Context, behavior change, and habit learning

Mark E. Bouton, Ph.D.
Department of Psychological Science
University of Vermont
Mark.Bouton@uvm.edu

Vermont Center on Behavior and Health
December 15, 2021
TODAY’S PLAN:
Context, behavior change, and habit learning

• Extinction is a basic form of behavior change
  • Context is crucial in both Pavlovian and operant extinction
  • Context is also crucial in other types of behavior change (punishment, omission, DRA)
  • There are many kinds of contexts

• Goal-directed actions and habits
  • Making habits
  • Breaking habits

• An integration
  • Action-to-habit conversion is another form of behavior change
  • Habit does not erase goal-direction, but like extinction, interferes with it in a context-specific way
  • Some implications for addiction
PAVLOVIAN AND OPERANT EXTINCTION

Pavlovian or respondent conditioning

Instrumental or operant conditioning

CS – no reinforcer
CS - reinforcer

R – no reinforcer
R – reinforcer

Performance

Trials
The renewal effect—Pavlovian learning

Fear conditioning


Appetitive conditioning

RENEWAL AFTER OPERANT EXTINCTION

<table>
<thead>
<tr>
<th></th>
<th>Acquisition</th>
<th>Extinction</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABA</td>
<td>A</td>
<td>B</td>
<td>A, B</td>
</tr>
<tr>
<td>AAB</td>
<td>A</td>
<td>A</td>
<td>A, B</td>
</tr>
</tbody>
</table>

Bouton, Todd, Vurbic, & Winterbauer, *Learning & Behavior, 2011*
# RENEWAL AFTER PUNISHMENT

<table>
<thead>
<tr>
<th></th>
<th>Acquisition</th>
<th>Punish</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punish</td>
<td>A: R-pellet</td>
<td>B: R-pellet/shock</td>
<td>A: R, B: R</td>
</tr>
<tr>
<td>Yoked</td>
<td>A: R-pellet</td>
<td>B: R-pellet/yoked shock</td>
<td>A: R, B: R</td>
</tr>
</tbody>
</table>

RENEWAL AFTER PUNISHMENT

<table>
<thead>
<tr>
<th></th>
<th>Acquisition</th>
<th>Punish</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punish A: R-pellet</td>
<td>B: R-pellet/shock</td>
<td>A: R, B: R</td>
<td></td>
</tr>
<tr>
<td>Yoked A: R-pellet</td>
<td>B: R-pellet/yoked shock</td>
<td>A: R, B: R</td>
<td></td>
</tr>
<tr>
<td>Ext A: R-pellet</td>
<td>B: R-</td>
<td>A: R, B:R</td>
<td></td>
</tr>
</tbody>
</table>

Broomer & Bouton, in progress
RENEWAL AFTER PUNISHMENT WITH CONTEXTUAL HISTORY CONTROLLED

<table>
<thead>
<tr>
<th>Acquisition</th>
<th>Punish</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: R1-pellet</td>
<td>A: R2-pellet/shock</td>
<td>A: R1, R2</td>
</tr>
<tr>
<td>B: R2-pellet</td>
<td>B: R1-pellet/shock</td>
<td>B: R1, R2</td>
</tr>
</tbody>
</table>

**RENEWAL AFTER REINFORCING ABSTINENCE (DRO)**

<table>
<thead>
<tr>
<th>Acquisition</th>
<th>Response elimination</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: R-pellet</td>
<td>B: R- (Ext.)</td>
<td>A: R, B: R</td>
</tr>
<tr>
<td>A: R-pellet</td>
<td>B: R-, pel. (Omission)</td>
<td>A: R, B: R</td>
</tr>
<tr>
<td>A: R-pellet</td>
<td>B: R- (Ext.)</td>
<td>A: R, B: R (pellets)</td>
</tr>
<tr>
<td>A: R-pellet</td>
<td>B: R-, pel. (Omission)</td>
<td>A: R, B: R (pellets)</td>
</tr>
</tbody>
</table>

---

*Rey, Traillkill, Goldberg, and Bouton, Journal of the Experimental Analysis of Behavior, 2020*
Renewal after behavior change

• Context plays a clear role in extinction
  • ABA, AAB, and ABC renewal effects all obtain

• Context plays a similar role after several types of behavior change
  • Extinction, punishment, omission training, differential reinforcement of alternative behavior

• Behavior change does not erase the original learning
  • It depends at least partly on the subject learning not to make a specific response in a specific context

• Renewal is a reason why treatment effects are rarely permanent.
  • And why problem behaviors seem so persistent.
  • Relapse is easy to obtain
There are many kinds of lapse/relapse effects

- Pavlovian extinction
  - Renewal
  - Reinstatement
  - Spontaneous recovery
  - Rapid reacquisition

- Operant extinction
  - Renewal
  - Reinstatement
  - Spontaneous recovery
  - Rapid reacquisition
  - Resurgence

All of these are context change effects.
Extinction learning is highly specific to its context.
There are many kinds of contexts

- **Exteroceptive contexts**
  - Apparatus, room, place, location, etc.

- **Interoceptive contexts**
  - Drug state
  - Hormonal state
  - Mood state
  - Social cues
  - Expectation of events
  - Time
  - Recent behaviors
  - Recent reinforcers
  - Stress state
  - Deprivation state

Bouton, *Psychopharmacology*, 2019
Bouton, Maren, & McNally, *Physiological Reviews*, 2021
Instrumental/operant behaviors come in two varieties

**Goal-Directed Actions**
- Goal-directed, deliberate
- Depend on knowledge of the relationship between behavior and the outcome or goal (R-O)
- Depend on knowledge of the goal’s value
- Sensitive to reinforcer devaluation

**Habits**
- Automatic, mechanical, “mindless”
- S-R
- Evident after extensive practice
- Insensitive to reinforcer devaluation

<table>
<thead>
<tr>
<th>Acquisition</th>
<th>Reinforcer Devaluation</th>
<th>Extinction Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-pellet</td>
<td>pellet → LiCl</td>
<td>R?</td>
</tr>
<tr>
<td></td>
<td>pellet / LiCl</td>
<td></td>
</tr>
</tbody>
</table>

*From, e.g., A. Dickinson, 1985, 1989, 1994, 2012; Balleine, 2019; Balleine & O’Doherty, 2010*
What creates a habit?

**Law of Effect** (Thorndike, 1911)

→ S-R “habit” association is stamped in with every reinforcement

**Rate Correlation View** (Dickinson, 1985, 1987; Perez & Dickinson, 2020)

→ Habits form when the correlation between behavior rate and reward rate becomes low

**Our view**

→ Habits develop when the reinforcer becomes predictable

  This allows us to pay less attention to behavior

  Extends the Pearce-Hall (1980) model of attention in Pavlovian learning
Partial Reinforcement (50%)

S

R

Continuous Reinforcement (100%)

30 s

S

R

Pearce-Hall attention rule
Uncertain reinforcers (50%) maintain attention
Predictable reinforcers (100%) do not

<table>
<thead>
<tr>
<th>Acquisition</th>
<th>Reinforcer Devaluation</th>
<th>Extinction Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-R-pellet</td>
<td>pellet → LiCl</td>
<td>S-R?</td>
</tr>
<tr>
<td></td>
<td>pellet / LiCl</td>
<td></td>
</tr>
</tbody>
</table>

Thrailkill, Trask, Vidal, Alcalá, & Bouton, *Journal of Experimental Psychology: Animal Learning and Cognition*, 2018
Partial Reinforcement (50%)

Continuous Reinforcement (100%)

Thrailkill, Trask, Vidal, Alcalá, & Bouton, Journal of Experimental Psychology: Animal Learning and Cognition, 2018
Partial Reinforcement (50%)

Continuous Reinforcement (100%)

Test

Similar result here
-- with an S that was 1/5 as long
-- and a reinforcement rate 10 times as rich

Making habits

• Habit learning occurs when the reinforcer becomes predictable
• It is prevented when the reinforcer stays unpredictable— as in our 50% PRF schedule.
• Consistent with theories of attention and learning (the Pearce-Hall model)
  • Though nobody pointed it out before.
• Habit learning happens when we can “tune out” a behavior
  • Goal-directed actions are ones that are “tuned in”

• This is a more flexible view of actions and habits than the prevailing view
  • Habit is not necessarily a fixed endpoint
  • Maybe we can turn a habit back into an action
  • If we make the reinforcer surprising again.
Implications for breaking a habit

Make the reinforcer surprising at the end of habit training

<table>
<thead>
<tr>
<th>Acquisition (simple RI-30)</th>
<th>Reinforcer Devaluation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 sessions R-O1</td>
<td>O1 Paired or Unpaired LiCl</td>
<td>R?</td>
</tr>
<tr>
<td>12 sessions R-O1; then 1 session R-O2</td>
<td>O1 Paired or Unpaired LiCl</td>
<td>R?</td>
</tr>
</tbody>
</table>

A surprising outcome at the end of habit training returned the habit to action

Bouton, Broomer, Rey, & Thrailkill, *Neurobiology of Learning and Memory*, 2020
Breaking Habits 2

Habits return to action status after other manipulations too

→ Surprising reinforcers presented just before the test

<table>
<thead>
<tr>
<th>Acquisition</th>
<th>Reinforcer Devaluation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 R-01</td>
<td>O1 Paired or Unpaired LiCl</td>
<td>R?</td>
</tr>
</tbody>
</table>

Pre-Feed O2: R?

![Graph showing response rate for Action and Habit groups.](image)

Bouton, Broomer, Rey, & Thrailkill, *Neurobiology of Learning and Memory*, 2020
## Breaking Habits 3– change the context

<table>
<thead>
<tr>
<th>Action (Context A)</th>
<th>Habit (Context B)</th>
<th>Reinforcer Devaluation</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 R-0</td>
<td>12 R-O</td>
<td>Paired or Unpaired LiCl</td>
<td>A: R? B: R?</td>
</tr>
</tbody>
</table>

**Test**

- **Action** (Context A)
- **Habit** (Context B)

**Reinforcer Devaluation**

- Paired or Unpaired LiCl

- **Test**
  - A: R? B: R?

---

### Action renews with context change after Habit learning

**Habit** is more context-specific than **Action**

---

Steinfeld and Bouton, *Behavioral Neuroscience*, 2021
We have come full circle

Action → habit conversion is like extinction:
Habit does not erase action; it interferes with it in a context-specific way

A general principle of associative learning

R-O → extinction
R-O → punishment
R-O → omission
R-O → habit

Bouton, Learning & Behavior, 2021
Summary

• Behavior change is not erasure
  • Lots of research on extinction, punishment, and other forms of retroactive interference
  • It is extremely sensitive to the context
• The action→habit conversion is similar
  • Habit doesn’t erase goal direction
  • It interferes with it in a context-specific way
• Habit learning itself occurs when conditions allow us to “tune out” our behavior
The Team

Scott Schepers  Sydney Trask  Michael Steinfeld

The Team

Eric Thrailkill

Matt Broomer

Noelle Michaud

Catalina Rey

NIH RO1 DA 033123