Rescorla-Wagner (1972)
Theory of Classical Conditioning
HISTORY

• Ever since Pavlov, it was assumed that any CS followed contiguously by any US would result in conditioning.
  – Not true: Contingency
  – Not true: Taste Aversion Learning
  – Not true: Blocking
Rescorla-Wagner Theory (1972)

- Emerged from Kamin’s work on blocking
- Organisms only learn when events violate their expectations
  - If a US is surprising, the organism searches its memory for possible causes.
  - If a US is expected, then an adequate predictor must be already available; no memory search occurs and no new learning takes place.
- These expectations are modified only when consequent events disagree with the composite expectation
- Expectations are the key!
The concepts of Rescorla and Wagner

– The precise amount of conditioning is dependent upon the amount of surprise.
– Surprise not only determines whether conditioning occurs but also how strong it is.

• In mathematical words
  – Change in the associative strength of a stimulus depends on the existing associative strength of that stimulus and all others present
  – If existing associative strength is low, then potential change is high; If existing associative strength is high, then very little change occurs
  – The speed and asymptotic level of learning is determined by the strength of the CS and UCS
Rescorla-Wagner Mathematical Formula

\[ \Delta V_{cs} = c (V_{max} - V_{all}) \]

- \( V \) = associative strength
- \( \Delta \) = change (the amount of change)
- \( c \) = learning rate parameter
- \( V_{max} \) = the maximum amount of associative strength that the UCS can support
- \( V_{all} \) = total amount of associative strength for all stimuli present
- \( V_{cs} \) = associative strength to the CS
Before conditioning begins:

- $V_{max} = 100$ (number is arbitrary & based on the strength of the UCS)
- $V_{all} = 0$ (because no conditioning has occurred)
- $V_{cs} = 0$ (no conditioning has occurred yet)
- $c = .5$ (c must be a number between 0 and 1.0 and is a result of dividing the CS intensity by the UCS intensity)
First Conditioning Trial

<table>
<thead>
<tr>
<th>Trial</th>
<th>$c$</th>
<th>$(V_{\text{max}} - V_{\text{all}})$</th>
<th>$\Delta V_{cs}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>$100 - 0$</td>
<td>50</td>
</tr>
</tbody>
</table>

Graph showing associative strength (V) against trials.
Second Conditioning Trial

\[ \text{Trial} \quad \frac{c}{2} \quad (V_{\text{max}} - V_{\text{all}}) \quad = \quad \Delta V_{\text{cs}} \]

\[ 2 \quad 0.5 \quad \times \quad 100 \quad - \quad 50 \quad = \quad 25 \]
Third Conditioning Trial

<table>
<thead>
<tr>
<th>Trial</th>
<th>c</th>
<th>(Vmax - Vall)</th>
<th>=</th>
<th>ΔVcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>.5 * 100 - 75</td>
<td>=</td>
<td>12.5</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing associative strength over trials]
4th Conditioning Trial

\[
\text{Trial} \quad c \quad (V_{\text{max}} - \text{Vall}) = \Delta V_{\text{cs}}
\]

\[
\begin{align*}
4 & \quad 0.5 \times 100 - 87.5 = 6.25
\end{align*}
\]
5th Conditioning Trial

\[
\text{Trial} \quad c \quad (V_{\text{max}} \quad - \quad V_{\text{all}}) \quad = \quad \Delta V_{\text{cs}}
\]

\[
5 \quad .5 \ast 100 \quad - \quad 93.75 \quad = \quad 3.125
\]
6th Conditioning Trial

<table>
<thead>
<tr>
<th>Trial</th>
<th>c</th>
<th>(V_max - V_all)</th>
<th>ΔV_cs</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>.5</td>
<td>100 - 96.88</td>
<td>1.56</td>
</tr>
</tbody>
</table>

Graph showing associative strength (V) over trials.
7th Conditioning Trial

<table>
<thead>
<tr>
<th>Trial</th>
<th>c (Vmax - Vall)</th>
<th>= ΔVcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>.5 * 100 - 98.44</td>
<td>= .78</td>
</tr>
</tbody>
</table>

![Graph showing a line with points at different trials and associative strength values.](image)
8th Conditioning Trial

\[
\text{Trial} \quad c \quad (V_{\text{max}} - V_{\text{all}}) = \Delta V_{cs}
\]

\[
8 \quad 0.5 \cdot 100 - 99.22 = 0.39
\]
# 1st Extinction Trial

<table>
<thead>
<tr>
<th>Trial</th>
<th>( c )</th>
<th>((V_{\text{max}} - V_{\text{all}}))</th>
<th>( \Delta V_{\text{cs}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5 * 0</td>
<td>- 99.61</td>
<td>-49.8</td>
</tr>
</tbody>
</table>

![Graph showing the extinction process with trials and associative strength](image)

- **V_{\text{all}}** represents the initial associative strength.
- **\( V_{\text{max}} \)** is the maximum associative strength.
- **\( c \)** is a constant factor used for calculation.
2nd Extinction Trial

<table>
<thead>
<tr>
<th>Trial</th>
<th>( c )</th>
<th>((V_{\text{max}} - \text{Vall}))</th>
<th>( \Delta V_{\text{cs}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.5</td>
<td>0 - 49.8</td>
<td>-24.9</td>
</tr>
</tbody>
</table>

\[
(\text{Vmax} - \text{Vall}) = \Delta V_{\text{cs}}
\]

![Graph showing Extinction trials](image_url)
# Extinction Trials

<table>
<thead>
<tr>
<th>Trial</th>
<th>c</th>
<th>(Vmax - Vall)</th>
<th>= ΔVcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>.5</td>
<td>0 - 12.45</td>
<td>= -12.46</td>
</tr>
<tr>
<td>4</td>
<td>.5</td>
<td>0 - 6.23</td>
<td>= -6.23</td>
</tr>
<tr>
<td>5</td>
<td>.5</td>
<td>0 - 3.11</td>
<td>= -3.11</td>
</tr>
<tr>
<td>6</td>
<td>.5</td>
<td>0 - 1.56</td>
<td>= -1.56</td>
</tr>
</tbody>
</table>
Hypothetical Acquisition & Extinction Curves with c=.5 and \( V_{\text{max}} = 100 \)
Acquisition & Extinction Curves with $c=0.5$ vs. $c=0.2$ ($V_{\text{max}} = 100$)
Conditioning can reach different strengths at different rates
Theory Handles other Phenomena: compound conditioning

• **Overshadowing**
  - Whenever there are multiple stimuli or a compound stimulus, then \( \text{Vall} = \text{Vcs}_1 + \text{Vcs}_2 \)

• Trial 1:
  - \( \Delta \text{Vnoise} = .2 (100 - 0) = (.2)(100) = 20 \)
  - \( \Delta \text{Vlight} = .3 (100 - 0) = (.3)(100) = 30 \)
  - Total Vall = current Vall + \( \Delta \text{Vnoise} + \Delta \text{Vlight} = 0 + 20 + 30 = 50 \)

• Trial 2:
  - \( \Delta \text{Vnoise} = .2 (100 - 50) = (.2)(50) = 10 \)
  - \( \Delta \text{Vlight} = .3 (100 - 50) = (.3)(50) = 15 \)
  - Total Vall = current Vall + \( \Delta \text{Vnoise} + \Delta \text{Vlight} = 50 + 10 + 15 = 75 \)
Other Phenomena: Blocking effect

\[ \Delta V_a = c(V_{max} - V_{ab}) \quad \Delta V_b = c(V_{max} - V_{ab}) \]

where \( V_{ab} = V_a + V_b \); \( c = 0.50 \)

<table>
<thead>
<tr>
<th>Trial</th>
<th>( V_n )</th>
<th>( \Delta V_n = c(V_{max} - V_n) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>( \Delta V = 0.50(1 - 0.00) = 0.50 )</td>
</tr>
<tr>
<td>2</td>
<td>0.50</td>
<td>( \Delta V = 0.50(1 - 0.50) = 0.25 )</td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>( \Delta V = 0.50(1 - 0.75) = 0.13 )</td>
</tr>
<tr>
<td>4</td>
<td>0.88</td>
<td>( \Delta V = 0.50(1 - 0.88) = 0.06 )</td>
</tr>
<tr>
<td>5</td>
<td>0.94</td>
<td>( \Delta V = 0.50(1 - 0.94) = 0.03 )</td>
</tr>
<tr>
<td>6</td>
<td>0.97</td>
<td>( \Delta V = 0.50(1 - 0.97) = 0.02 )</td>
</tr>
<tr>
<td>7</td>
<td>0.99</td>
<td>( \Delta V = 0.50(1 - 0.99) = 0.01 )</td>
</tr>
<tr>
<td>8</td>
<td>1.00</td>
<td>( \Delta V = 0.50(1 - 1.00) = 0.00 )</td>
</tr>
<tr>
<td>9</td>
<td>1.00</td>
<td>( \Delta V = 0.50(1 - 1.00) = 0.00 )</td>
</tr>
<tr>
<td>10</td>
<td>1.00</td>
<td>( \Delta V = 0.50(1 - 1.00) = 0.00 )</td>
</tr>
</tbody>
</table>
\[ \Delta V_a = c(V_{\text{max}} - V_{\text{ab}}) \]
\[ \Delta V_b = c(V_{\text{max}} - V_{\text{ab}}) \]

<table>
<thead>
<tr>
<th>Trials</th>
<th>( V_n )</th>
<th>( \Delta V_a = c(V_{\text{max}} - V_{\text{ab}}) )</th>
<th>( \Delta V_b = c(V_{\text{max}} - V_{\text{ab}}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Va</td>
<td>1.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>1</td>
<td>Vb</td>
<td>0.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>2</td>
<td>Va</td>
<td>1.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>2</td>
<td>Vb</td>
<td>0.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>3</td>
<td>Va</td>
<td>1.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>3</td>
<td>Vb</td>
<td>0.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
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<tr>
<td>4</td>
<td>Va</td>
<td>1.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>4</td>
<td>Vb</td>
<td>0.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>5</td>
<td>Va</td>
<td>1.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
<tr>
<td>5</td>
<td>Vb</td>
<td>0.00</td>
<td>0.50(1 - 1.00) = 0.00</td>
</tr>
</tbody>
</table>
Theory Handles other Phenomena

- Overexpectation Effect: the victory of the model!
  - Separately condition two simple CS's until both are fully conditioned
  - for the first time, present the two together as a compound CS
  - Expect 200% of associative value (twice the reward)
  - the model predicts that, as the compound is paired with the US trial after trial, the associative value of the compound CS will actually decrease until it reaches the same maximum that a simple CS would sustain
Conceptual problems with the Rescorla-Wagner model

• V represents the strength of a theoretical association (not a real one). How do we relate measures of overt behavior to associative strength?
• We need to know the values of c and Vmax before we can predict V. How do we do that?
• Solution = it is not necessary to know the exact values to test the model; use arbitrary values instead.
• The use of arbitrary values will not allow us to make precise quantitative predictions. For example, we cannot predict how many drops of saliva will occur after 20 pairings of a TONE (CS) with a FOOD (US).
• The use of arbitrary values will allow us to make qualitative predictions. For example, we can predict whether the amount of saliva will increase or decrease over trials.
What is missing?

- A major parameter left out of the model is time. All changes take place as a function of trials, and although trials follow themselves in time, such parameters as the length of a CS presentation, time between US presentations, or duration of a trace interval are not explicitly included in the Rescorla-Wagner model. As these factors have strong effects on the course of conditioning, their absence from the model was always a serious limitation.
Rescorla-Wagner Model

• The theory is not perfect

• But, it has been the “best” theory of Classical Conditioning