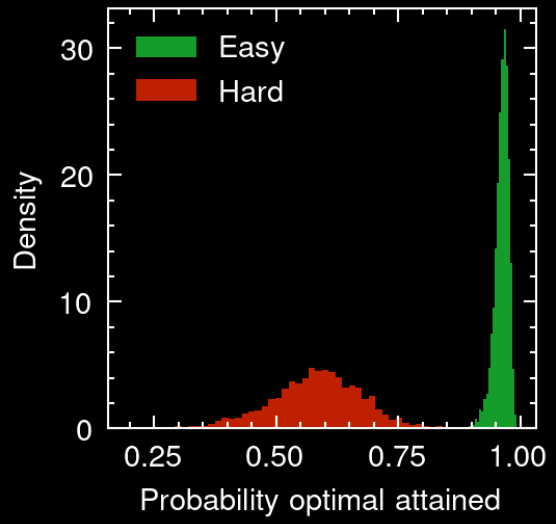


C

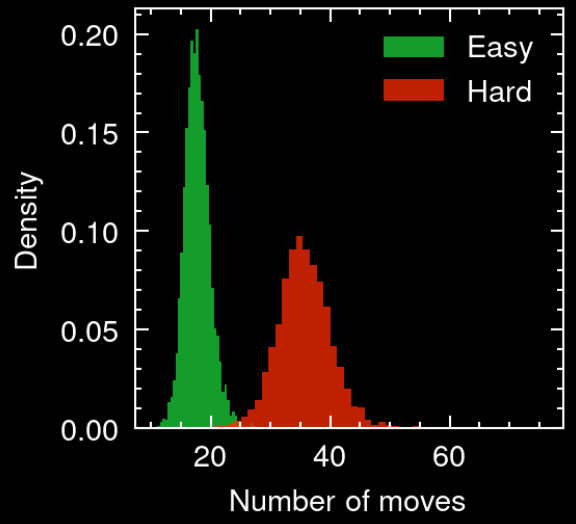


Effectiveness of complexity manipulation

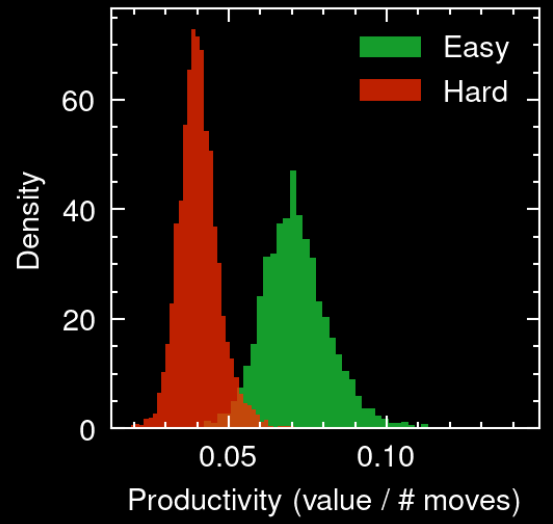
A

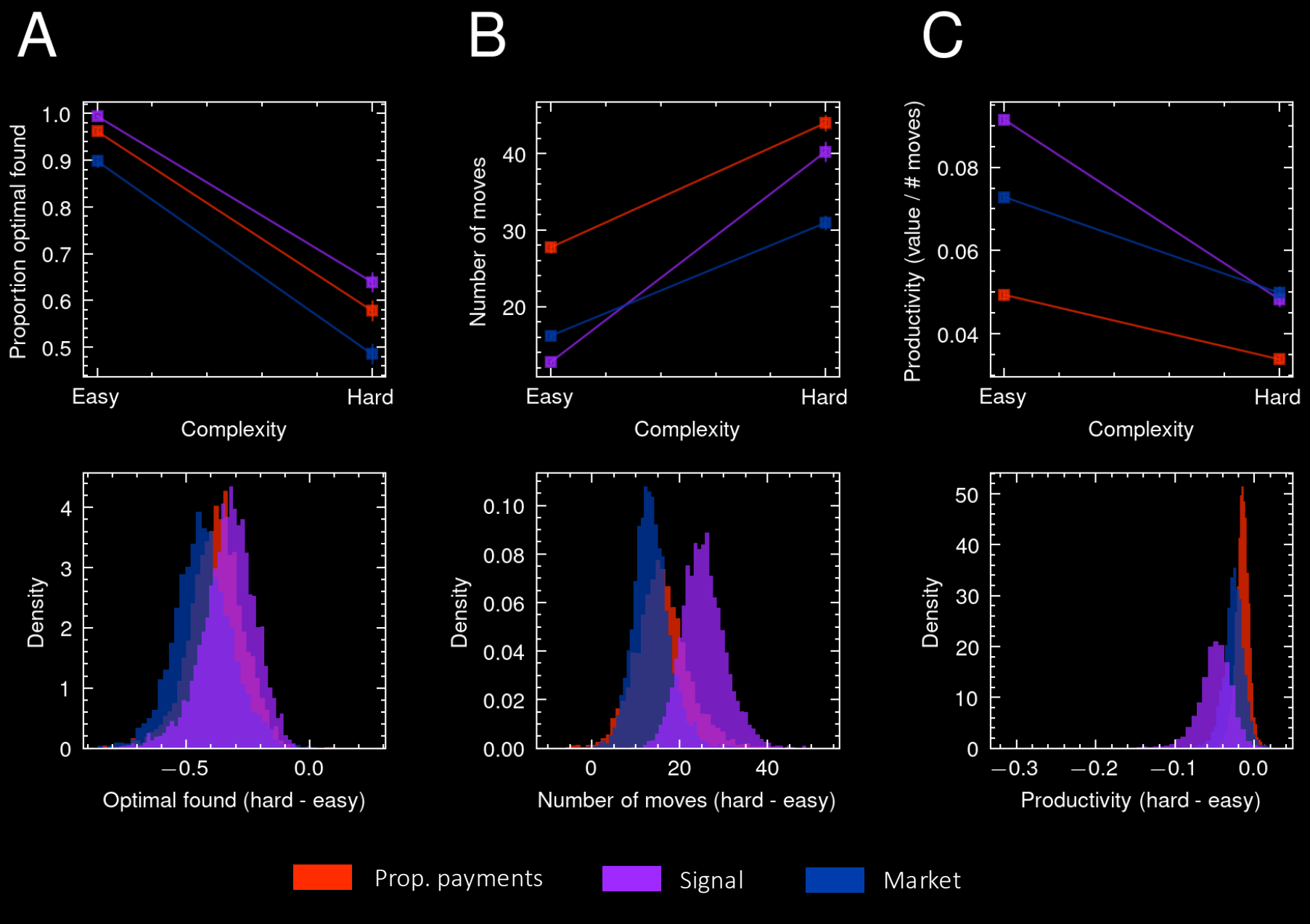


B



C




A
B
C
Proportion optimal found
1.0
0.9
0.8
0.7
0.6
0.5
Easy
Hard
Complexity
Number of moves
40
30
20
Easy
Hard
Complexity
Productivity (value / # moves)
0.08
0.06
0.04
Easy
Hard
Complexity
Density
4
3
2
1
0
−0.5
0.0
Optimal found (hard - easy)
Density
0.10
0.08
0.06
0.04
0.02
0.00
0
20
40
Number of moves (hard - easy)
Density
50
40
30
20
10
0
−0.3
−0.2
−0.1
0.0
Productivity (hard - easy)
Prop. payments
Signal
Market

Price efficiency and returns