How should we incentivize learning? An optimal feedback mechanism for educational games and online courses

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MAX-PLANCK-GESELLSCHAFT

Introduction

- Only **15%** of the students enrolled in a MOOC actually finish it[1].
- Game elements are used to overcome motivational obstacles but are often ineffective or even harmful[2].
- Recent work suggests that optimal gamification can help people make better decisions[3].
- Can optimal gamification help people overcome the motivational obstacles to life long learning?

Optimal incentives for self-directed learning

Problem: When should people complete a task using the already acquired skills vs. try to learn a better way to accomplish their goals?

Approach:

1. Model skill acquisition
2. Calculate optimal brain points
3. Integrate the optimal brain points into the learning environment.

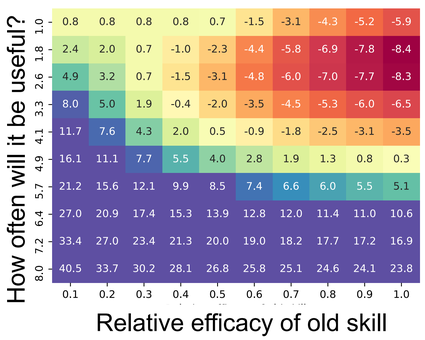
Question: Can optimal brain points improve people's study choices, persistence, and learning outcomes?

Quantifying the value of practice

Skill acquisition can be modeled as a Markov Decision Process (MDP)

$M_{\text{skill}} = \{S \times D, A, \gamma, T, r\}$

A : one action for each skill
S : set of attainable skill levels
$D \subset \mathbb{N}_0$: work required to complete current task
γ: probability that the skill will still be useful in the next step



The value of practice is
$\text{VOP}((\boldsymbol{s}, d), a) = Q^*((\boldsymbol{s}, d), a) - V^{\pi_{\text{stop learning}}}((\boldsymbol{s}, d))$,
with $V^{\pi_{\text{stop learning}}}((\boldsymbol{s}, d)) = g \cdot \frac{\gamma^{d-1}}{1-\gamma^d} = \frac{1}{1-\gamma}$.

To compute the VOP we solve the MDP by dynamic programming.

Optimal brain points

- *Brain points* reward effort and persistence rather than performance[4].
- The ***optimal*** *brain points* of learning activity a communicate the value of the expected improvement in the value of the learner's skills:

$$\text{BrainPoints}(\boldsymbol{s}, a) = \Delta V(\boldsymbol{s}, a) + r(\boldsymbol{s}, a)$$

reward for getting it right

$$\Delta V(\boldsymbol{s_t}, a) = \gamma \cdot \mathbb{E}[V^*(\boldsymbol{S_{t+1}}) | \boldsymbol{s_t}, a] - V(\boldsymbol{s_t})$$

value of learning — Expected value of the new skill level — value of current skill level

The Spaceship Adventure Paradigm

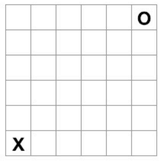
Goal*:* Move spaceship (**X**) to its destination (**O**)

Your score is: -4

Step 4 / Round 1

Your total step: 4

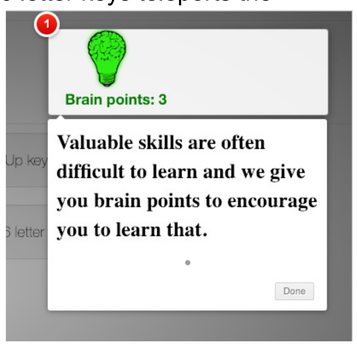
There is a 6 percent probability that your spaceship will crash in the next step!



To learn or not to learn?

a) **Exploit Skill 1:** Navigate using the arrow keys (known but inefficient)

b) **Learn Skill 2:** Discover which of the 26 letter keys teleports the spaceship to its destination (unknown but efficient)



Experimental design:

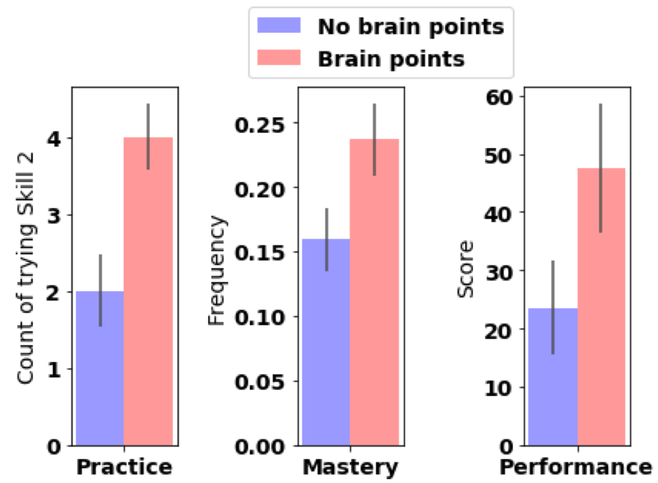
Optimal Brain Points
vs.
No Brain Points

Optimal brain points convey the **value of practice**.

- 450 Amazon Mechanical Turk workers ($n_{\text{experimental}}$ = 224, n_{control} = 226)
- 6 ± 2 min task duration, \$0.75 base pay, M_{bonus} = \$0.10 (SD_{bonus}=\$0.10)

Effects of optimal brain points

1. **Practice:** Brain points increased the proportion of people who attempted to learn skill 2 by **14%** ($\chi^2(1) = 5.74$, $p = .0165$) and **doubled** their additional learning attempts ($t(448) = 1.86$, $p = .0323$).
2. **Mastery:** With brain points **24%** of participants mastered skill 2 – compared to 15% in the control condition ($\chi^2(1) = 3.77$, $p = .0523$).
3. **Performance:** Brain points **doubled** the number of points participants earned ($t(448) = 1.74$, $p = .0414$).



Conclusion and future directions

1. Optimal brain points can effectively motivate people to learn valuable new skills.
2. Optimal brain points help learners persist in the face of setbacks.
3. Optimal gamification can be applied to many different learning environments.

References

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