Environmental enrichment effects on reward sensitivity
Environmental enrichment during rearing produces a variety of neurobiological and behavioral changes:

- When compared to isolated condition (IC) rats, enriched condition (EC) rats are less sensitive to psychostimulant-induced locomotor activity
  - Only at low unit doses
- Environmental enrichment decreases responding for psychostimulants, and also for visual stimuli (Bardo & Dwoskin, 2004)
- EC rats engage in more goal-tracking whereas IC rats engage in more sign-tracking in Pavlovian conditioned approach task (Beckman & Bardo, in press)
Environmental enrichment appears to provide a “protective effect” against addictive behaviors. This may be due to:
- Reduced incentive learning
- Reduced reward sensitivity/discrimination
- Impaired motivational processes
- Impaired reward prediction/anticipation
Method: Overall timeline
Method: Overall timeline

Rats arrive

21 Days
Method: Overall timeline

Rats arrive
21 Days
Loc 1
22 Days
Method: Overall timeline

Rats arrive

21 Days  

Loc 1

Rearing Period

22 Days
Method: Overall timeline

- Rats arrive
  - 21 Days
- Loc 1
- Loc 2
- 22 Days
- 52 Days
- Rearing Period
Method: Overall timeline

- Rats arrive
- 21 Days
- Loc 1
- 22 Days
- Loc 2
- 52 Days
- Rearing Period
- Reward Sensitivity Testing
Method: Overall timeline

- **Rats arrive**
  - 21 Days

- **Loc 1**
  - 22 Days
  - Rearing Period

- **Loc 2**
  - 52 Days
  - Reward Sensitivity Testing

- **Loc 3**
  - ~8 Months
  - SAL vs. AMP
Method: Rearing, LOC 1 and LOC 2
Method: Rearing, LOC 1 and LOC 2

- Rats reared for 30 days
Method: Rearing, LOC 1 and LOC 2

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  - Enriched Condition (EC, n=8)
Method: Rearing, LOC 1 and LOC 2

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  - Standard condition (SC, n=8)
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- Rats reared for 30 days
  - Enriched Condition (EC, n=8)
  - Standard condition (SC, n=8)
  - Isolated condition (IC, n=8)
- Testing in locomotor chamber for 60 min before and after rearing
Method: Rearing, LOC 1 and LOC 2

- Rats reared for 30 days
  - Enriched Condition (EC, n=8)
  - Standard condition (SC, n=8)
  - Isolated condition (IC, n=8)
- Testing in locomotor chamber for 60 min before and after rearing
- Used different bedding in two tests to maintain novelty
Rearing condition modulates locomotor activity in a novel environment

- No group differences prior to rearing period
- EC decreased locomotor activity
- IC and SC increased locomotor activity
- Interaction between rearing condition and test (LOC 1 vs. LOC 2)
Rearing condition modulates locomotor activity in a novel environment

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**Method:** Long-term effects of environmental rearing

Rats arrive at Loc 1 after 21 Days.

22 Days later, Rats are moved to Loc 2 for the Rearing Period.

52 Days after the Rearing Period, Rats are moved to Loc 3 for ~8 Months.

During this period, Reward Sensitivity Testing is conducted.

**Comparison:** SAL vs. AMP at Loc 3.
Method: Long-term effects of environmental rearing

- **Rats arrive**
- **21 Days**
- **Loc 1**
- **22 Days**
- **Loc 2**
- **52 Days**
- **Loc 3**
- **~8 Months**
- **SAL vs. AMP**

- **Rearing Period**
- **Reward Sensitivity Testing**
Enrichment effects on locomotor activity are maintained under AMP

- Comparison of LOC 2 vs. LOC 3 (SAL) conditions:
  - Locomotor activity was higher in LOC 3
  - Rearing effects were maintained (EC lower than both IC and SC)
  - Significant correlation between LOC 2 and LOC 3 activity scores
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$r = .81$
AMP effects on locomotor activity

- Rats arrive: 21 Days
- Loc 1
- Loc 2
- 22 Days
- 52 Days
- Rearing Period
- Reward Sensitivity Testing
- SAL vs. AMP
- Loc 3
- ~8 Months
AMP effects on locomotor activity

- Rats arrive: 21 Days
- Loc 1: 22 Days
- Loc 2: 52 Days
- Loc 3: ~8 Months
- Rearing Period
- Reward Sensitivity Testing

SAL vs. AMP
AMP-induced locomotor activity occurs in all rearing conditions

- Comparison of LOC 3 (SAL) and LOC 3 (AMP)
  - AMP increased locomotor activity
  - Rearing effects were still present, even under AMP
AMP-induced locomotor activity occurs in all rearing conditions

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- Comparison of LOC 3 (SAL) and LOC 3 (AMP)
  - AMP increased locomotor activity
  - Rearing effects were still present, even under AMP
Enrichment reduced locomotor activity post-rearing, whereas standard and isolated conditions increased activity.

The effects of rearing condition were maintained over a period of more than 6 months.

AMP increased locomotor activity, but the effects of rearing condition were still apparent.
Reward Sensitivity Testing: Method

- Discrete-trial, two-lever, VI 30-s schedule
  - Only one lever inserted at a time
  - 120-s Inter-trial interval
Reward Sensitivity Testing: Method

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Reward Sensitivity Testing: Timeline
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53 Days

Base 1
30 days

Contrast (1:4)
20 days
Reward Sensitivity Testing: Timeline

53 Days

Base 1
30 days

Contrast (1:4)
20 days

1:2 10 days
1:3 10 days
2:3 10 days
2:4 10 days
Base 2 (1:1) 10 days
Reward Sensitivity Testing: Timeline

53 Days

- Base 1
  - 30 days
- Contrast (1:4)
  - 20 days

1:2
- 10 days
1:3
- 10 days
2:3
- 10 days
2:4
- 10 days
Base 2 (1:1)
- 10 days

2:4
- 10 days
2:3
- 10 days
1:3
- 10 days
1:2
- 10 days
Base 2 (1:1)
- 10 days
Contrast and Reward Sensitivity Test: Method

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  - Only one lever inserted at a time
  - 120-s Inter-trial interval
Contrast and Reward Sensitivity Test: Method

- Discrete-trial, two-lever, VI 30-s schedule
  - Only one lever inserted at a time
  - 120-s Inter-trial interval

SM

LG
Contrast and Reward Sensitivity Test: Method

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  - Only one lever inserted at a time
  - 120-s Inter-trial interval
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SM

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Contrast and Reward Sensitivity Test: Method

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Reward Sensitivity Test: Timeline

- 53 Days
  - 30 days
  - 20 days
  - Base 1
  - Contrast (1:4)

- 1:2 10 days
- 1:3 10 days
- 2:3 10 days
- 2:4 10 days
- Base 2 (1:1)

- 2:4 10 days
- 2:3 10 days
- 1:3 10 days
- 1:2 10 days
- Base 2 (1:1)

Reward Sensitivity Test: Timeline

53 Days

Base 1
30 days

Contrast (1:4)
20 days

1:2 10 days
1:3 10 days
2:3 10 days
2:4 10 days
Base 2 (1:1)
10 days

2:4 10 days
2:3 10 days
1:3 10 days
1:2 10 days
Base 2 (1:1)
10 days
Isolated condition showed greater responding during baseline

- IC rats respond more for 1-pellet food rewards during baseline VI 30 s schedule
- No difference between EC and SC
- No difference between “Small” and “Large” levers (no pre-existing lever biases)
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Contrast Sensitivity Test

53 Days

Base 1
30 days

Contrast (1:4)
20 days

1:2 10 days
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2:4 10 days
Base 2 (1:1)
10 days

2:4 10 days
2:3 10 days
1:3 10 days
1:2 10 days
Base 2 (1:1)
10 days
Contrast Sensitivity Test

53 Days

Base 1
30 days

Contrast (1:4)
20 days

1:2 10 days
1:3 10 days
2:3 10 days
2:4 10 days
Base 2 (1:1) 10 days

2:4 10 days
2:3 10 days
1:3 10 days
1:2 10 days
Base 2 (1:1) 10 days
Enrichment did not affect contrast sensitivity

- All enrichment conditions showed an induction response on the LG lever
  - Sensitivity to increase in reward
- No significant negative contrast in any condition
- IC rats did not generalize to the SM lever
Enrichment did not affect contrast sensitivity

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Reward Sensitivity Test

53 Days

Base 1 30 days

Contrast (1:4) 20 days

1:2 10 days 1:3 10 days 2:3 10 days 2:4 10 days Base 2 (1:1)

2:4 10 days 2:3 10 days 1:3 10 days 1:2 10 days Base 2 (1:1)
Reward Sensitivity Test

53 Days

- Base 1
  - 30 days (1:2, 10 days)
  - 20 days (1:3, 10 days)
- Contrast (1:4)
  - 10 days (2:3, 10 days)
  - 10 days (2:4, 10 days)

Base 2 (1:1)
- 10 days (2:4, 10 days)
- 10 days (2:3, 10 days)
- 10 days (1:3, 10 days)
- 10 days (1:2, 10 days)
Enrichment did not affect responding for the LG reward

- All rearing conditions significantly increased their relative response rate on the large lever as a function of reward magnitude
- No effect of rearing condition on response to LG reward
Enrichment did not affect responding for the LG reward

- All rearing conditions significantly increased their relative response rate on the large lever as a function of reward magnitude
- No effect of rearing condition on response to LG reward
Enrichment resulted in more generalization to SM lever

- EC and SC rats generalize LG responding in SM-1 condition
- IC rats do not generalize to SM-1
Enrichment resulted in more generalization to SM lever

- EC and SC rats generalize LG responding in SM-1 condition
- IC rats do not generalize to SM-1
Enrichment increased sensitivity to changes in the SM reward

- EC and SC rats increase their SM response when SM reward is increased from 1 to 2 pellets
- IC rats do not increase their response when SM reward increases
Enrichment increased sensitivity to changes in the SM reward

- EC and SC rats increase their SM response when SM reward is increased from 1 to 2 pellets.
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Enrichment increased sensitivity to changes in the SM reward

- EC and SC rats increase their SM response when SM reward is increased from 1 to 2 pellets
- IC rats do not increase their response when SM reward increases
Conclusions

- Environmental enrichment produced:
  - Lower amounts of locomotor activity, both with and without AMP
  - Lower baseline response rates of lever pressing
- These two results suggest that enrichment may be reducing overall motivation/reward-seeking behavior
- Lower motivation to seek rewards could play a role in the protective effect of enrichment against drug-seeking behaviors.
Environmental enrichment did not affect the response to the increase in magnitude on the large lever

- This suggests an intact incentive motivational response to food

But, enrichment did increase generalization to the SM lever

- This indicates that the EC and SC rats were poorer at discriminating between the SM and LG outcomes (or in lever-outcome associations)
Environmental enrichment appears to provide a “protective effect” against addictive behaviors

This may be due to:

- Reduced incentive learning
- Reduced reward sensitivity/discrimination
- Impaired motivational processes
- Impaired reward prediction/anticipation
Environmental enrichment appears to provide a “protective effect” against addictive behaviors

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Environmental enrichment appears to provide a “protective effect” against addictive behaviors.

This may be due to:

- Reduced incentive learning 😞
- Reduced reward sensitivity/discrimination 😬?
- Impaired motivational processes
- Impaired reward prediction/anticipation
Conclusions

- Environmental enrichment appears to provide a “protective effect” against addictive behaviors
  - This may be due to:
    - Reduced incentive learning 😞
    - Reduced reward sensitivity/discrimination 🤔
    - Impaired motivational processes 😊
    - Impaired reward prediction/anticipation 😐
Environmental enrichment appears to provide a “protective effect” against addictive behaviors.

This may be due to:

- Reduced incentive learning 😞
- Reduced reward sensitivity/discrimination 😞
- Impaired motivational processes 😊
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Environmental enrichment appears to provide a “protective effect” against addictive behaviors

- This may be due to:
  - Reduced incentive learning 😞
  - Reduced reward sensitivity/discrimination 😕
  - Impaired motivational processes 😊
  - Impaired reward prediction/anticipation 😕

Impaired response-outcome associations 😕
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