Behavioral Time Allocation

Overconfidence and Uncertainty Aversion in Time-Performance Tradeoffs

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Motivation

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- Studied in cognitive science and psychology i.e. in movement (Dean et al., 2007), motor control (Nagengast et al., 2011), visual discrimination (Rinkenauer et al., 2004), overview in Heitz (2014)
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- Focus on more intuitive decision tasks in miliseconds time

- In economics, decision times mostly informative "byproduct" in binary choice (Alós-Ferrer et al., 2021; Chabris et al., 2009; Fudenberg et al., 2018; Oud et al., 2016)

This Project

time as key input in a salient time-performance tradeoff in a “cognitive visual search task”

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Hypotheses:

- Over(under)confident agents take less (more) time
- Uncertainty averse (seeking) agents take more (less) time

Simple model

Experiment

Individual choice experiment with 91 participants

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Features

1. Stage I: Individual measures of
   - Performance
   - Subjective beliefs about performance ("overconfidence")
   - Within-domain uncertainty aversion
2. Stage II: Endogenous time choice in salient time-performance tradeoff

Cognitive Visual Search Task

14	17	31	34
19	35	16	41
37	38	15	36
30	42	28	22

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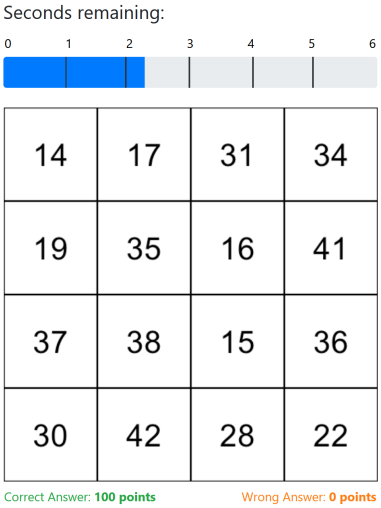
30	42	28	22

Advantages:

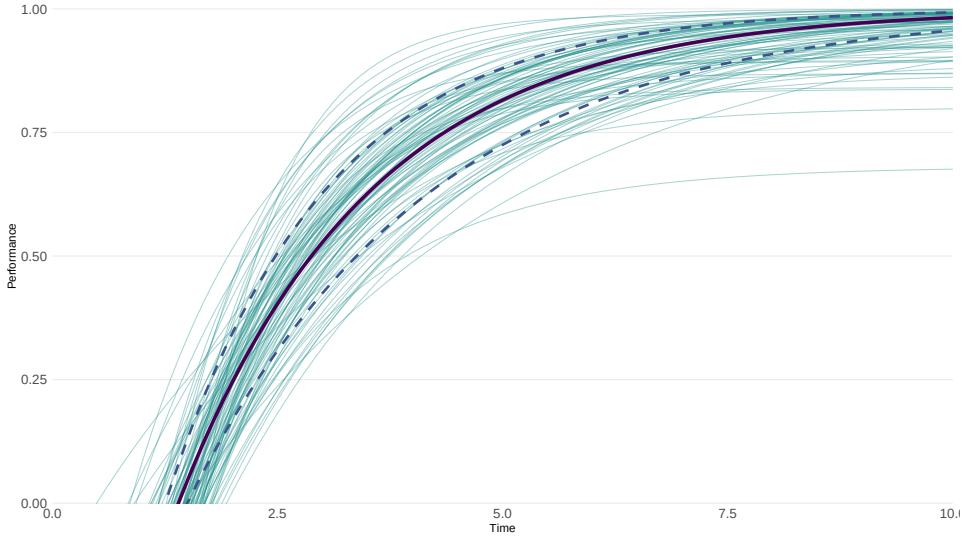
- performance increasing in ***t***
- precise estimates of time-dependent performance possible (large number of repetitions)

Measuring Performance

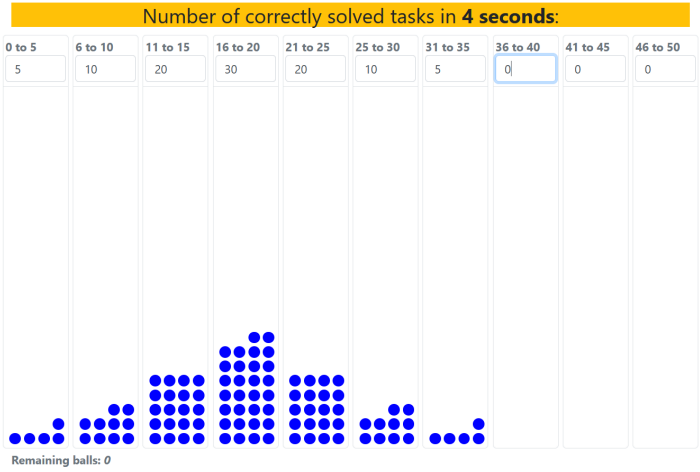


- 50 tasks with 2, 3, 4, 5, and 6 seconds each
- Fit time-dependent three-parameter performance function (Dean et al., 2007) Performance function Performance fit

Performance Functions



Measuring Beliefs



- $\forall\, t \in (2, 3, 4, 5, 6)$

Method: Delavande & Rohwedder, 2011, Drerup et al., 2017; binarized Quadratic Scoring Rule: Hossain & Okui, 2013

Belief Weighting Functions

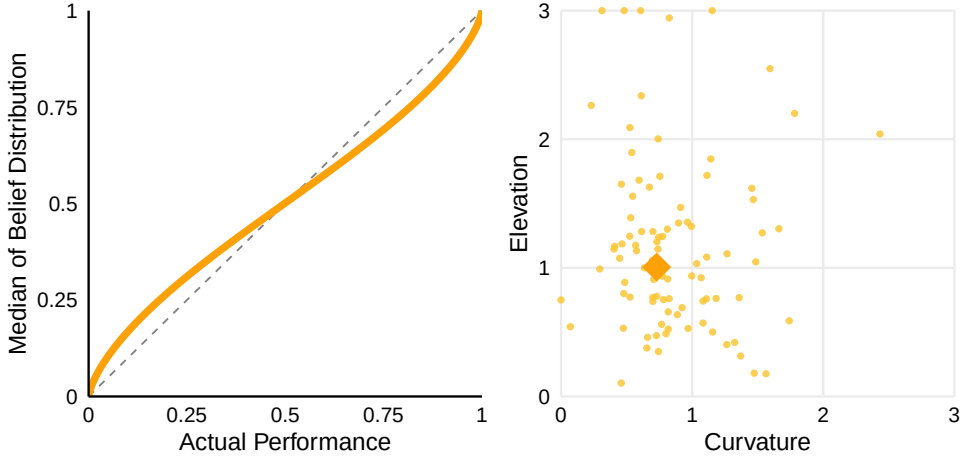


Figure 1: This plot shows the estimated parameters from a Goldstein & Einhorn two parameter weighting function. The left panel uses pooled data from all participants and plots the resulting average function. The right panel shows the individual estimates.

Measuring Certainty Equivalents

4 seconds Decision Time					
	Payout scheme A			Payout scheme B	
	If correct:	If wrong:		If correct or wrong:	
1.	100 points	0 points	◉	○	0 points
2.	100 points	0 points	◉	○	5 points
3.	100 points	0 points	◉	○	10 points
4.	100 points	0 points	○	◉	15 points
5.	100 points	0 points	○	◉	20 points
6.	100 points	0 points	○	◉	25 points
7.	100 points	0 points	○	◉	30 points
8.	100 points	0 points	○	◉	35 points
9.	100 points	0 points	○	◉	40 points
10.	100 points	0 points	○	◉	45 points
11.	100 points	0 points	○	◉	50 points
12.	100 points	0 points	○	◉	55 points
13.	100 points	0 points	○	◉	60 points
14.	100 points	0 points	○	◉	65 points
15.	100 points	0 points	○	◉	70 points
16.	100 points	0 points	○	◉	75 points
17.	100 points	0 points	○	◉	80 points
18.	100 points	0 points	○	◉	85 points
19.	100 points	0 points	○	◉	90 points
20.	100 points	0 points	○	◉	95 points
21.	100 points	0 points	○	◉	100 points

- $\forall\, t \in (2, 3, 4, 5, 6)$
- Decision in randomly drawn row determines payoff scheme (for 10 tasks each)

NCE Weighting Functions

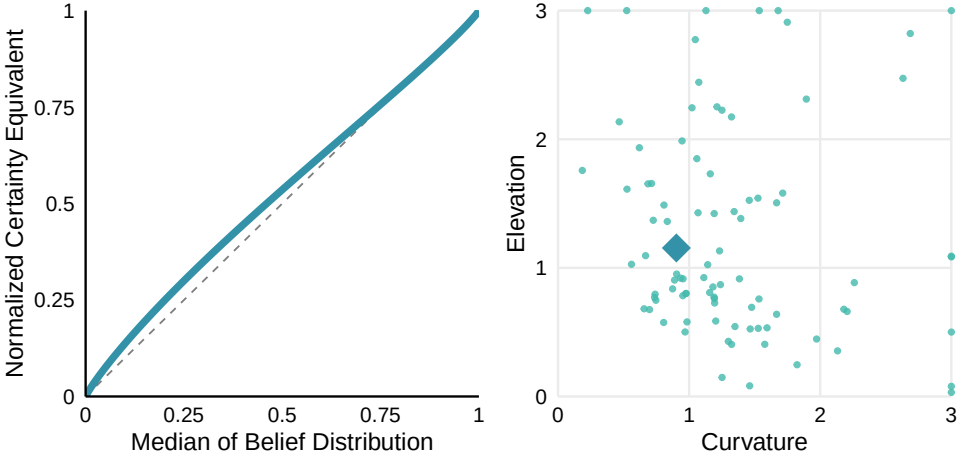
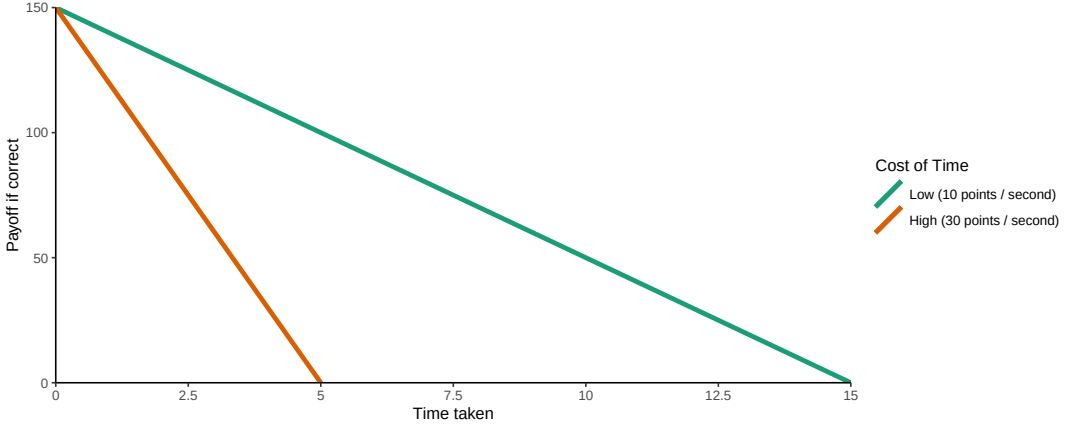


Figure 2: This plot shows the estimated parameters from a Goldstein & Einhorn two parameter weighting function. The left panel uses pooled data from all participants and plots the resulting average function. The right panel shows the individual estimates.

SPT: Cost of Time δ

$$\Pi(t) = \begin{cases} Y - \delta * t & \text{if correct} \\ 0 & \text{otherwise} \end{cases}$$



SPT: Two modes

Prospective

- Decide **ex-ante** on time for *all* subsequent tasks (40)
- Single decision

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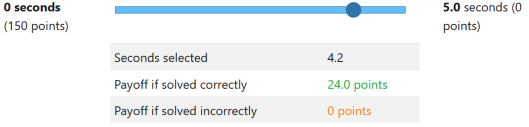

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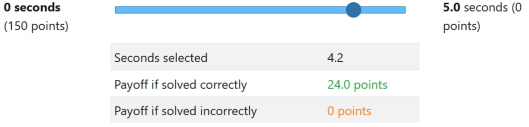

Simultaneous

- Decide individually **while solving** tasks (40)
- Mean time taken

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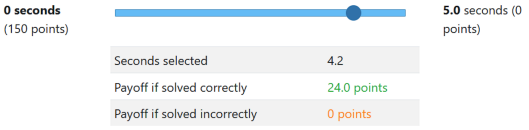

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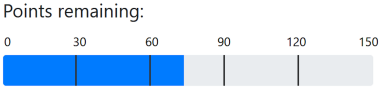

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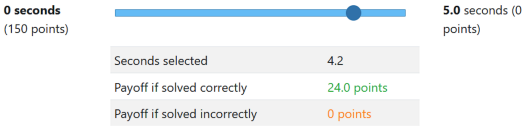

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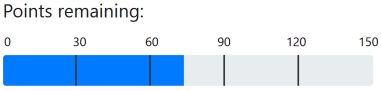


- 4 time choices per individual (2 modes $\times$ 2 costs)

Time decisions

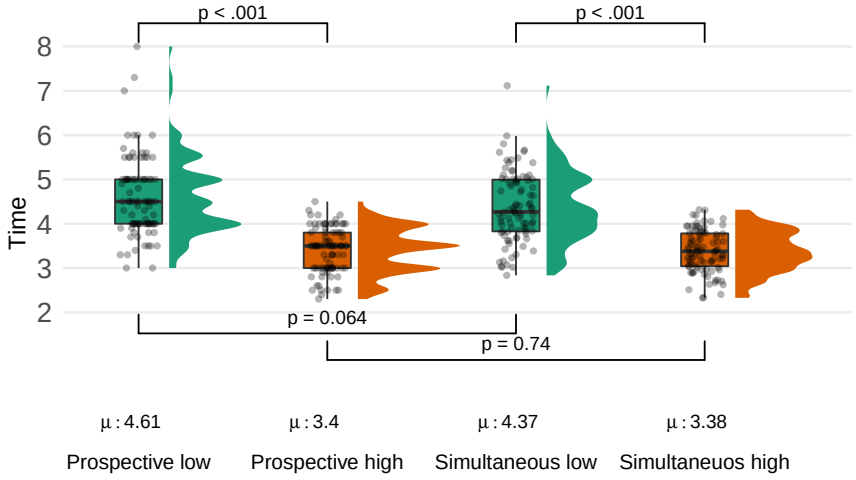
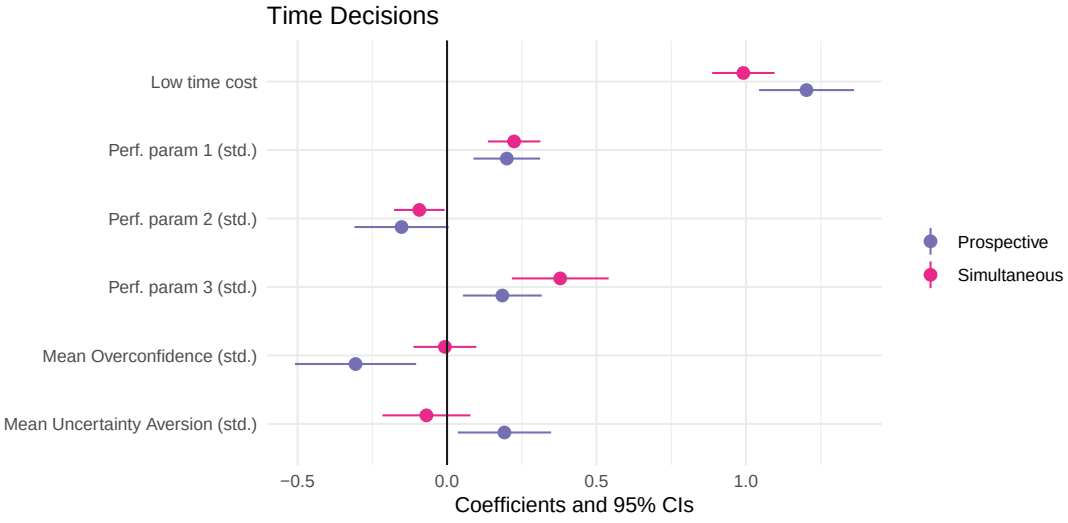


Figure 3: This graph shows the time selected in the prospective mode and mean time taken (μ) in the simultaneous mode for both costs of time. p-values from pairwise t-tests.

Time decisions: Regression



Panel model with individual random effects, Cluster robust standard errors, clustered on the individual level

Distance from “optimal” action

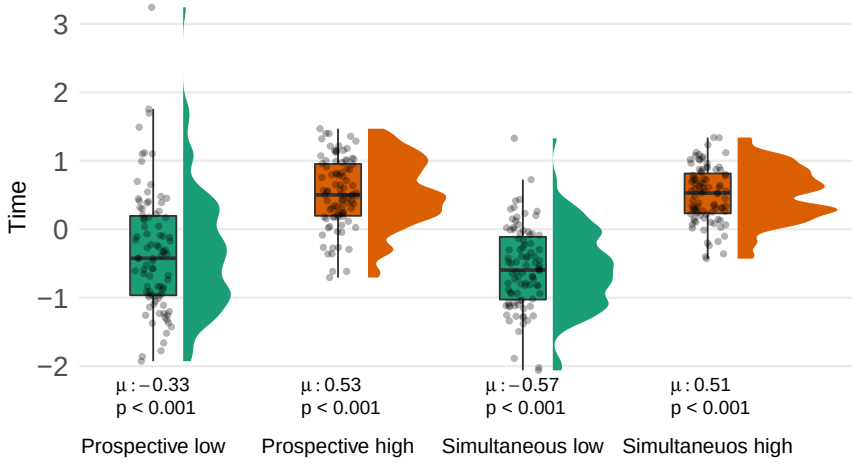


Figure 4: This graph shows (time choice $-$ t^*) in all four conditions. P-values from a t-test of the mean being equal to 0. μ provides the mean.

Conclusion

- Large heterogeneity in time choices, performance, beliefs about performance and within-domain uncertainty attitudes

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- Large heterogeneity in time choices, performance, beliefs about performance and within-domain uncertainty attitudes
- Facing a time-performance tradeoff
  - the cost of time and indiv. performance predict time choices
  - in addition, overconfidence and uncertainty aversion predict *prospective*, but *not simultaneous* time choices
- In a high (low) cost-of-time environment, participants choose “too much” (“too little”) time

Thank you!

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Time-Performance Tradeoffs: Simple theory

- Generally:

$$t^* = argmax_t\ R(t) = B(t) - C(t) \tag{1}$$

- Our setting:

$$t^* = argmax_t\ \mathbb{E}[R(t)] = p(t) \times (Y - \delta \times t) \tag{2}$$

- Behavioral channels:

$$t^b = argmax_t\ \mathbb{E}[R(t)] = w(\tilde{p}(t)) \times (Y - \delta \times t) \tag{3}$$

Back to Main

Hypotheses

Based on the rational account, two hypotheses emerges:

1. A more performant (worse) agent chooses less (more) time: $p(t) \uparrow \rightarrow t^* \downarrow$, $p(t) \downarrow \rightarrow t \uparrow$
2. If the cost of time increases (decreases), an agents chooses less (more) time: $\delta \uparrow, t^b \downarrow, \delta \downarrow, t^b \uparrow$.

In addition, the *behavioral* explanation suggest the following additional channels:

3. An over(under)confident agent chooses less (more) time: $\tilde{p}(t) > p(t) \rightarrow t^b \downarrow$, $\tilde{p}(t) < p(t) \rightarrow t^b \uparrow$
4. An over(unter)weighting agent chooses less (more) time: $w(\tilde{p}(t)) > \tilde{p}(t) \rightarrow t^{b'} \downarrow$, $w(\tilde{p}(t)) < \tilde{p}(t) \rightarrow t^{b'} \uparrow$

Time decisions as inattentive decisions

- Implemented time decision t^b as intermediate action between rational action t^* and some default choice t^d, which is *independent* on any deliberation.

$$t^b = m_t t^* + (1 - m_t) t^d$$

- t^* depends on "true" expected reward function
  $t^* = \text{argmax}\, E[Y] = \text{argmax}\, p(t) * (Y - \delta \times t)$
- Inattention in estimates about $p(t)$ main drivers of m_t.
- Two distinct channels how $p(t)^b \neq p(t)$ enters the decision process:
- Inattentive estimates about agent-specific characteristic
  $x_a^b = m_{x_a} x_a + (1 - m_{x_a}) x_a^d$ Hence $p(t, x_a) = m_{p_a} p(t, x_a) + m_{p_a} p(t)^d$ generating "over/under confidence"
- Conditional on some estimate x_a^b, agents are likely to be inattentive to the true $p(t|x_a^b)^b$ as $p(t|x_a^b) = m_p * p(t|x_a^b) + (1 - m_p) * p^d$, where p^d is some *time-invariant* default value. This generate non-standard subjective probability weighting.

The Belief Measure

- We define the median of the belief distribution of participant i at time t as $b^{\text{med}}(t)$
  - We fit a two parameter gamma distribution if a participant choose more than 1 bin and obtain moments from the fitted distribution
  - We calculate moments of a isosceles trapezoid distribution if participants choose only 1 bin

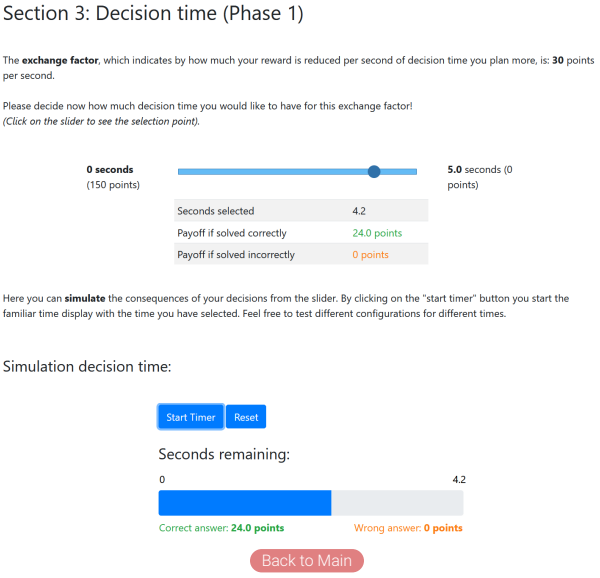
- We furthermore construct a measure of overconfidence, defined as:

$$\text{overconfidence}_i := \sum_{t=2}^{6} \begin{cases} b^{\text{med}}(t) - \widehat{p^l(t)} & \text{if} \quad b^{\text{med}}(t) < \widehat{p^l(t)} \\ 0 & \text{if} \quad \widehat{p^l(t)} < b^{\text{med}}(t) < \widehat{p^u(t)} \\ b^{\text{med}}(t) - \widehat{p^u(t)} & \text{if} \quad b^{\text{med}}(t) > \widehat{p^u(t)} \end{cases}$$

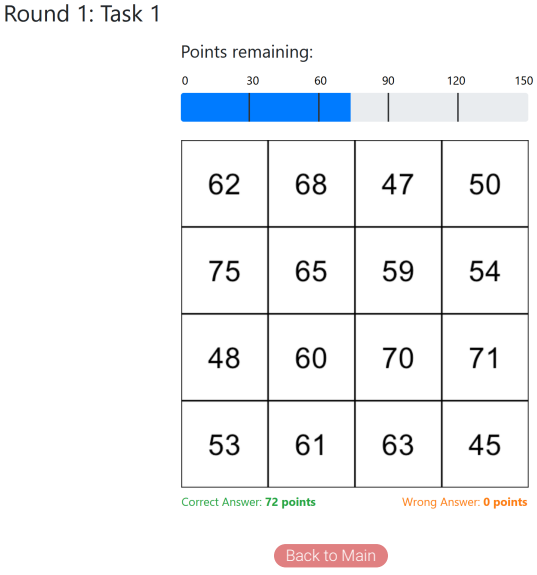
- This measure is scaled by its own SD to facilitate interpretation

Back to Main

Decision screen in prospective planning condition



Decision screen in simultaneous condition



Performance

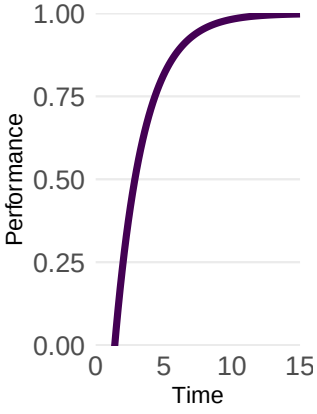
- We estimate an individuals performance function following McElree & Carrasco (1999) and Dean et al. (2007), i.e.

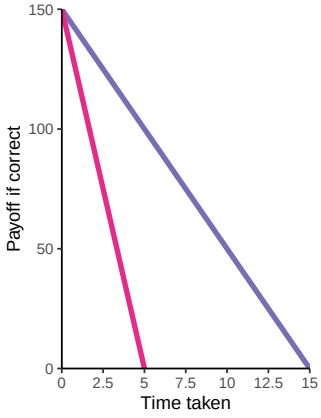
$$\widehat{p(t)} = \beta(1 - e^{-(t-\delta)/\lambda})$$

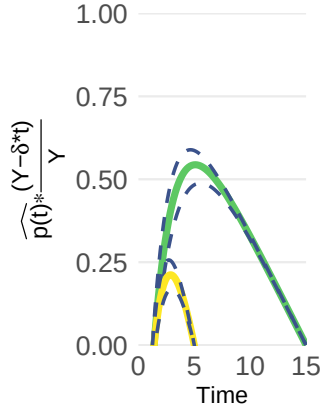
- **95%** Wilson score CIs for each t are calculated to estimate the upper ($\widehat{p^u(t)}$) and lower ($\widehat{p^l(t)}$) bound of performance
- Optimizing $\max_t (\widehat{p(t)} * (Y - \delta * t)) \quad \forall\, \delta \in \{10, 30\}$, t^* is obtained
- Using $\widehat{p^u(t)}$ and $\widehat{p^l(t)}$ instead of $\widehat{p(t)}$ and maximizing provides upper and lower bounds for t^*

Back to Main

Optimization

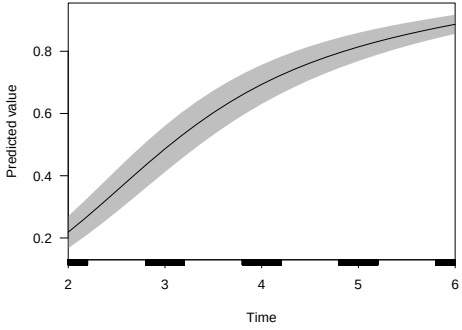


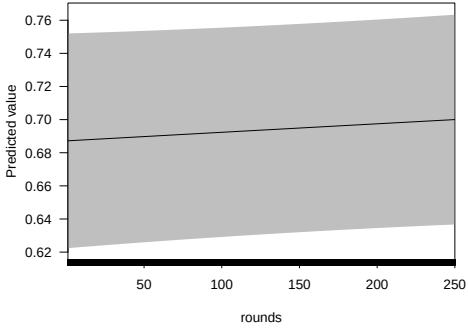




Back to Main

Learning Effects Marginal Effect





Back to main

Learning Effects - Regression

Table 1: Learning over time

	Learning over time
	Performance
Round	0.0002
	(0.990)
Time	2.659
	(7.170)
I(Time^2)	−0.373
	(−3.738)
I(Time^3)	0.022
	(2.653)
Constant	−5.309
	(−12.297)
individual dummies	Yes
Observations	22,750
Note:	*p<0.1; **p<0.05; ***p<0.01

Back to main

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