



# SCENT INTERVENTION

## *For Simulated Driving Scenarios*

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MAS.S63 Affective Computing and Multimodal Interaction

MIT Media Lab

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# Problem & Motivation

**NO,  
MIKEY,  
NO!**

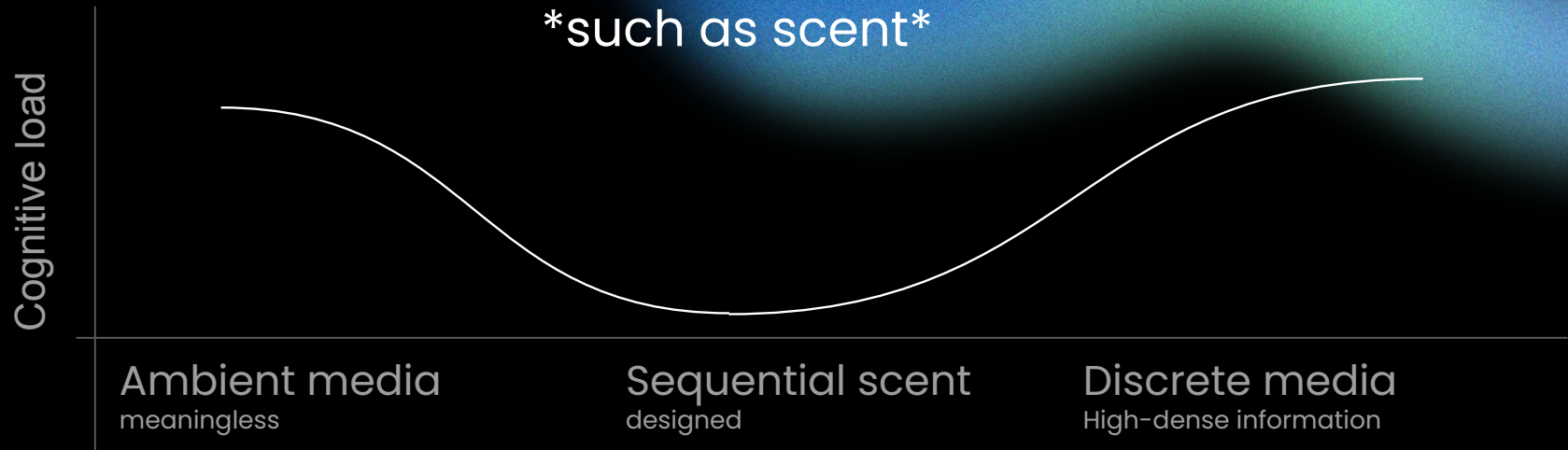
**NETFLIX**

**6 MOST DRAMATIC  
MOMENTS**

Driving is high-stress, attention-demanding  
Race car driving is even more stressful, attention-demanding

Text-based communication is not a “good enough” solution  
Opportunities for “ambient modalities”

\*such as scent\*



# Research Opportunities

Lv, Y. et al. (2025). Measuring emotions triggered by fragrance through behavioral paradigms. *Frontiers in psychology*, 16, 1468416.

Dmitrijs Dmitrenko et al. (2018). I Smell Trouble: Using Multiple Scents To Convey Driving-Relevant Information.

Jiaotao Cai et al. (2025) Olfactory sensation emotion regulation: The implicit emotion regulation function of positive olfactory stimuli during emotional picture processing, *NeuroImage*,

Kandhasamy Sowndhararajan. et al. (2016). Influence of Fragrances on Human Psychophysiological Activity: With Special Reference to Human Electroencephalographic Response

Manik Mahachandra et al. (2015) The Effectiveness of In-vehicle Peppermint Fragrance to Maintain Car Driver's Alertness

Scent as an intervention  
(olfactory sensation) has been  
explored recently

## Gaps

Prior work focuses on *isolated/consistent scents*.  
Little research evaluate the *cumulative* effect of  
scent on *emotion*, not to say *dynamic*  
*sequential scent*?

# Research Question

What is the effectiveness of sequential scent intervention  
on high-stress driving?

# Methodology

What is the effectiveness of sequential scent intervention  
on high-stress simulated race car driving?

# Metrics for “effectiveness”

Arousal (excitement etc) – stress – attention/focus level

How we measure arousal level – breakdown of the EDA  
(i.e. SCL, SCR)

How we measure attention/focus level  
(EDA+Respiratory+Self reported)

Regulation on affective status in reducing stress  
and improving focus level

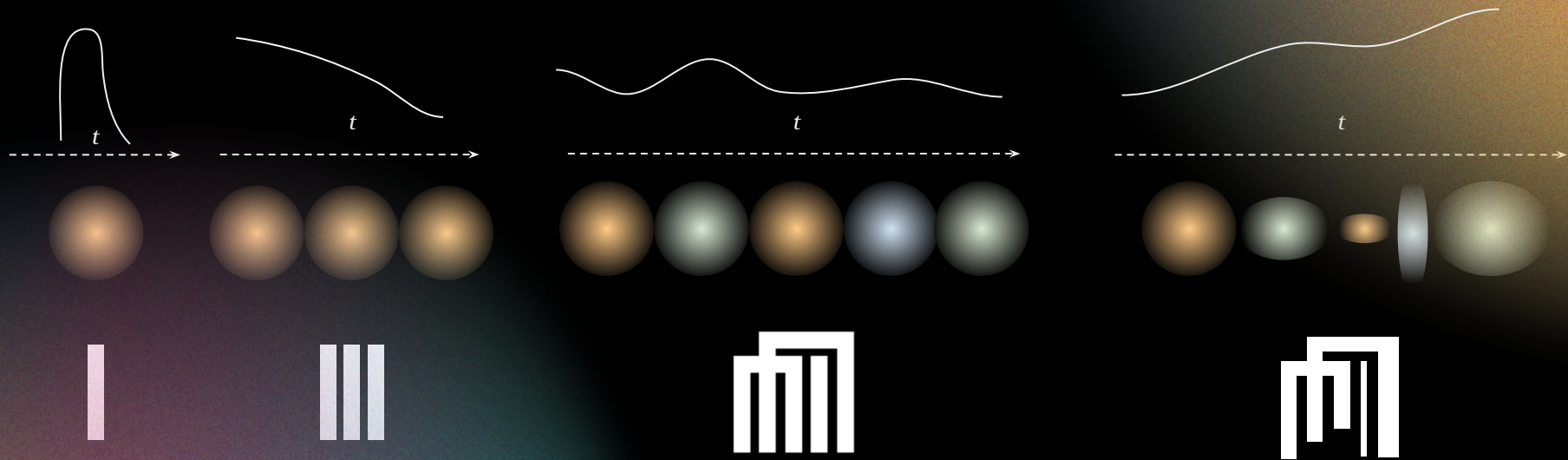
Arousal / focus level relationship (i.e. formula,  
positively related- add research reference)

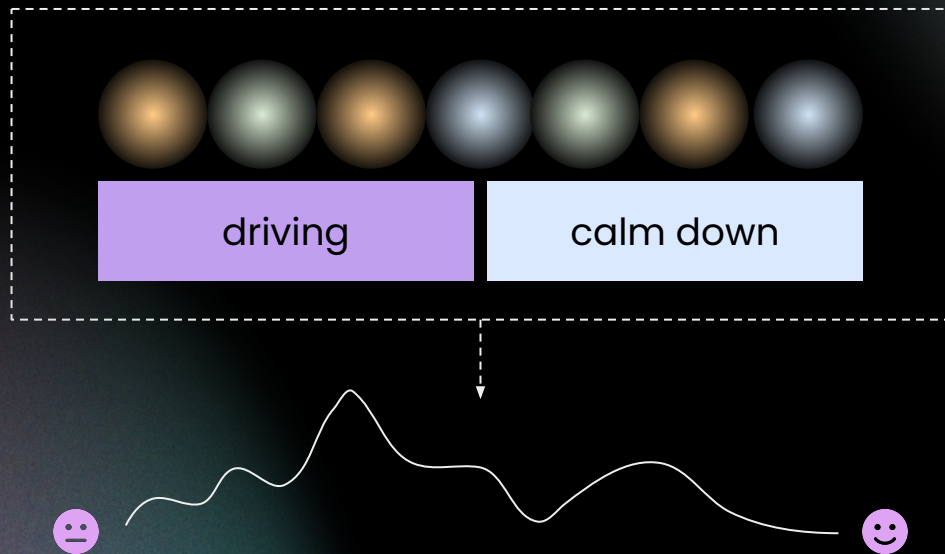
# **“Sequential Scent”**

What defines a sequential scent?

How much variation between each smell for it to be noticeably different?

How do we deliver the sequential scent?



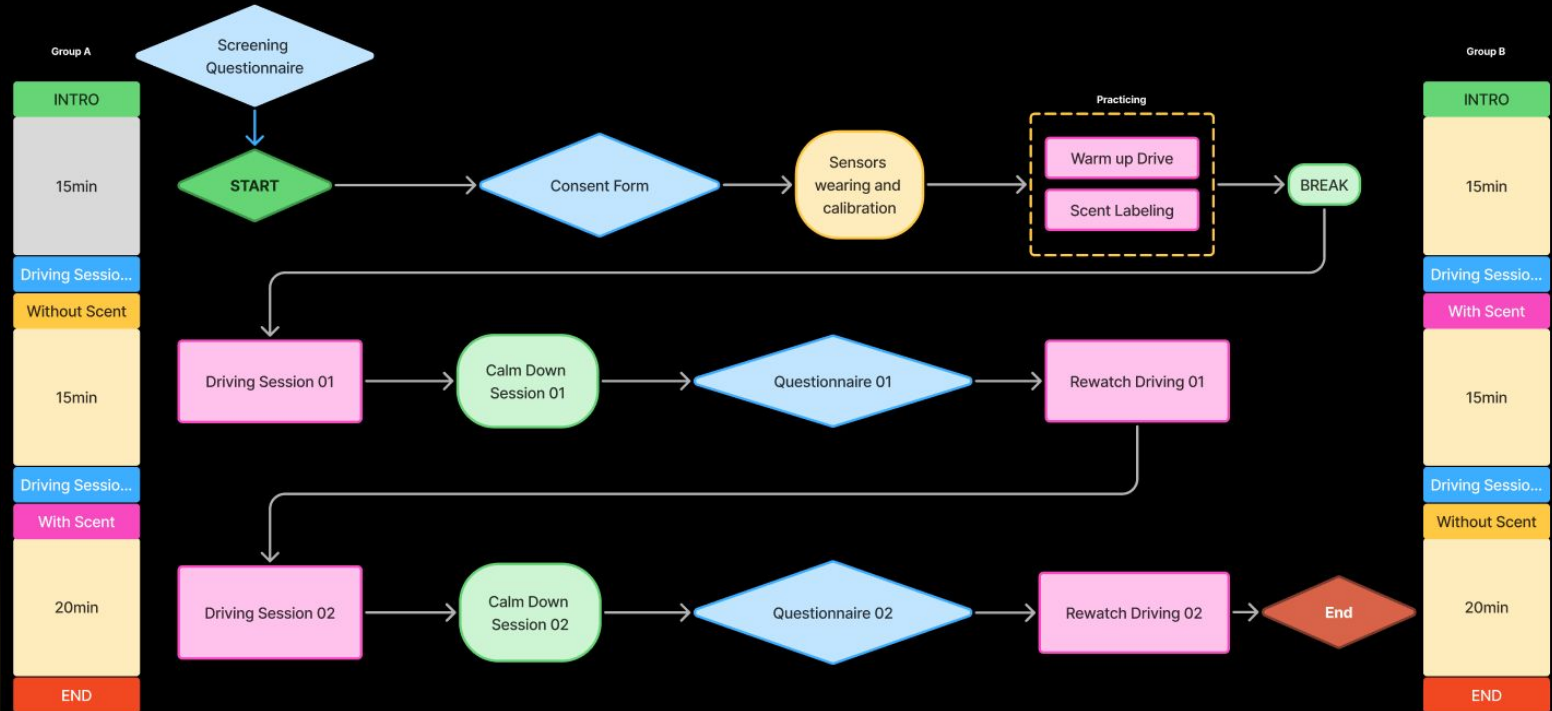


# Implementation

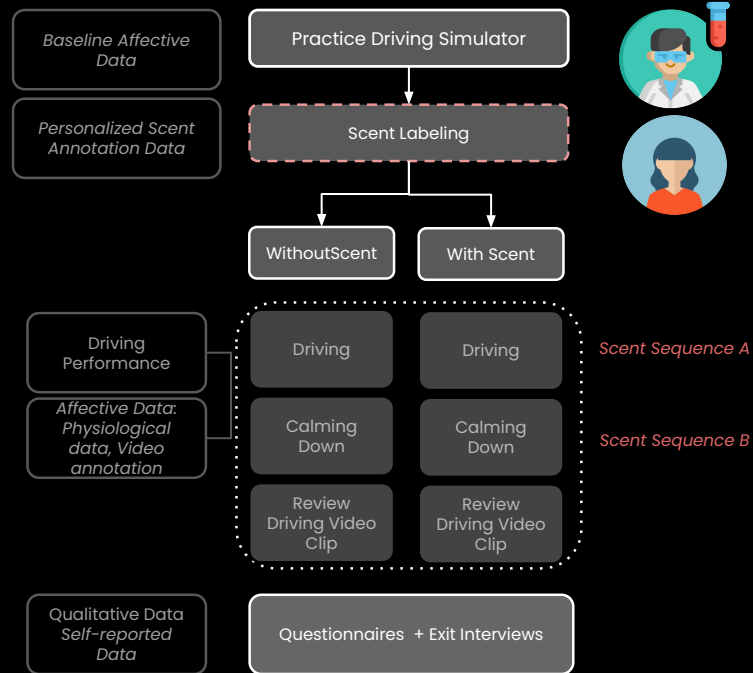
## User Study Set up



# User Study Flow



# Data Collecting Flow



# Data Collection Devices

Scent



Neck Band

*Neckwear Digital Scent Player*

Emotional regulation effect



Empatica Embrace Plus



Zephyr Bioharness

Driving Performance Signals



Logitech Driving Simulator

*Objective signal for racing performances  
Lap Time (LT) (Primary)*

# Sample Questions in the questionnaire

**Do you use any strategies to manage your emotions while racing?** (*Music/Breathing Exercises/Scent/Fragrances*)

**How would you rate your emotional state during the driving simulation?** (*Rate 1-7*)

**How would you rate the effectiveness of the scent intervention in calming you down?** (*Rate 0=1-7*)

**Do you think the scent intervention affects your focus level? And how?** (*Interview Questions*)

Which aspects of the scent intervention did you notice?  
(*characteristics/intensity or concentration/timing and dynamics/relationship to the context*)

# Results

We did 22 user study sessions in total,  
ultimately analyzed complete data from **12** participants.

## Physiological

### EDA raw data

- Feature extraction
- EDA Skin Conductance Level (SCL)
- Skin Conductance Response (SCR)

$$zEDA(t) = \frac{EDA(t) - E\bar{D}A}{\sigma_{EDA}}$$

### Breathing Rate

- Amplitude
- Variability

$$EDAV(t) = std(EDA(t : t + window))$$

## Behavioral

### Driving Data

- Driving Event Log Data
- Time Sequence Data
- Driving stability
- Emergency response
- Lap time)

- Accelerometer
- Hard Brakes Frequency
- Drive Off way
- Crashes
- Control Level
- Speed Variance

## Self-Reported

### Driving Data

- Persona
- SAM (Self-Assessment Manikin)
- PANAS (Positive and Negative Affect Schedule)
- Interview Qualitative

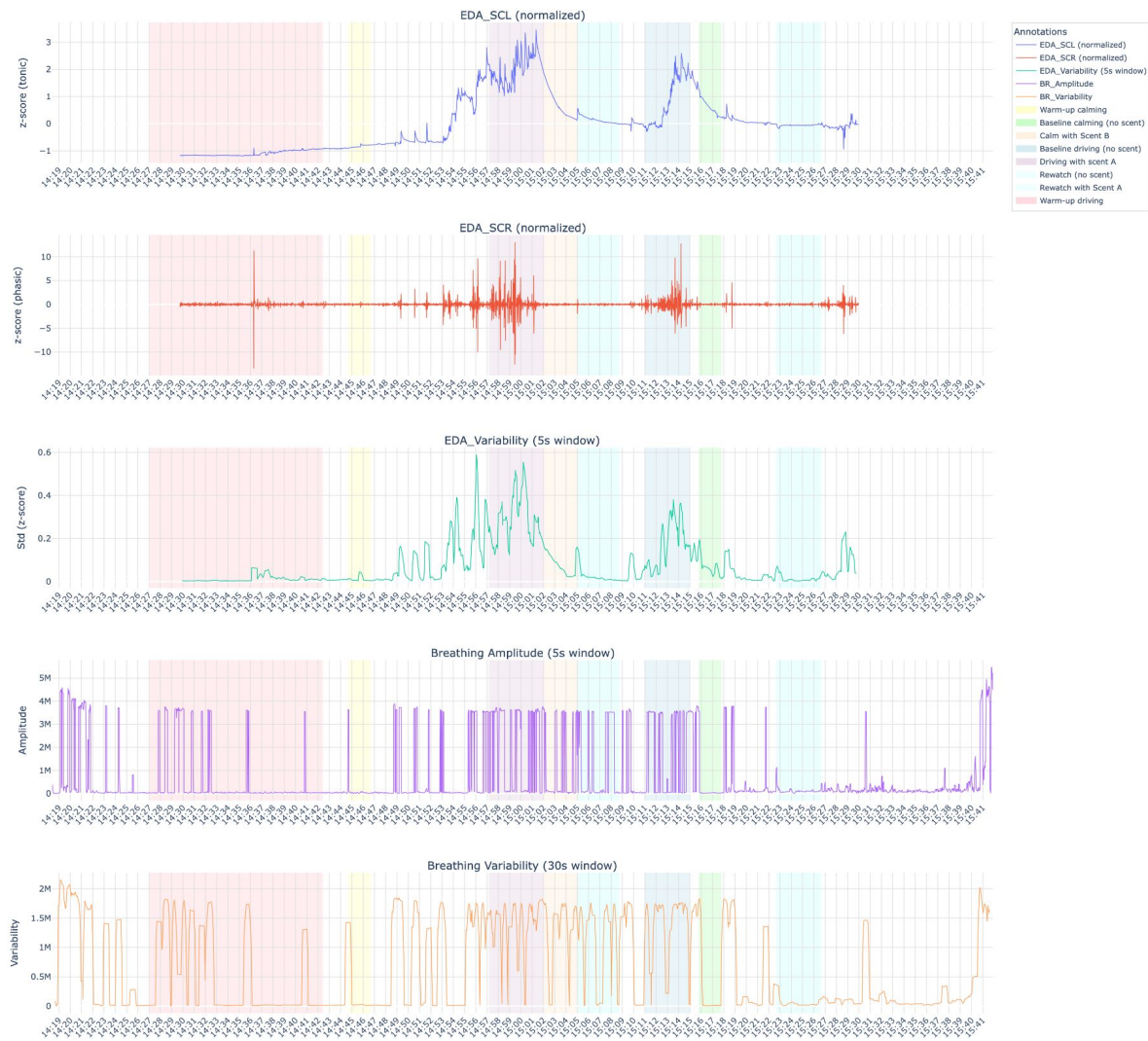
- SAM (valence / arousal / dominance)
- Interview

# Participant #01

|                       |                   |
|-----------------------|-------------------|
| Age Group             | 25-34             |
| Gender                | Female            |
| Driving Experience    | Occasional driver |
| Racing Experience     | Not a racer       |
| Driving Stressfulness | Frequently        |
| Driving Emotion       | Anxious           |
| Used Intervention     | Music             |

|                                         |                                         |
|-----------------------------------------|-----------------------------------------|
| drive_with_scent                        | drive_no_scent                          |
| Self-reported valence = 2 out of 7      | Self-reported valence = 2 out of 7      |
| Self-reported stress level = 6 out of 7 | Self-reported stress level = 6 out of 7 |

Self-reported scent effectiveness = 4 out of 7

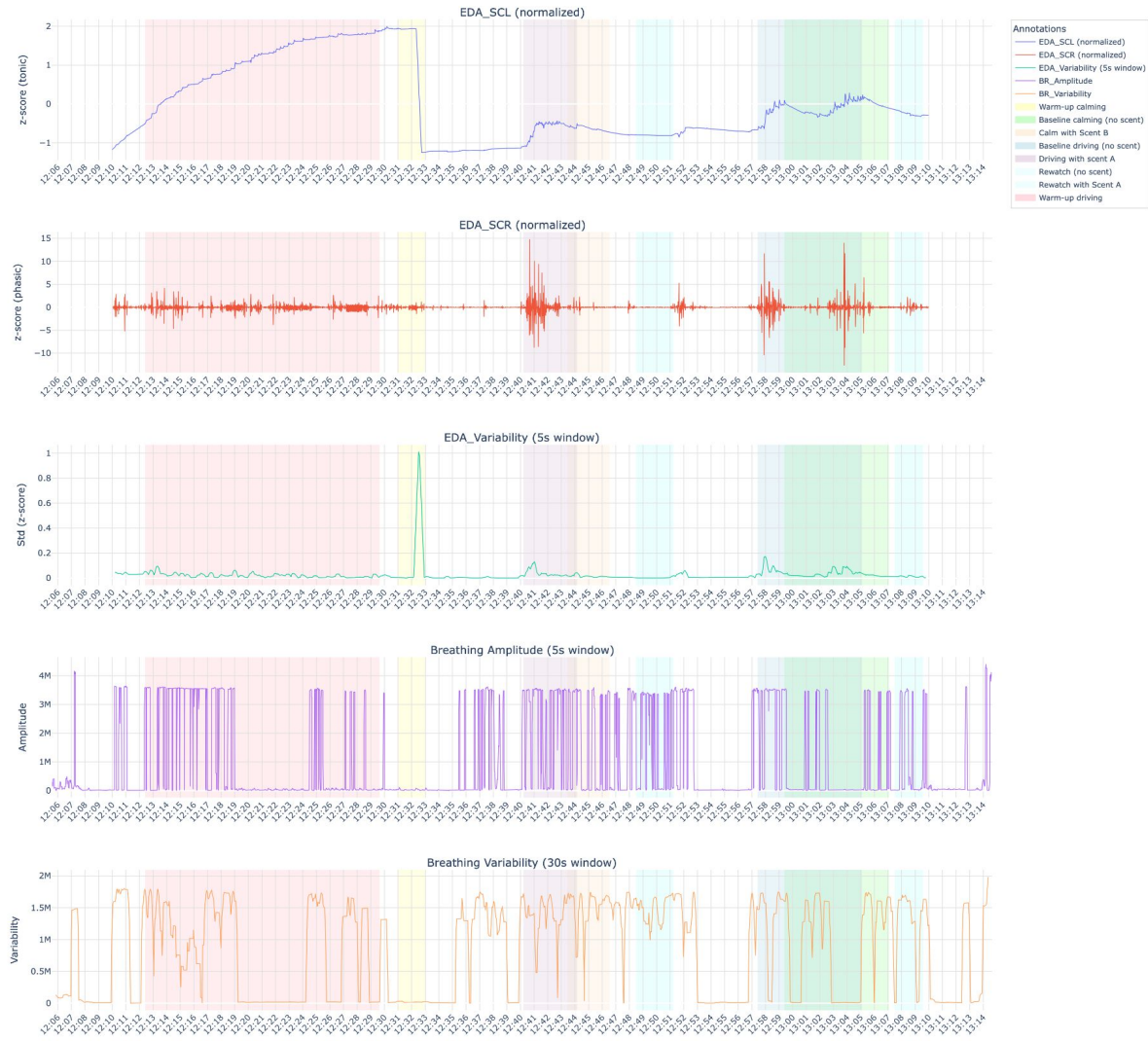


# Participant #02

|                       |                  |
|-----------------------|------------------|
| Age Group             | 18-24            |
| Gender                | Female           |
| Driving Experience    | Very Experienced |
| Racing Experience     | Novice racer     |
| Driving Stressfulness | Occasionally     |
| Driving Emotion       | Calm             |
| Used Intervention     | Music            |

|                                         |                                         |
|-----------------------------------------|-----------------------------------------|
| drive_with_scent                        | drive_no_scent                          |
| Self-reported valence = 2 out of 7      | Self-reported valence = 5 out of 7      |
| Self-reported stress level = 7 out of 7 | Self-reported stress level = 3 out of 7 |

Self-reported scent effectiveness = 1 out of 7



# Participant #01

Mean Value by Phase

| Phase          | SCL_mean  | SCR_mean | EDA_var_mean | BR_amp_mean | BR_var_mean |
|----------------|-----------|----------|--------------|-------------|-------------|
| drive_scent    | 2.047 (H) | -0.003   | 0.292 (H)    | 2069171.586 | 1399591.312 |
| drive_no_scent | 0.848 (L) | 0        | 0.175 (L)    | 1835870.631 | 1373782.991 |
| calm_scent     | 0.691 (H) | 0.004    | 0.084 (H)    | 1127739.23  | 1286576.394 |
| calm_no_scent  | 0.625 (L) | 0.001    | 0.069 (L)    | 140932.264  | 254760.315  |

Mann-Whitney U test

| Phase                               | SCL                                                             | SCR                                               | EDA_var                                                         | BR_amp                                                          | BR_var                                                          |
|-------------------------------------|-----------------------------------------------------------------|---------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|
| Drive_scent<br>vs<br>Drive_no_scent | U = 58444.00,<br>p = 0.00000<br>→ <b>Significant difference</b> | U = 36635.00,<br>p = 0.33715<br>→ Not significant | U = 52989.00,<br>p = 0.00000<br>→ <b>Significant difference</b> | U = 47376.50,<br>p = 0.00000<br>→ <b>Significant difference</b> | U = 31369.00,<br>p = 0.04223<br>→ <b>Significant difference</b> |
| Calm_scent<br>vs<br>Calm_no_scent   | U = 10979.00,<br>p = 0.45816<br>→ Not significant               | U = 11845.00,<br>p = 0.70972<br>→ Not significant | U = 13372.00,<br>p = 0.01934<br>→ <b>Significant difference</b> | U = 21111.50,<br>p = 0.00000<br>→ <b>Significant difference</b> | U = 20519.00,<br>p = 0.00000<br>→ <b>Significant difference</b> |

## Participant #02

Mean Value by Phase

| Phase          | SCL_mean   | SCR_mean | EDA_var_mean | BR_amp_mean | BR_var_mean |
|----------------|------------|----------|--------------|-------------|-------------|
| drive_scent    | -0.62 (L)  | 0.002    | 0.041 (L)    | 2462363.407 | 1366247.11  |
| drive_no_scent | -0.249 (H) | 0.009    | 0.07 (H)     | 2566815.144 | 1294133.723 |
| calm_scent     | -0.627 (L) | 0        | 0.016 (L)    | 1602086.839 | 1499989.344 |
| calm_no_scent  | -0.075 (H) | -0.001   | 0.032 (H)    | 604082.68   | 871132.559  |

Mann-Whitney U test

| Phase                               | SCL                                                            | SCR                                               | EDA_var                                                         | BR_amp                                                          | BR_var                                                          |
|-------------------------------------|----------------------------------------------------------------|---------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|
| Drive_scent<br>vs<br>Drive_no_scent | U = 4587.00,<br>p = 0.00000<br>→ <b>Significant difference</b> | U = 11342.00,<br>p = 0.89345<br>→ Not significant | U = 5315.00,<br>p = 0.00000<br>→ <b>Significant difference</b>  | U = 11291.50,<br>p = 0.84203<br>→ Not significant               | U = 9075.00,<br>p = 0.00216<br>→ <b>Significant difference</b>  |
| Calm_scent<br>vs<br>Calm_no_scent   | U = 0.00,<br>p = 0.00000<br>→ <b>Significant difference</b>    | U = 42736.00,<br>p = 0.88130<br>→ Not significant | U = 17092.00,<br>p = 0.00000<br>→ <b>Significant difference</b> | U = 53667.50,<br>p = 0.00000<br>→ <b>Significant difference</b> | U = 64325.00,<br>p = 0.00000<br>→ <b>Significant difference</b> |

# Main Finding #1

## The Significance of Scent on Driving and Calming

The analysis across 10 participants **consistently** suggests a **significant difference** in EDA levels (i.e., SCL and variability) and breathing rate (i.e., amplitude and variability) between driving and calming sessions with scent and without scent.

# Main Finding #1

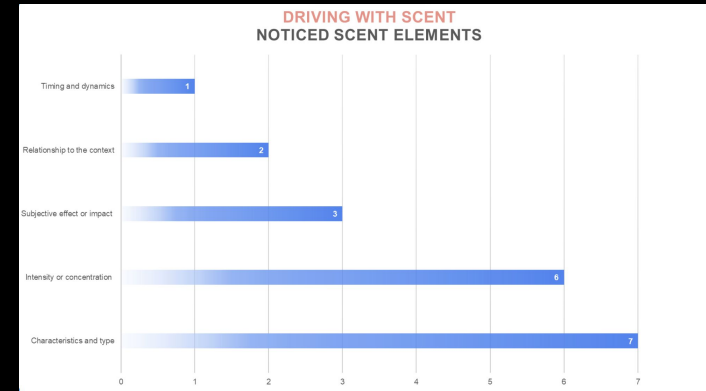
## The Modulating Role of Scent: Long-Term State Stabilization over Immediate Reaction

- Scent has a significant effect on **Tonic Arousal (SCL)**, which reflects a slower, long-term shift in physiological state (10 to 60-second scale).
  - Scent does not appear to have a significant influence on **Phasic Arousal (SCR)**, which reflects rapid, short-term reactions to acute stimuli (1 to 5-second scale, e.g., a "crash").
- This suggests scent is primarily a **"sustained modulator"** of the overall emotional/arousal state, rather than an immediate reactive mechanism. This finding also aligns with established literature on scent's temporal effects.

# Main Finding #1

## EDA vs. Self-Reported Discrepancy

While physiological data (EDA and BR) showed "significant difference," self-reported data often did not reflect a substantial change. This supports the hypothesis that scent's influence is often **\*subconscious\*** or **\*subliminal\***, affecting a participant's state without full conscious awareness or ability to accurately self-report the magnitude of the change.



# Main Finding #2

## Half as “Scent Reducers”

Reported with a Calming/Stabilizing Effect:

Scent Intervention leads to **Lower EDA Arousal** and **Reduced Variability** (e.g., more balanced breathing rate) in both driving and calming sessions.

| Phase          | SCL_mean   | SCR_mean | EDA_var_mean |
|----------------|------------|----------|--------------|
| drive_scent    | -0.62 (L)  | 0.002    | 0.041 (L)    |
| drive_no_scent | -0.249 (H) | 0.009    | 0.07 (H)     |
| calm_scent     | -0.627 (L) | 0        | 0.016 (L)    |
| calm_no_scent  | -0.075 (H) | -0.001   | 0.032 (H)    |

## Half as “Scent Enhancers”

Reported with an Arousing/Distracting Effect:

Scent Intervention leads to **Higher EDA Arousal** and **Increased Variability** or distraction, in both driving and calming sessions.

| Phase          | SCL_mean  | SCR_mean | EDA_var_mean |
|----------------|-----------|----------|--------------|
| drive_scent    | 2.047 (H) | -0.003   | 0.292 (H)    |
| drive_no_scent | 0.848 (L) | 0        | 0.175 (L)    |
| calm_scent     | 0.691 (H) | 0.004    | 0.084 (H)    |
| calm_no_scent  | 0.625 (L) | 0.001    | 0.069 (L)    |

# Main Finding #2

## “Reducers” vs “Enhancers”

The effectiveness of scent is influenced by individual olfactory sensitivity, focus level, and driving expertise.

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## “Reducers” vs “Enhancers”

The effectiveness of scent is influenced by individual olfactory sensitivity, focus level, and driving expertise.

*“The scent made me **de-stress** from the turns and stops.”*

*— an occasional driver / racer*

*“Driving for me is **multitasking**. I put 80% of my attention on driving. And it's good to have the scent take the rest of it, so I will not wander around and can be more **focused**.”*

*— a novice driver*

*“I don't think it (**scent switch**) makes me any more **distracted**. Anything that distracts you in your breaking movement can cause slower lap time.”*

*— an experience racer*

*“Yes, it made me more **distracted**. which is **good** because I didn't want to focus too hard on the unpleasant emotions that comes with driving.”*

*— an experienced driver*

# Design Implication #1

## Personalized Scent Interaction Archetypes

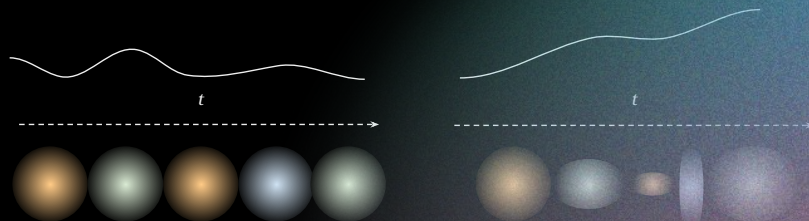
**Personalization is necessary.** A one-size-fits-all approach to scent delivery would have the opposite of the intended effect on nearly half of the user population. Future HAI systems incorporating olfactory feedback must first classify the user's physiological archetype (Regulator or Enhancer) to determine the appropriate scent type, concentration, or timing to achieve the desired state (e.g., calm or alert).

# Design Implication #2

## Transitional Design of the Scent Sequence

For high-reactive individuals, especially professional drivers and racers, the "jarring and abrupt" transitions between different scents in the sequence proved distracting.

The system should be designed to create a **smoother, more gradual flow** (like music) between scent states, minimizing the abrupt change that breaks the user's "flow state" or focus.



# Learnings

# 01

Our nonlinear / pivoted  
pathway:  
change of applications;  
iterations of user study  
design

# 03

Balance between vision and  
reality, (overly) ambitious,  
which is both good and bad

# 02

Lack of experience in  
(physio) data processing:  
Hard to do reverse-thinking:  
e.g., knowing what data  
should be collected before  
we conduct user studies

# 04

Noise variables exist to make  
it hard to solely examine the  
effectiveness from scent



# Further Discussion\*

## **Research Question #1**

What is the effectiveness of sequential scent intervention  
on high-stress driving?



## Research Question #2



How can AI generate **personalized** scent interventions to induce **desired affective changes** in high-stress driving?



How can AI understand the user's affective status and generate appropriate scent intervention accordingly?



# AI and Scent Understanding

## Existing Work:

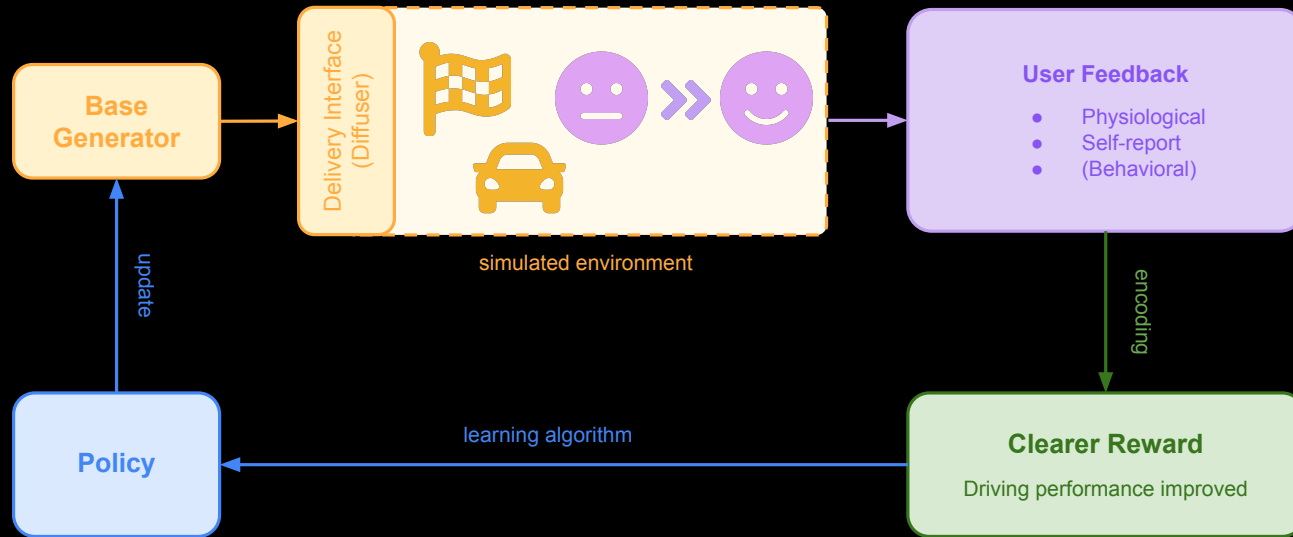
- a. SmellNet and similar databases digitize natural smells and train AI models to recognize them.
- b. Studies on AI-based scent generation often involve chemoinformatics, where AI predicts or generate odors based on their molecular structures.
- c. (Affective Road dataset)

## Gaps:

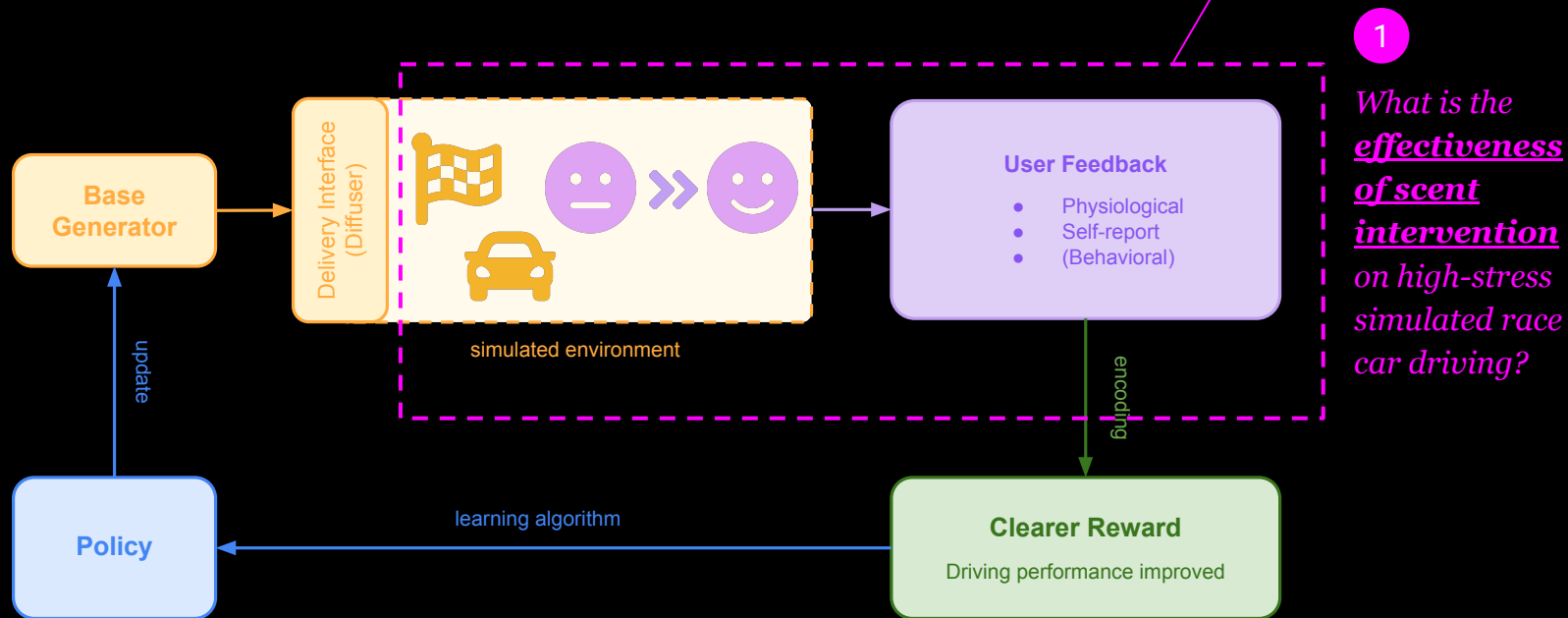
- d. Towards more *human-centric* generative models for scent → Scent Embedding Space with Emotions?
- e. Lack of *intelligent control policy* for temporal scent generation



# How can AI generate personalized scent interventions to induce *\*affective changes\** in a simulated race car driving?



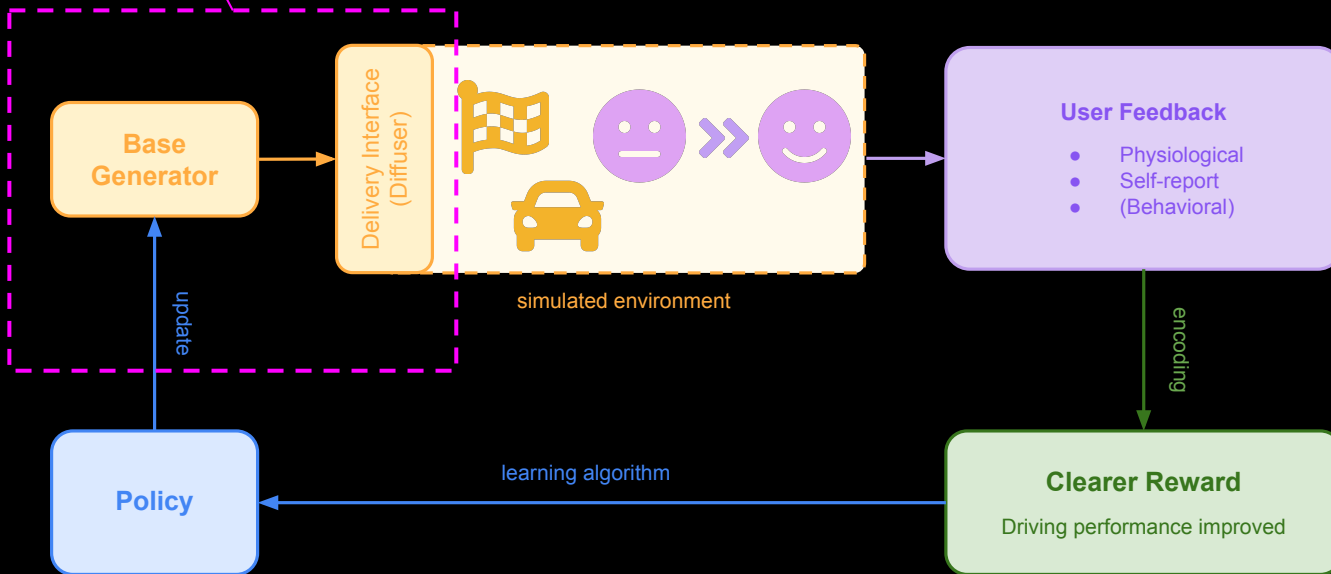
Q: How can AI generate personalized scent interventions to induce **\*affective changes\*** in a simulated race car driving?



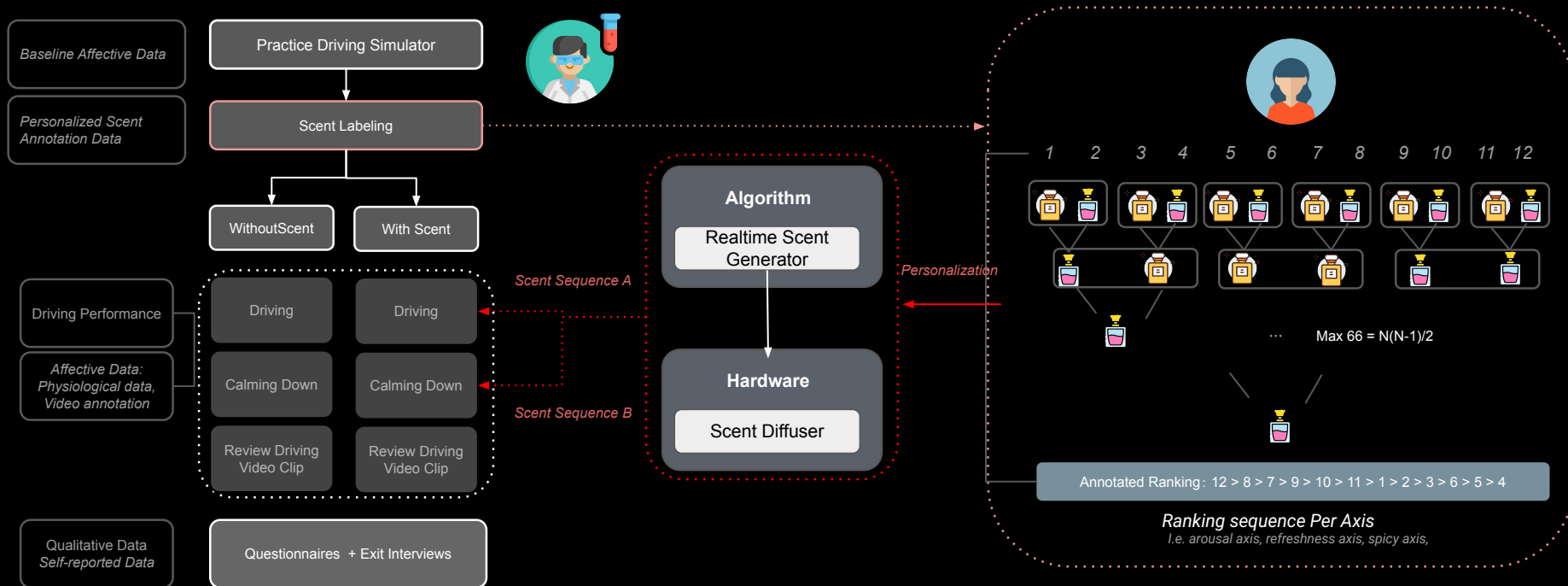
Q: How can AI generate personalized scent interventions to induce *\*affective changes\** in a simulated race car driving?

2

How can AI  
“understand”  
relations  
between scent  
and emotion?



# Comparative Scent Annotation

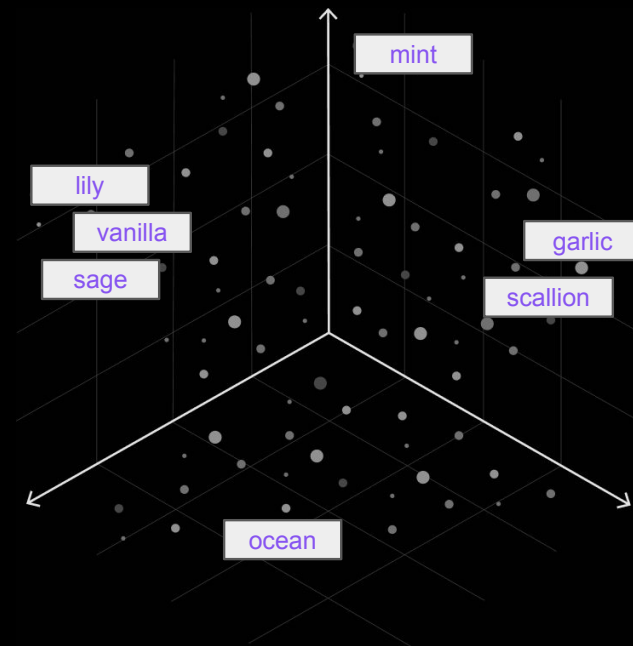


## 2 How can AI “understand” relations between scent and emotion?

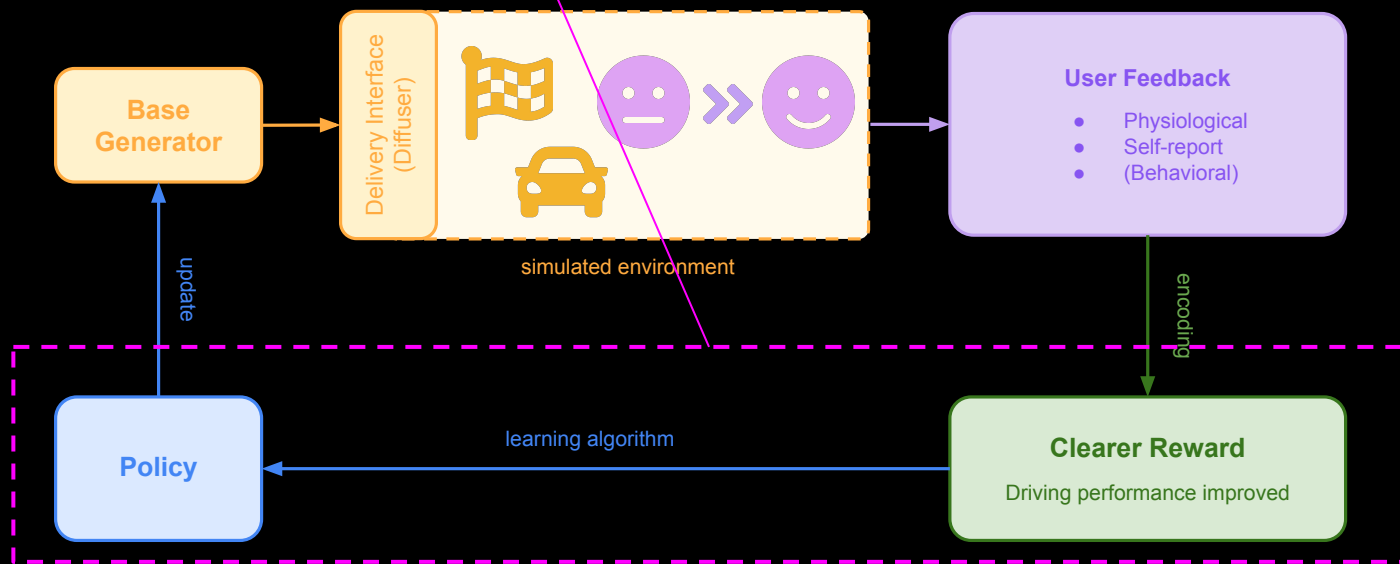
Each scent is represented in a multidimensional vector:

E.g., [V: 6.5, A: 2.0, D: 3.0, Fr: 6.0, S: 6.0, H: 1.0, Fl: 3.4]

|         | Axis 1: V | Axis 2: A | Axis 3: D | Axis 4: F | Axis 5: S | Axis 6: R | Axis 7: Fl |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| Scent 1 | 6.2       | 3.2       | 4.5       | 1.3       | 7.0       | 5.8       | 3.4        |
| Scent 2 | 3.4       | 3.8       | 1.2       | 4.4       | 5.0       | 3.6       | 6.2        |
| Scent 3 | 5.6       | 5.5       | 2.6       | 2.4       | 3.3       | 0.5       | 7.0        |
| Scent 4 | 2.5       | 6.4       | 5.5       | 1.8       | 3.8       | 2.0       | 3.3        |
| Scent 5 | 1.2       | 2.3       | 4.9       | 0.2       | 1.3       | 4.1       | 1.6        |
| Scent 6 | ...       | ...       | ...       | ...       | ...       | ...       | ...        |



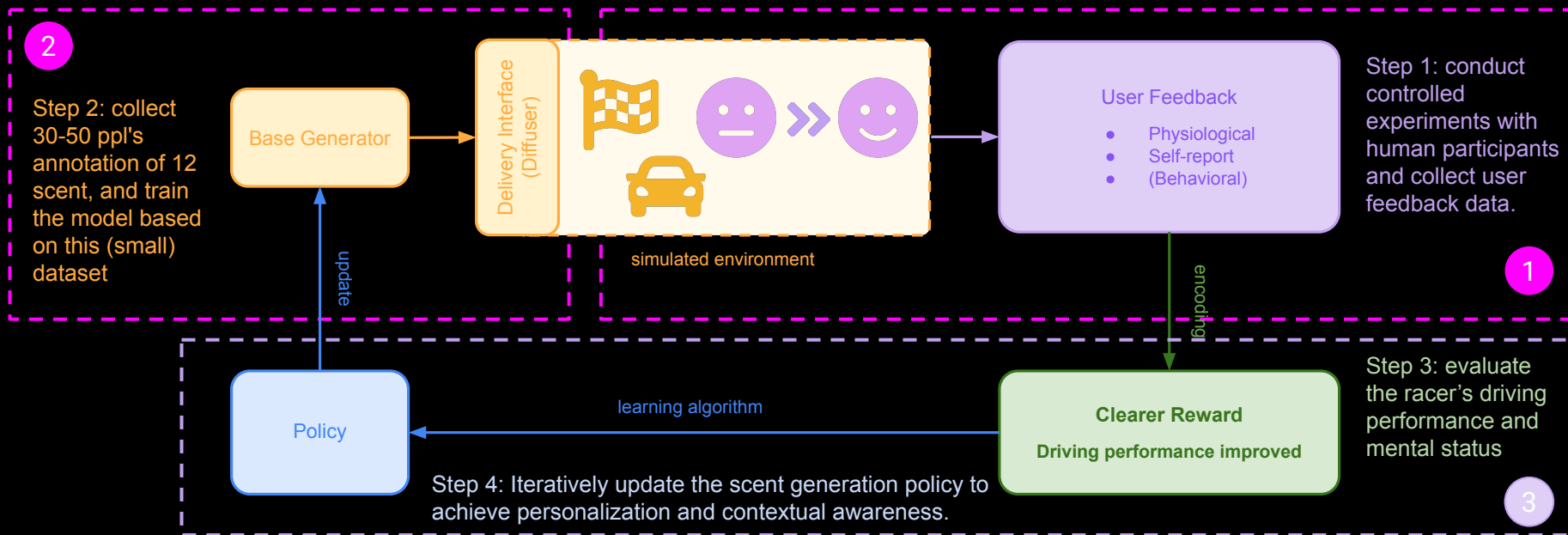
Q: How can AI generate **personalized** scent interventions to induce *\*affective changes\** in a simulated race car driving?



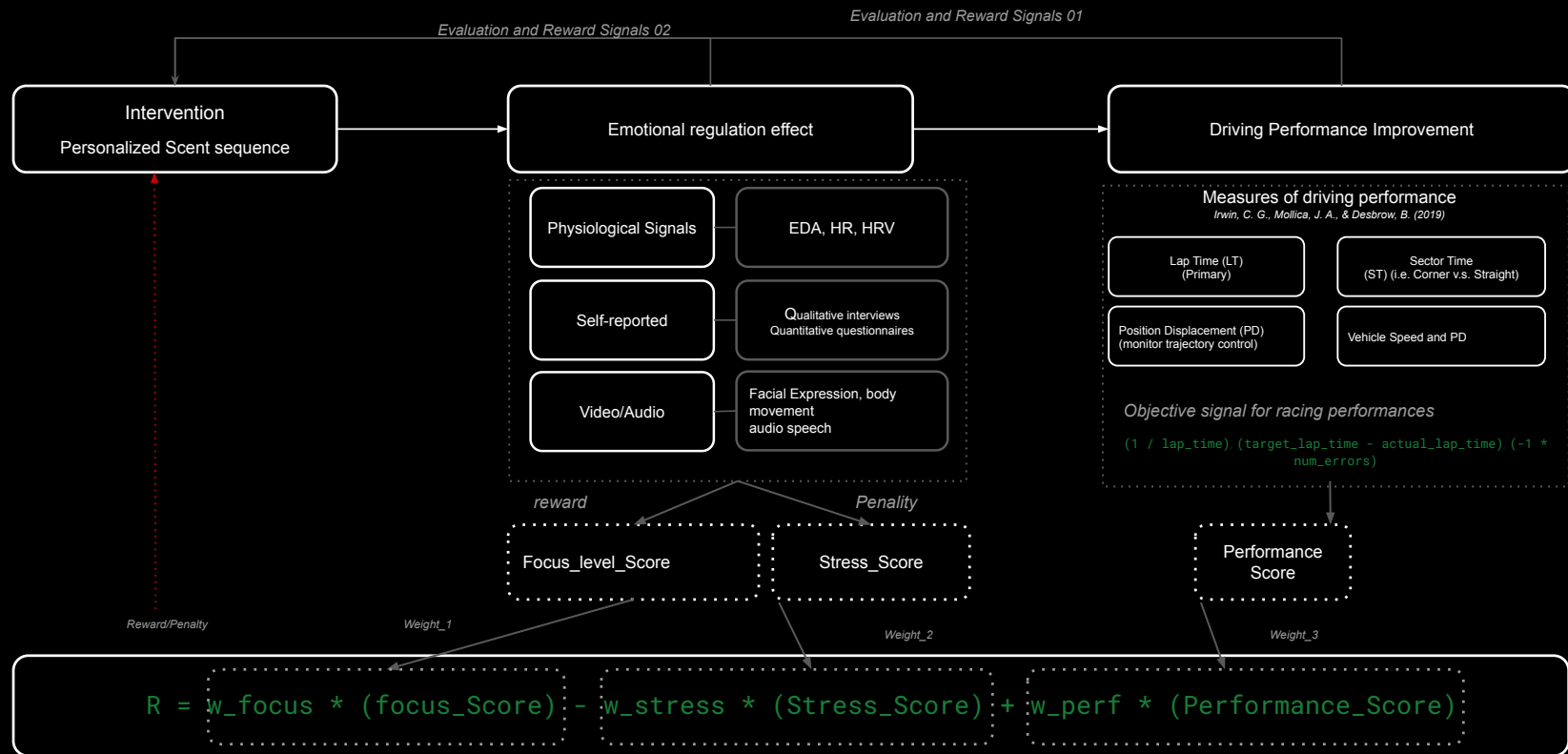
3

*What can the model generate & iterate its scent design based on the user's preference and needs?*

# Q: How can AI generate personalized scent interventions to induce *\*affective changes\** in a simulated race car driving?

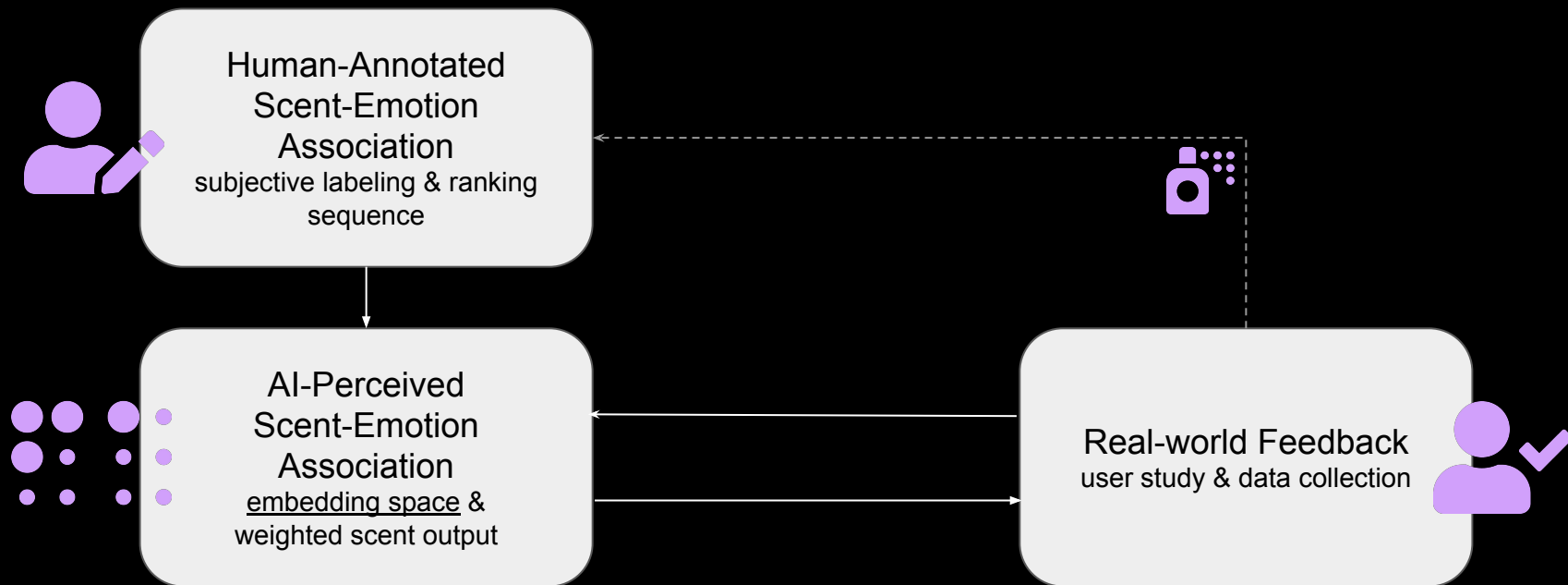


# Reward Model



# \*Higher-Level Framework\*

Synthesized Modalities ● ————— ● Affective Status



# THANK YOU

Awu Chen (awwu@media.mit.edu), Nomy Yu (nomyyu@mit.edu), Xixi Li (xixili@mit.edu)

## EDA + Breathing (Amplitude &amp; Variability) - v6\_raw



```
=====  
Statistical Comparison: drive_scent vs drive_no_scent  
=====
```

```
--- EDA_Tonic_z: drive_scent vs drive_no_scent ---
```

```
n1=2555, n2=2875
```

```
drive_scent mean=-0.6510 ± 0.6372
```

```
drive_no_scent mean=-0.0396 ± 0.7187
```

```
U=1963163.00, p=0.00000
```

```
→ Significant difference ✓
```

```
--- EDA_Phasic_z: drive_scent vs drive_no_scent ---
```

```
n1=2555, n2=2875
```

```
drive_scent mean=0.0000 ± 1.0022
```

```
drive_no_scent mean=-0.0002 ± 1.4263
```

```
U=3681806.00, p=0.87606
```

```
→ Not significant ✗
```

```
--- EDA_Clean_z_std_5s: drive_scent vs drive_no_scent ---
```

```
n1=2555, n2=2875
```

```
drive_scent mean=0.2037 ± 0.1177
```

```
drive_no_scent mean=0.2944 ± 0.1224
```

```
U=2134444.00, p=0.00000
```

```
→ Significant difference ✓
```

```
...
```

```
drive_scent mean=255910.2175 ± 434187.2117
```

```
drive_no_scent mean=80715.7918 ± 147980.8240
```

```
U=2597675.00, p=0.00000
```

```
→ Significant difference ✓
```

```
=== Summary Comparison ===
```

|   | condition      | n samples | EDA Tonic z mean | EDA Tonic z std | EDA Phasic z mean | EDA Phasic z std | EDA var 5s mean | BR amp mean   | BR amp std    | BR var mean   | BR var std    |
|---|----------------|-----------|------------------|-----------------|-------------------|------------------|-----------------|---------------|---------------|---------------|---------------|
| 0 | drive scent    | 2555      | -0.650956        | 0.637169        | 0.000041          | 1.002235         | 0.203677        | 274680.784736 | 664434.152020 | 255910.217531 | 434187.211733 |
| 1 | drive no scent | 2875      | -0.039566        | 0.718687        | -0.000187         | 1.426302         | 0.294434        | 118311.206957 | 112743.266133 | 80715.791832  | 147980.824007 |

Mind Monitor - Absolute Brain Waves

