The Nuts & Bolts of Scent Detection
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Learning Objectives

- Describe three factors that influence scent availability
- Design a basic scent-detection training protocol
- Conduct an evaluation of a scent-detection animal
- Describe three challenges associated with scent detection
Scent Detection Behavioral Analysis

A

Antecedent
Target Stimulus Present

Behavior
Indication Behavior

Consequence
Reinforcer

B

Antecedent
Target Stimulus Absent

Behavior
Indication Behavior

Consequence
No Reinforcer

C
Volatilized Chemical Compounds

Availability depends on:

- Temperature
- Humidity
- Air currents
- Volatility of the compound

Phelan & Webb, 2003
Warning: volatile compounds are difficult to control!

Major issues in scent detection research and operations:

- Cross-contamination – positive sample material contaminating negative sample material

- Handling samples differently can result in introduction of other compounds/cues

- The distribution of volatiles is influenced by environmental factors

- Usually, we cannot detect the presence of the compound
Species considerations:

Detection threshold (minimum detectable concentration)
  • Behavioral outcome measure, not just a sensor count
  • Compound-specific

Other considerations
  • Animal care: cost-effectiveness
  • Ease of handling
  • Trainability: operant conditioning acquisition rates
  • Suitability for specific task: physical characteristics, indication response
Characteristics of a good indication response:

- Within the animal’s repertoire or readily shaped
- Easily identifiable and, ideally, with potential for automated recording
- Response effort too low: high false indication rate
- Response effort too high: high miss rate
- Time-based indications can be adjusted to optimize performance
Scent Detection Consequence

Reinforcer:
- “Marker”: conditioned reinforcer/$S^D$
- Relevant establishing operation
A basic training progression:

Early

Intermediate

Advanced
Scent Detection Training

Discrete Trial:
1. Detector is presented with discrete units for evaluation
2. Only those indications that occur in the presence of target stimulus are reinforced
Free Search:
1. Detector can emit indication at any time
2. Only those indications that occur in the presence of (within X cm of) target are reinforced
3. Searching is reinforced by onset of $S^D$
Scent Detection Evaluation

Blind probe:
Most targets are complex: “bouquets”
Concept formation

- Herrnstein & Loveland, 1964
- Instances of the $S^D$ are not identical
- Large set of exemplars required before generalization occurs (multiple exemplar training)

Herrnstein, Loveland, & Cable (1976)
Scent Detection Evaluation

Generalization/blind tests:

- Train with limited exemplars
- Test for generalization to novel exemplars
- Add novel exemplars to training set and continue training
Confirmed positive samples
• Never reward indication of negative sample
• Challenging with disease detection
Comparable negative samples

- Otherwise, behavior can come under the control of other stimuli
Scent Detection Requirements

Large number of sample sources
• Many samples from the same “mother sample” doesn’t count
Intermittent reinforcement

- Resistance to extinction
- Evaluation of blind and otherwise unknown samples

Reynolds, 1968
Blind evaluation

- Trainer not informed of sample location/status
Confirmed positive and negative samples for evaluation

<table>
<thead>
<tr>
<th>Test Outcome</th>
<th>Condition Positive</th>
<th>Condition Negative</th>
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<tbody>
<tr>
<td>Test Outcome Positive</td>
<td>True Positive (Type I error)</td>
<td>False Positive</td>
</tr>
<tr>
<td>Test Outcome Negative</td>
<td>False Negative (Type II error)</td>
<td>True Negative</td>
</tr>
</tbody>
</table>

**Sensitivity** = \( \frac{\Sigma \text{True Positive}}{\Sigma \text{Condition Positive}} \)

**Specificity** = \( \frac{\Sigma \text{True Negative}}{\Sigma \text{Condition Negative}} \)

**Positive predictive value** = \( \frac{\Sigma \text{True Positive}}{\Sigma \text{Test Outcome Positive}} \)

**Negative predictive value** = \( \frac{\Sigma \text{True Negative}}{\Sigma \text{Test Outcome Negative}} \)
SOP and QA

- Critical to stability/reliability
- Critical for sample preparation and handling
Market research:
• What is the current solution, if any, and why is your scent detection product superior?
• What does it take to get integrated into the existing framework?

Industry expertise:
• Develop deep understanding of the relevant technology and processes
• Establish yourself as an industry expert
Scent Detection Examples
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![Image of a dog in a scent detection training session.](image-url)
Scent Detection Examples


