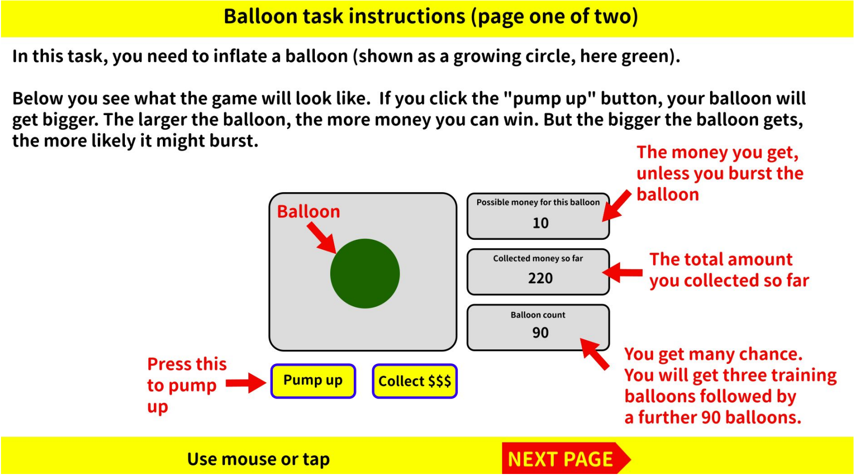
Introduction to Decision Making Studies 02

Balloon Analog Risk Task (BART) 01

Presenter: Qiuyu Yu

Balloon Analog Risk Task (BART)

- Measuring **risk-taking tendencies** and the identification of individuals who are prone to take risks - impulsivity and sensation-seeking
- Participants are **not** informed about the probability of the balloon exploding.
- Typically, the degree of risk-taking on the BART is measured by the **adjusted BART score**, which is the average number of pumps for unexploded balloons. *The adjusted BART score is preferable because it is not directly affected by the explosion probability.*



Four parameters: α, μ, γ, τ

Assumption 1: Prior probability/belief + update per trial

- update the belief about the **probability (p) of the balloon exploding** after each trial.
- initially has a **prior belief** about the probability of the balloon exploding and **updates** the prior belief based on observation on each trial
- **α and μ (RL):** the degree of learning from observations

$$p_k^{burst} = 1 - \frac{\alpha + \sum_{i=0}^{k-1} n_i^{success}}{\mu + \sum_{i=0}^{k-1} n_i^{pumps}} \qquad with 0 < \alpha < \mu$$

Four parameters: α, μ, γ, τ

Assumption 2: Participants decide the optimal number of pumps before each trial (expode)

- **prospect theory**
- **r:** is the amount of reward per successful pump
- **γ:** risk-taking propensity

Expected utility (value) after l pumps on trial k $U_{kl} = (1 - p_k^{burst})^l (lr)^\gamma$

Optimal number of pumps $v_k = \frac{-\gamma}{In(1 - p_k^{burst})} with \gamma \geq 0$

The probability that the participant will pump the: $p_{kl}^{pump} = \frac{1}{1 + e^{\tau(l - v_k)}} with \tau \geq 0$

Softmax: $p(D|\alpha, \mu, \gamma, \tau) = \prod_{k=1}^{k^{last}} \prod_{l=1}^{l_k^{last}} p_{kl}^{pump} (1 - p^{pump} k, lk^{last} + 1)^{d_k}$

Four-parameter Model: reparametrized

Emphasizing the asymmetry between the **gain side and the loss side**, use rho instead.

ϕ: prior belief of success

η: updating coefficient

ρ^{+}: risk preference for gain

ρ^{-}: risk preference for loss

τ: inverse temperature

λ: loss aversion

$$U_{kl}^{pump} = (1 - p_k^{burst})r^{\rho^+} - p_k^{burst}\lambda\{(l-1)r\}^{\rho^-} \; with 0 < \rho^+, \rho^- < 2, \lambda > 0$$

$$U_{kl}^{transfer} = 0$$

Non-learning version (Par3 model): θ, γ, τ

Participants **do not learn** (update their belief of the probability of the balloon exploding) during the BART - v & p will be fixed value.

$$v = \frac{-\gamma}{In(1-\theta)} with \gamma \geq 0$$

$$p_l^{pump} = \frac{1}{1 + e^{\tau(l-v)}} with \tau \geq 0$$

Reparametrized version (Par4 model): reparametrizing α & μ

$$\phi = \frac{\alpha}{\mu} \quad \eta = \frac{1}{\mu}$$

- Reparametrize **α, μ → Φ, η** to make each parameter more **independent** and interpretable
- Remove the α < μ constraint to enhance the efficiency of Bayesian estimation (especially MCMC)
- **Φ**: initial belief that pumping will not make the balloon explode
- **η**: an updating coefficient of the participant's belief by the observed data; =0 -> not affected by the observed data
- The participant determines the optimal number of pumps before each trial may be unjustified: the participant may decide whether to pump the balloon or not just before each pump.

$$p_k^{burst} = 1 - \frac{\phi + \eta \sum_{i=0}^{k-1} n_i^{success}}{1 + \eta \sum_{i=0}^{k-1} n_i^{pumps}} with 0 < \phi < 1, \eta > 0$$

The exponential-weight model (EW model)

ψ: prior belief of burst

ξ: updating exponent

ρ: risk preference

τ: inverse temperature

λ: loss aversion

Define: $\psi = 1 - \phi$

$$p_k^{burst} = \omega_{k-1}\psi + (1 - \omega k - 1)Pk - 1with0 < \psi < 1, \eta > 0$$

$$U_{kl}^{pump} = (1 - p_k^{burst})r^{\rho} - p_k^{burst}\lambda\{(l-1)r^{\rho}\}$$

$$with0 < \rho < 2, \lambda > 0, U_{kl}^{transfer} = 0$$

$$p_{kl}^{pump} = \frac{1}{1 + e^{\tau(U_{kl}^{transfer} - U_{kl}^{pump})}} with\tau \geq 0$$

The Exponential-Weight Mean–Variance model (EWMV model)

- **Mean–variance analysis instead of prospect theory**
- Subjective utility of an option can be formulated by a linear combination of the expected value and the variance of potential outcomes.
- Risk preference is defined as a **coefficient of the variance term**, which is a proxy for risk.

$$U_{kl}^{pump} = (1 - p_k^{burst})r - p_k^{burst}\lambda(l-1)r + \rho p_k^{burst}(1 - p_k^{burst})\left\{r + \lambda(l-1)r\right\}^2 with\lambda > 0, U_{kl}^{transfer} = 0$$

Reference & Resource

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