COMS30017
Computational Neuroscience

Week 7 / Video 3 / Classical conditioning

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Intended Learning Outcomes

- Pavlovian conditioning
- Rescorla-Wagner
- Conditioning paradigms including

Classical (Pavlovian) conditioning

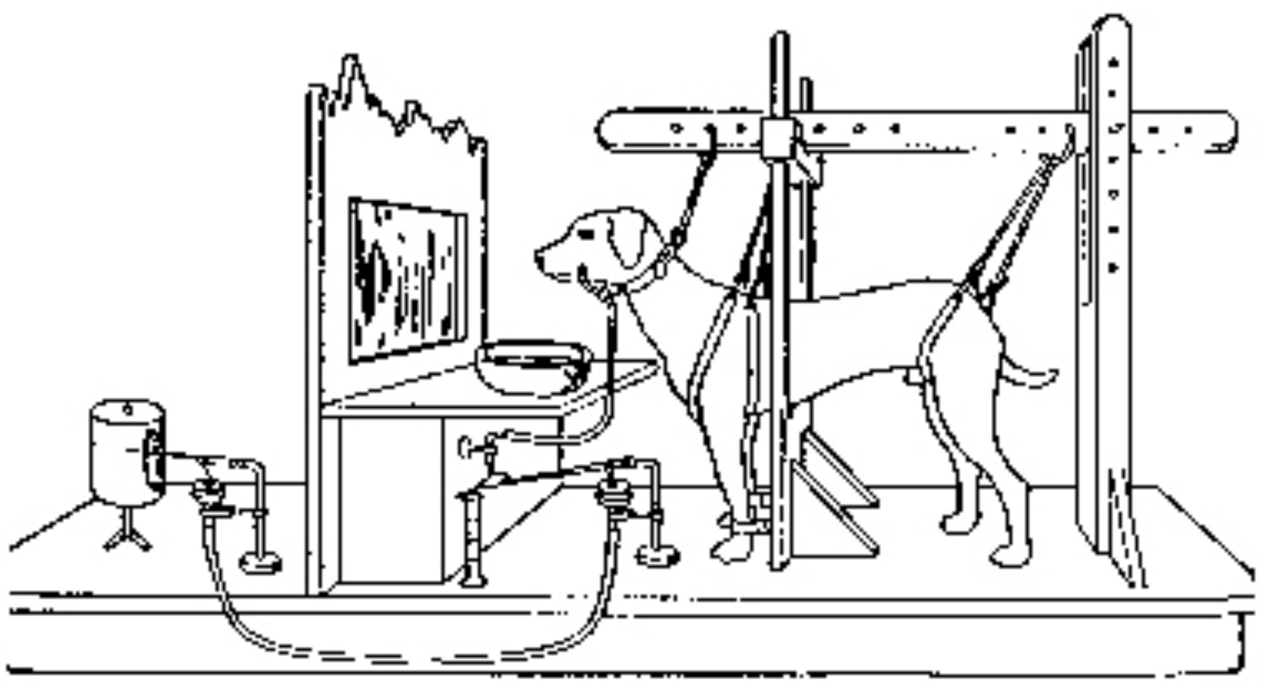
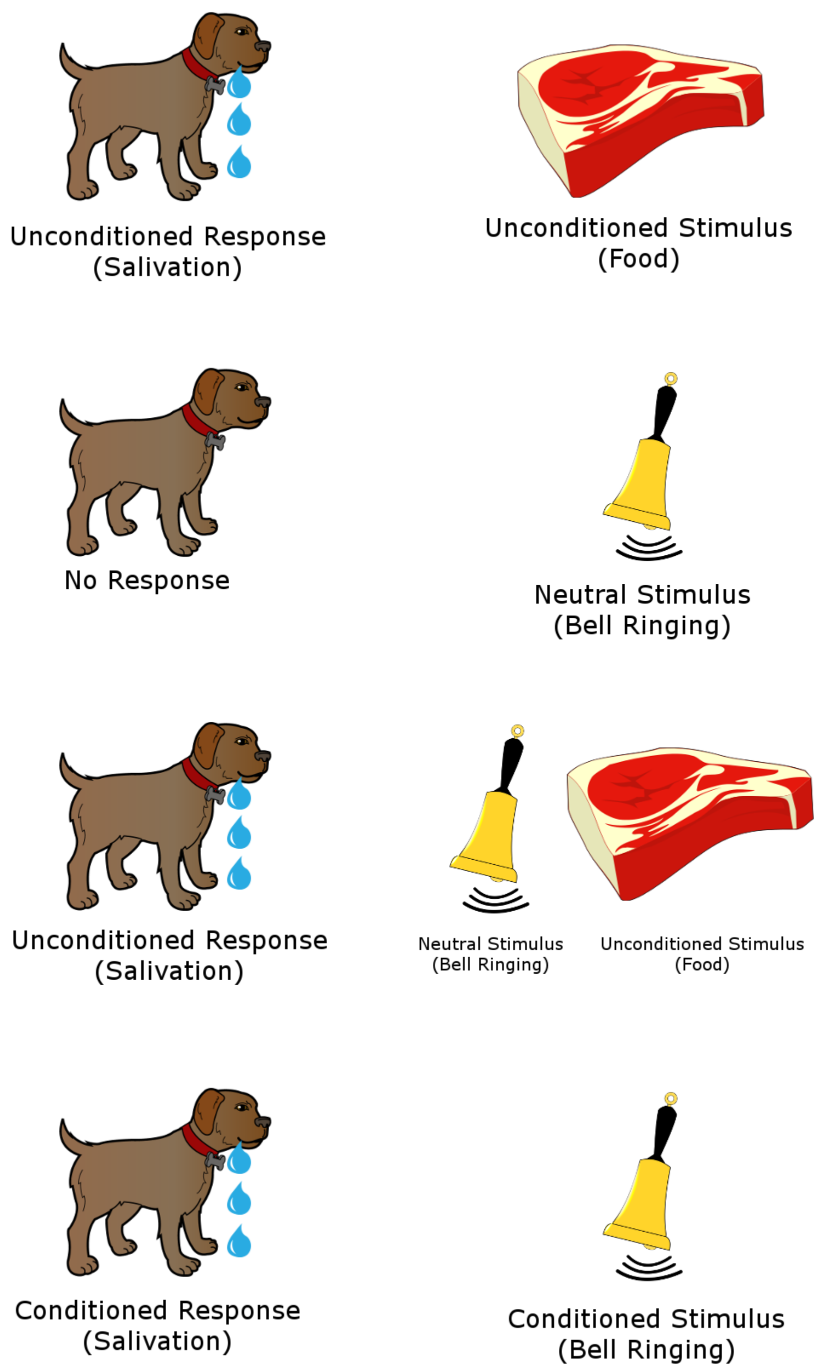


Fig. 2.



Model: "Rescorla-Wager" == delta rule

- "conditioned" stimuli (lights, bells etc.) = x_i
- expected reward $= v = \sum_i w_i x_i \; (= y)$
- true reward ("unconditioned" stimulus) $= r (= y^*)$
- prediction error $\delta = r - v$
- update rule:

$$\Delta w_i = \eta \delta x_i$$

Pavlovian conditioning

- bell ($x_1 = 1$)
- reward ($r = 1$)
- Initially, $w_1 = 0$, so $v = w_1 x_1 = 0 \times 1 = 0$ (i.e. dog doesn't expect reward when bell)
- Predictions errors, $\delta = 1$, which drive learning: $\Delta w_1 = \eta \delta x_1$ is positive.
- Eventually, $w_1 = 1$, so $v = w_1 x_1 = 1 \times 1 = 1$, (i.e. dog expects reward and drools).
- No further learning as $v = r$, so $\delta = 0$

Extinction

- bell ($x_1 = 1$)
- reward ($r = 0$)
- Initially, $w_1 = 1$, (e.g. due to previous Pavlovian conditioning) so $v = w_1 x_1 = 1{\times}1 = 1$ (i.e. dog expects reward when bell)
- Negative prediction errors, $\delta = -1$, which drive learning: $\Delta w_1 = \eta \delta x_1$ is negative.
- Eventually, $w_1 = 0$, so $v = w_1 x_1 = 0{\times}1 = 0$, (i.e. dog expects reward and drools).
- No further learning as $v = r$, so $\delta = 0$

Partial

- bell ($x_1 = 1$)
- Probabilistic rewards:
  - $P(r = 1) = \alpha$
  - $P(r = 0) = 1 - \alpha$
- Eventually, $w_1 = \alpha$, so $v = w_1 x_1 = \alpha \times 1 = \alpha$, (equals the expected reward).
- Positive prediction errors when rewarded, negative prediction errors when not rewarded cancel out, to give no further learning

Blocking

- bell ($x_1 = 1$) AND light ($x_2 = 1$)
- pre-training to associate bell with reward, so initially, $w_1 = 1$, $w_2 = 0$
- present both bell and light, $x_1 = x_2 = 1$, and give reward, $r = 1$
- Prediction already correct: $v = w_1 x_1 + w_2 x_2 = 1$ $= r$, so no prediction errors, $\delta = 0$, and no learning.
- Thus, we still have $w_2 = 0$, so light isn't associated with reward (light alone doesn't predict reward).

Inhibitory

- bell ($x_1 = 1$) AND light ($x_2 = 1$)
- alternate
  - light, no bell, reward, ($x_1 = 1$, $x_2 = 0$ $\mathrm{r} = 1$)
  - light and bell, no reward ($x_1 = x_2 = 1$, $\mathrm{r} = 0$)
- to eliminate prediction errors, we need $w_1 = 1$, $w_2 = -1$
- light (x_2) predicts absence of a reward that you would otherwise have gotten

Overshadowing

- bell ($x_1 = 1$) AND light ($x_2 = 1$)
- light, bell, reward, ($x_1 = x_2 = 1,\ \mathrm{r} = 1$)
- to eliminate prediction errors, we need $w_1 + w_2 = 1$ so $w_1 = \alpha$, $w_2 = 1 - \alpha$
- the bell and light predict part of the reward

Secondary conditioning (failure of Rescorla-Wagner)

- bell ($x_1 = 1$) AND light ($x_2 = 1$)
- initially, reward associated with bell $w_1 = 1$, $w_2 = 0$
- present $x_2 = 1$, *then* $x_1 = 1$, then no reward
- RW predicts $w_1 = \alpha$, $w_2 = -\alpha$ (combination of inhibitory conditioning and extinction). (You would get this if you presented bell and light simultaneously).
- But here $x_2 = 1$ PREDICTS $x_1 = 1$, which predicts reward.
- Therefore, $x_2 = 1$ comes to predict positive reward!

End