Tactile Motion for Breath Guiding in Virtual Reality

在虛擬實境中藉由觸覺流動進行呼吸引導

黃琬庭

指導教授：洪一平 博士

Outline

- Introduction
- Related Work & Design Consideration
- Implementation
- Exploration Study
- Evaluation
- Conclusion & Future Work

Outline

- Introduction
- Related Work & Design Consideration
- Implementation
- Exploration Study
- Evaluation
- Conclusion & Future Work

Introduction

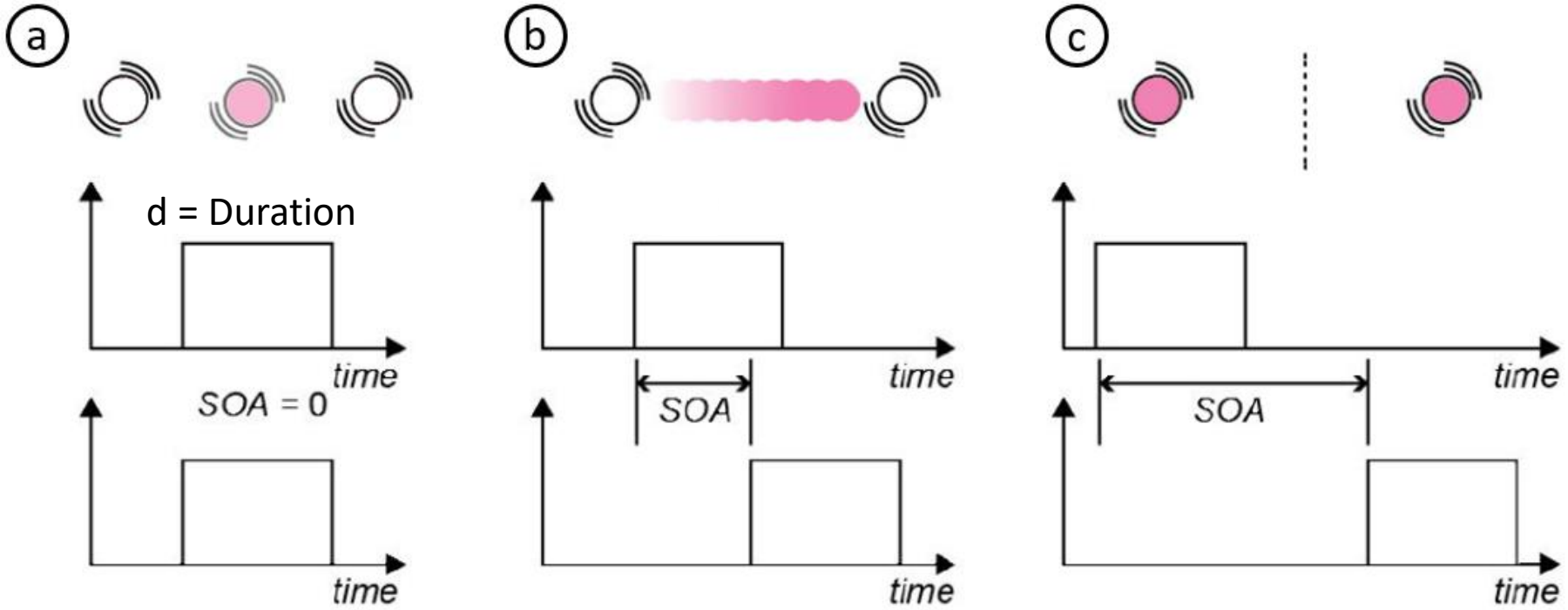
- Design a **tactile chair cushion** and an **interface for designing tactile instruction pattern** (TIP)
- Put forward some **design considerations** for TIP
- Studies to **find intuitive TIP** for breath guiding
- A Study to find the user's preferences of **multi-modal instruction**
- Propose a system to guide breathing with **less interference**

Outline

- Introduction
- Related Work & Design Consideration
  - Tactile Illusion
  - Apparent Motion Illusion
  - Tactile Instruction Pattern (TIP)
- Implementation
- Exploration Study
- Evaluation
- Conclusion & Future Work

Tactile Illusion

SOA = Stimulus Onset Asynchrony

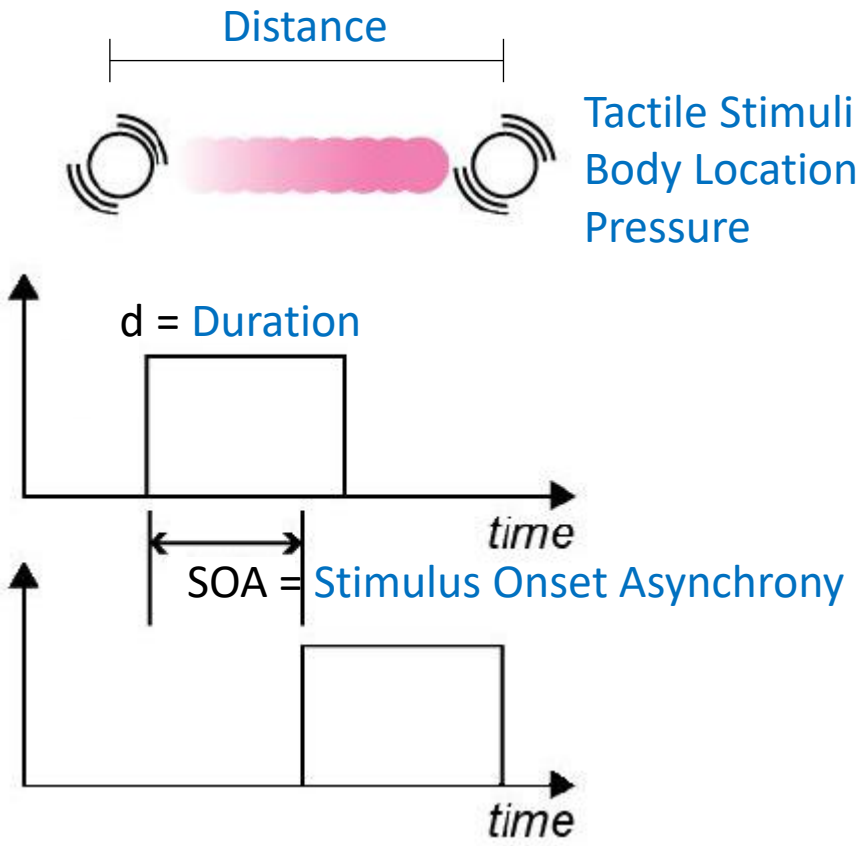


Phantom Illusion | Apparent Motion Illusion | Discrete Vibrations

Pittera, D., M. Obrist, and A. Israr. *Hand-to-hand: An Intermanual Illusion of Movement*. In Proceedings of the 19th ACM International Conference on Multimodal Interaction. 2017.

Apparent Motion Illusion

- Major influence
  - Tactile Stimuli Used
  - Body Location
  - Duration
  - Stimulus Onset Asynchrony (SOA)
- Secondary influence
  - Pressure
- No influence
  - Distance



Tactile Instruction Pattern (TIP)

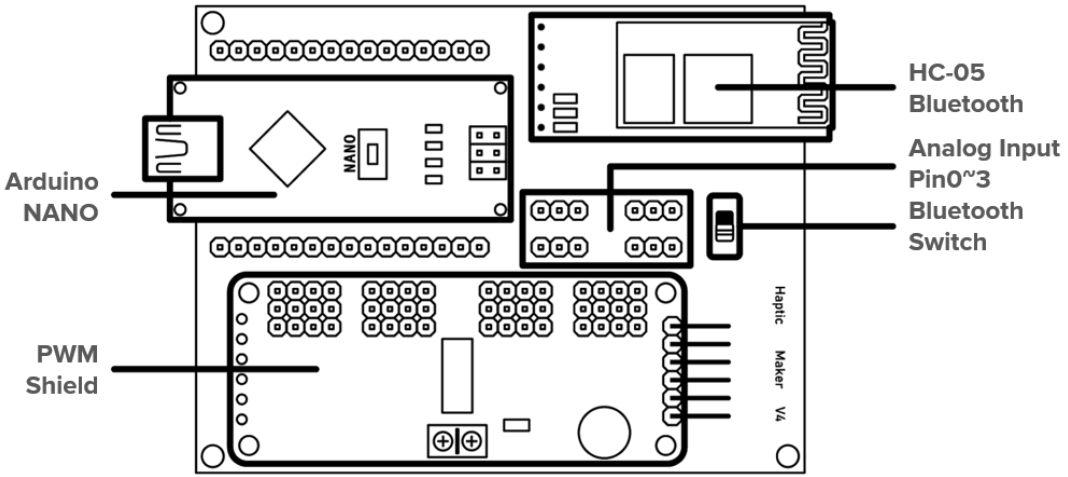
- Distinguishable
  - Different actions need to have different TIPs.
  - The TIP for the latter action should **not be the same as** the end of the TIP of the previous action.
  - The TIP for each action must be completed to a **stop**.
- Noninterference
  - If they cannot accept the vibration patterns, it is better **not to provide vibration** for that action than give the TIP that they dislike.

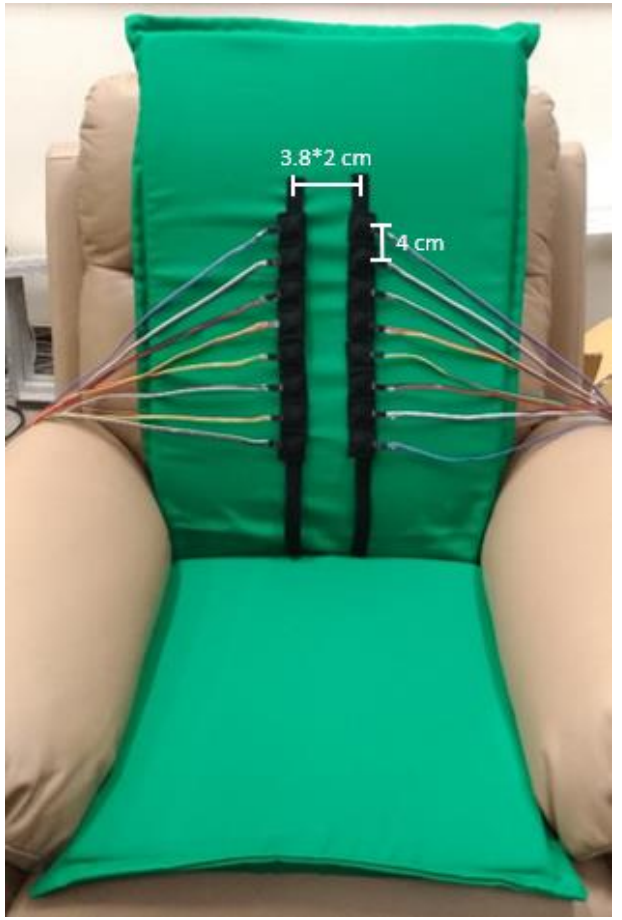
Outline

- Introduction
- Related Work & Design Consideration
- Implementation
  - Tactile Chair Cushion
  - TIP Design Interface
- Exploration Study
- Evaluation
- Conclusion & Future Work

Tactile Chair Cushion

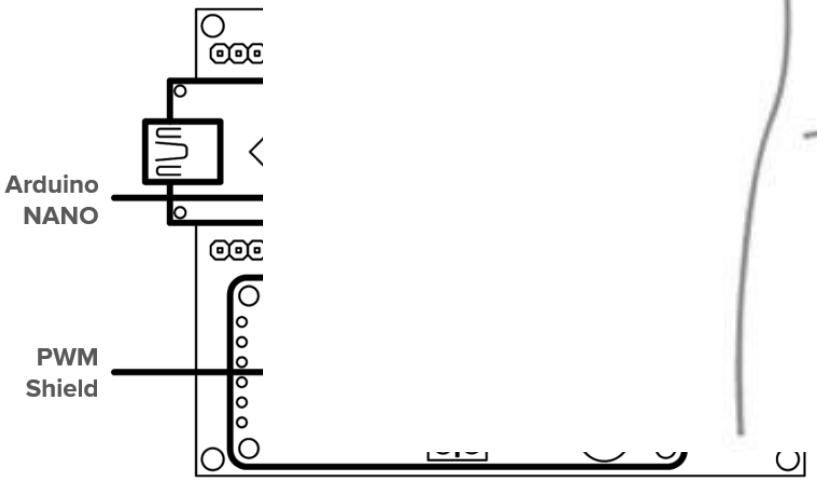
- Tactile Stimuli Used: 16 Arduino vibration motor module
- Body Location: Inner Bladder Meridian
- Distance: 4 centimeters
- Control: Haptic Maker & Unity

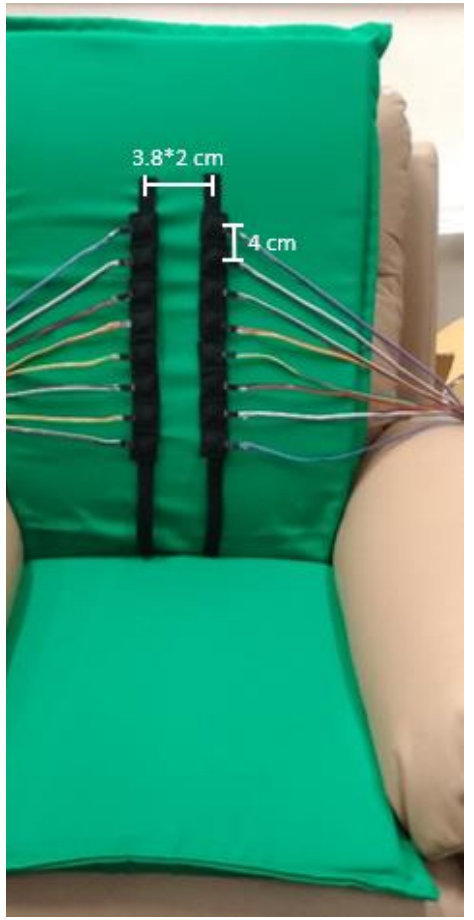




Tactile Chair Cushion

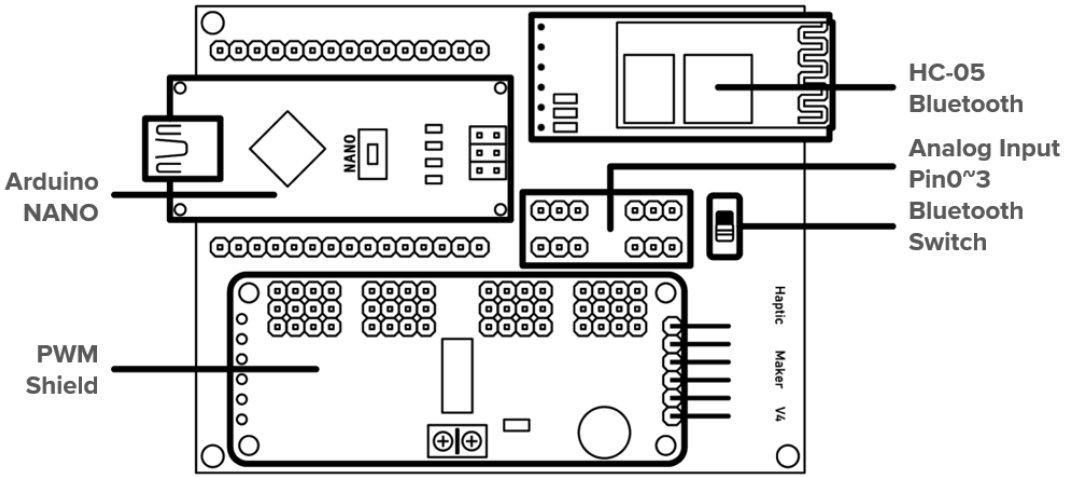
- Tactile Stimu
  module
- Body Locatic
- Distance: 4 c
- Control: Hap

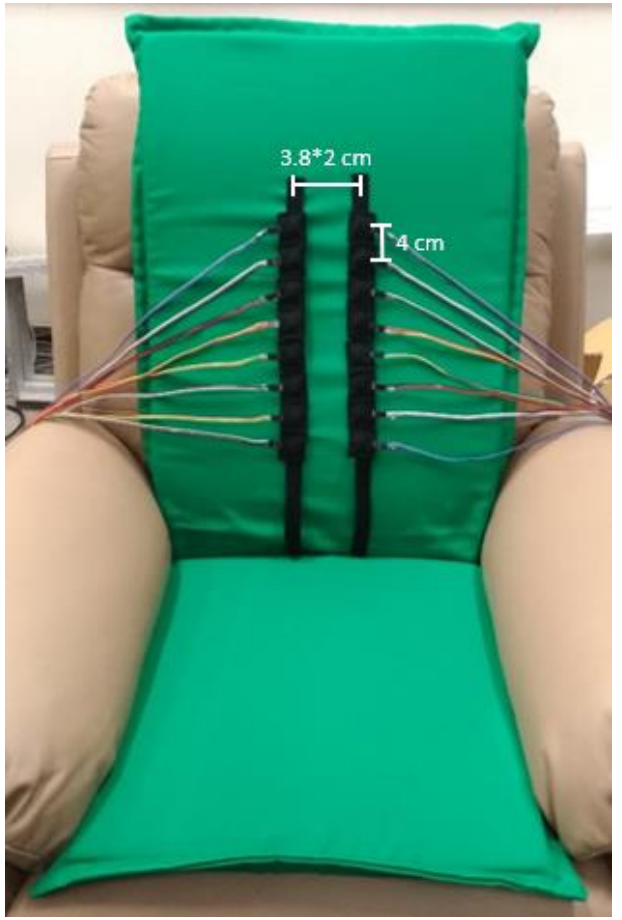




Tactile Chair Cushion

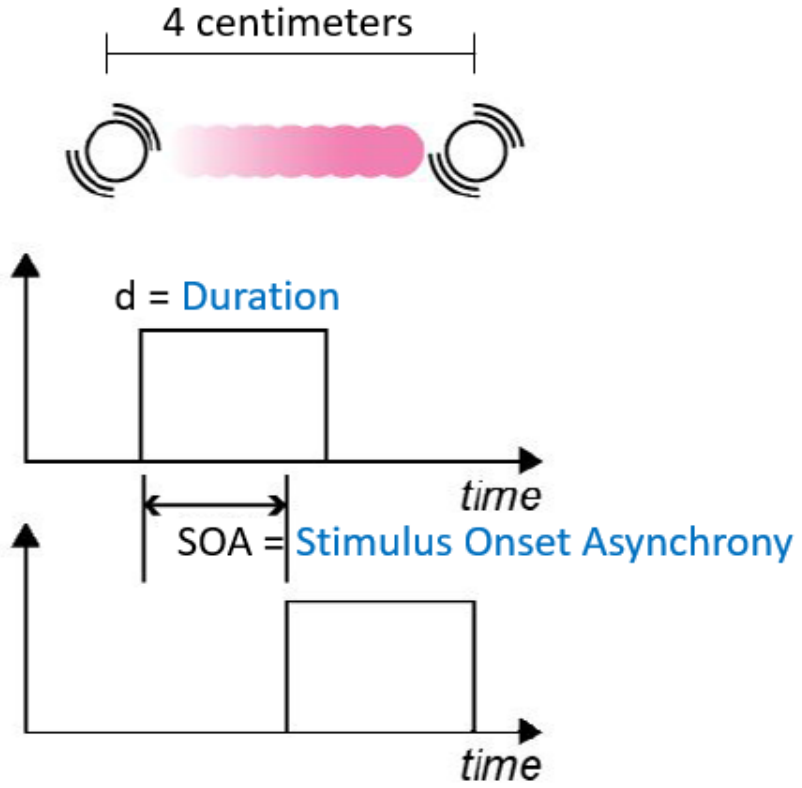
- Tactile Stimuli Used: 16 Arduino vibration motor module
- Body Location: Inner Bladder Meridian
- Distance: 4 centimeters
- Control: Haptic Maker & Unity





Duration and SOA

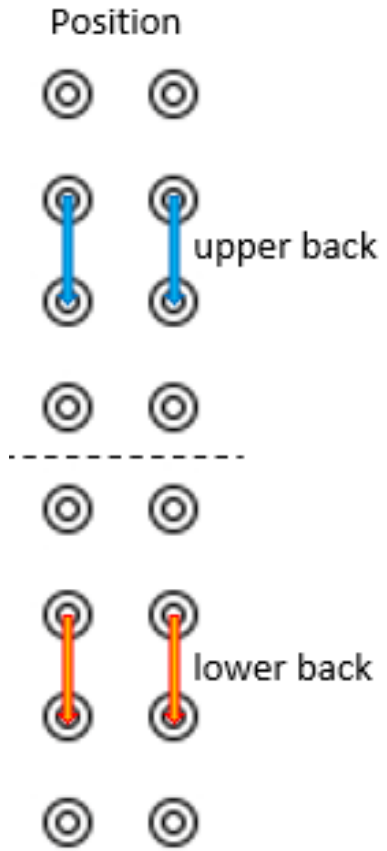
- Refer to the experimental method of Tactile Brush.
- Given duration, find upper- and lower-SOA threshold values.
- Two durations: 500, 1000 milliseconds
- Two positions: upper back, lower back



Israr, A. and I. Poupyrev. *Tactile brush: drawing on skin with a tactile grid display*. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 2011.

Duration and SOA

- Refer to the experimental method of Tactile Brush.
- Given duration, find upper- and lower-SOA threshold values.
- Two durations: 500, 1000 milliseconds
- Two positions: upper back, lower back



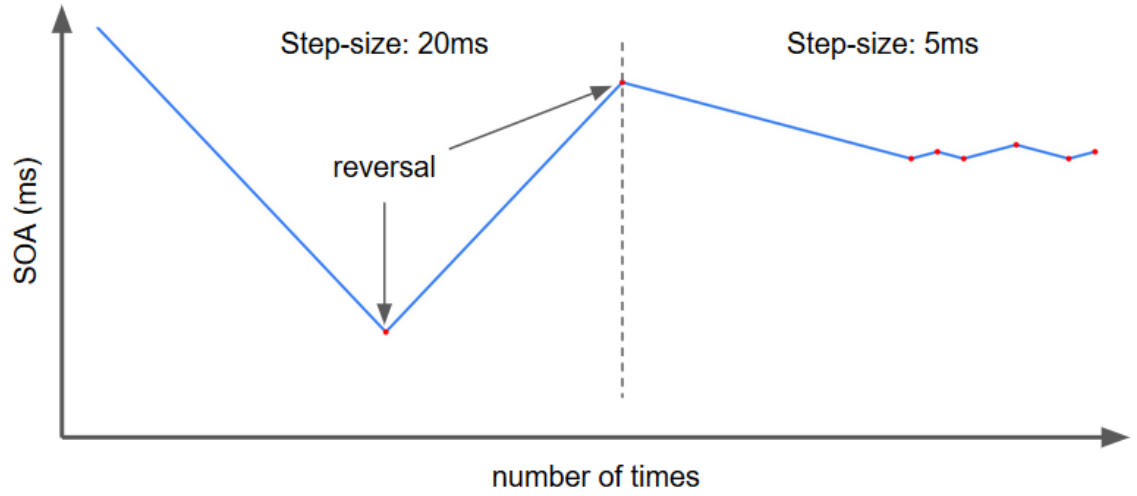
Israr, A. and I. Poupyrev. *Tactile brush: drawing on skin with a tactile grid display*. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 2011.

Duration and SOA (cont.)

- Measuring the **upper threshold** of SOA
  - Initial **SOA equals duration**
- Question: Can you feel **individual discrete actuators**?
  - Answer **Yes**: the SOA value **decreased**
  - Answer **No**: the SOA value **increased**

Duration and SOA (cont.)

- Initial SOA step-size of **20 milliseconds**.
- After the first **2 reversals**, the step-size decreased to **5 milliseconds**.
- Terminated after total of **8 reversals.**
  - One-up one-down
- An average SOA threshold was computed from the last **4 reversals**.



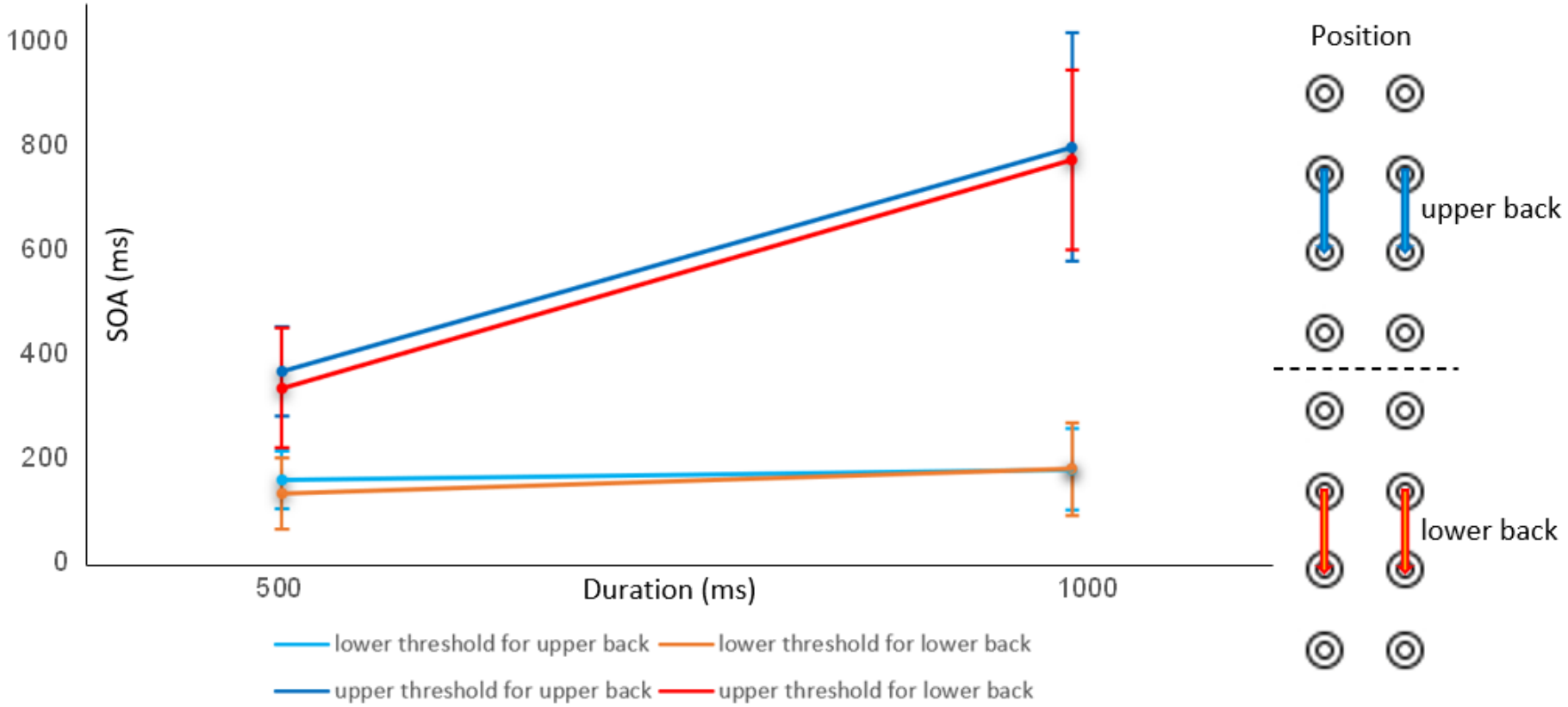
Duration and SOA (cont.)

- Measuring the **lower threshold** of SOA
  - Initial **SOA equals 0**
- Question: Do you feel actuators **merged as one**?
  - Answer **Yes**：the SOA value **increased**
  - Answer **No**：the SOA value **decreased**

Duration and SOA (cont.)

- Participants
  - 12 participants (8 males and 4 females)
  - 21 to 25 years old (mean = 23.17 years old, std = 1.19)
  - Only one participant have never used massage chairs before.
    - 6 of them like to use massage chairs
    - 6 of them have no special feeling for massage chairs

Results



Position	Optimal SOA model
Upper back	SOA = 0.456 * duration + 20
Lower back	SOA = 0.492 * duration - 28

Pressure

- Three interfaces
  - Sitting Upright (100 degrees)
  - Half Lying (120 degrees)
  - Lying Down (140 degrees)
- 7-point scale
  - Pressure level (Do you obviously feel the vibrators?)
    - 1: No feeling, like sitting on a normal chair cushion ~ 7: There are noticeable bumps
  - Comfort level
    - 1: Very uncomfortable ~ 7: Very comfortable
- Yes–no question
  - Do you feel the vibrations in the bone structure?

Pressure

- Participants
  - 12 participants (8 males and 4 females)
  - 22 to 30 years old (mean = 24.25 years old, std = 2.67)

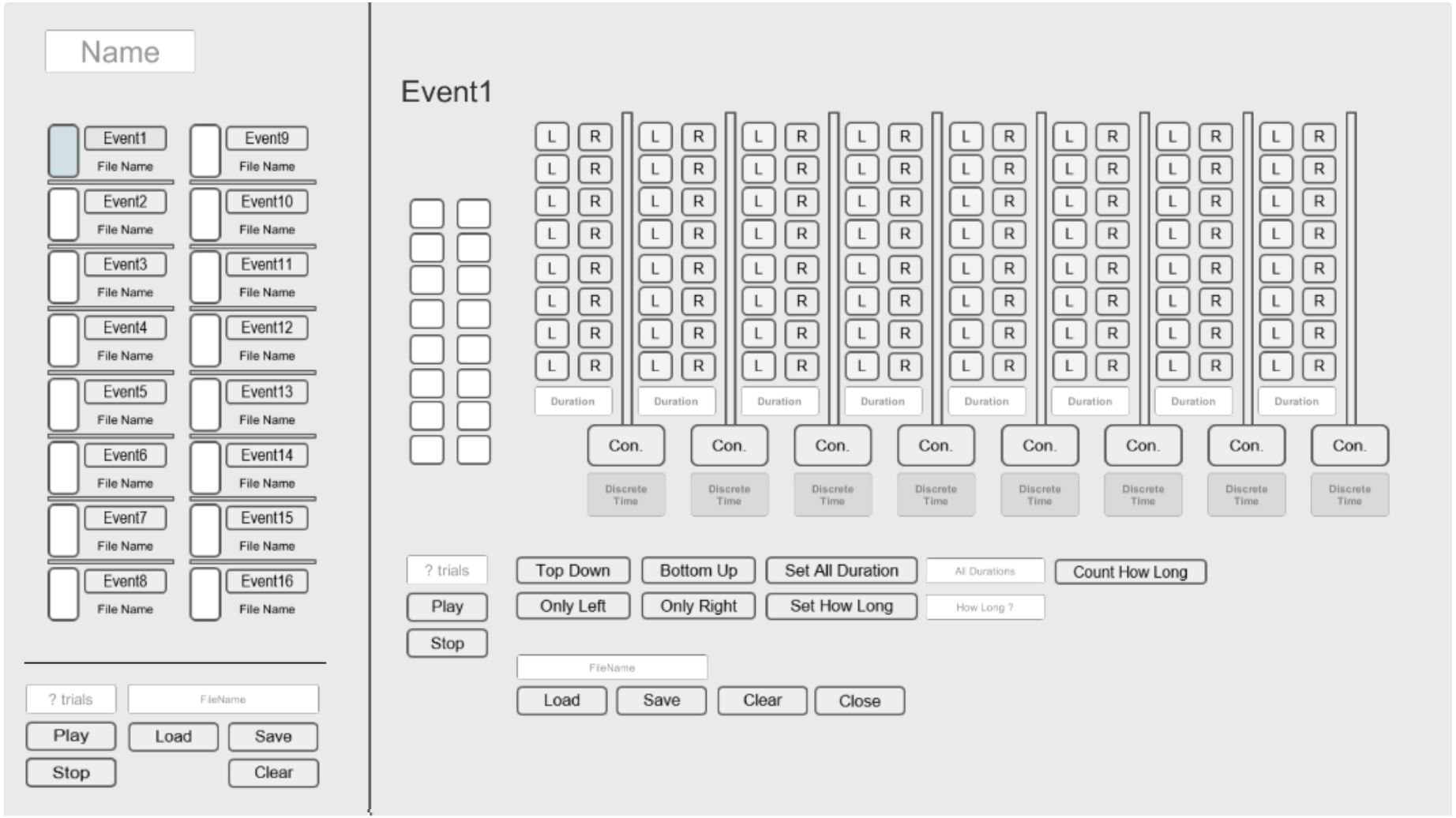
Results

- All no for the yes–no question.

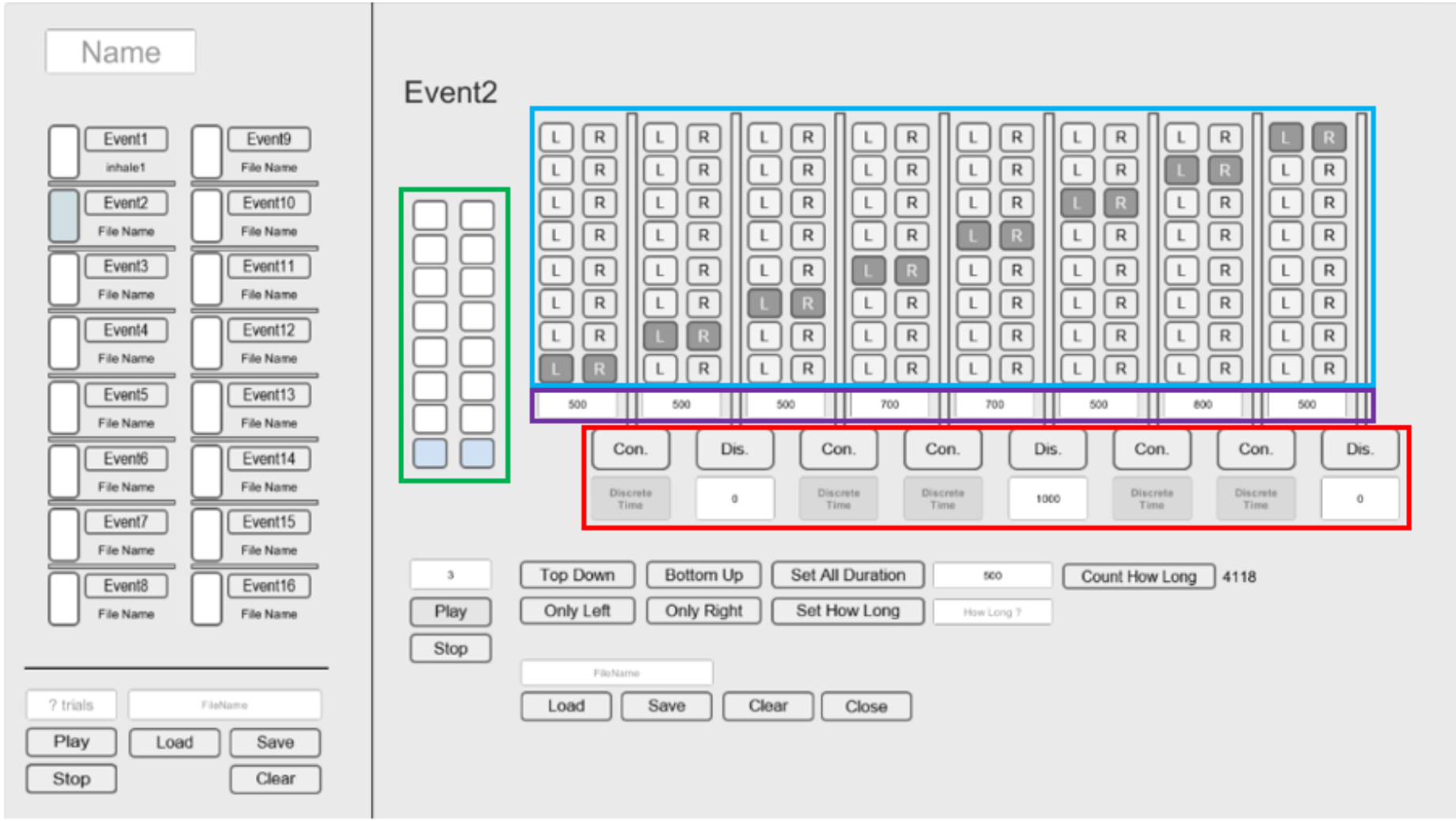
	Sitting Upright	Half Lying	Lying Down	ANOVA
Pressure level	2.17 (1.27)	2 (1.21)	2.25 (1.22)	F=0.16, p=0.85
Comfort level	4.06 (1.24)	4.25 (1.61)	4.5 (1.4)	F=1.88, p=0.16

TIP Design Interface

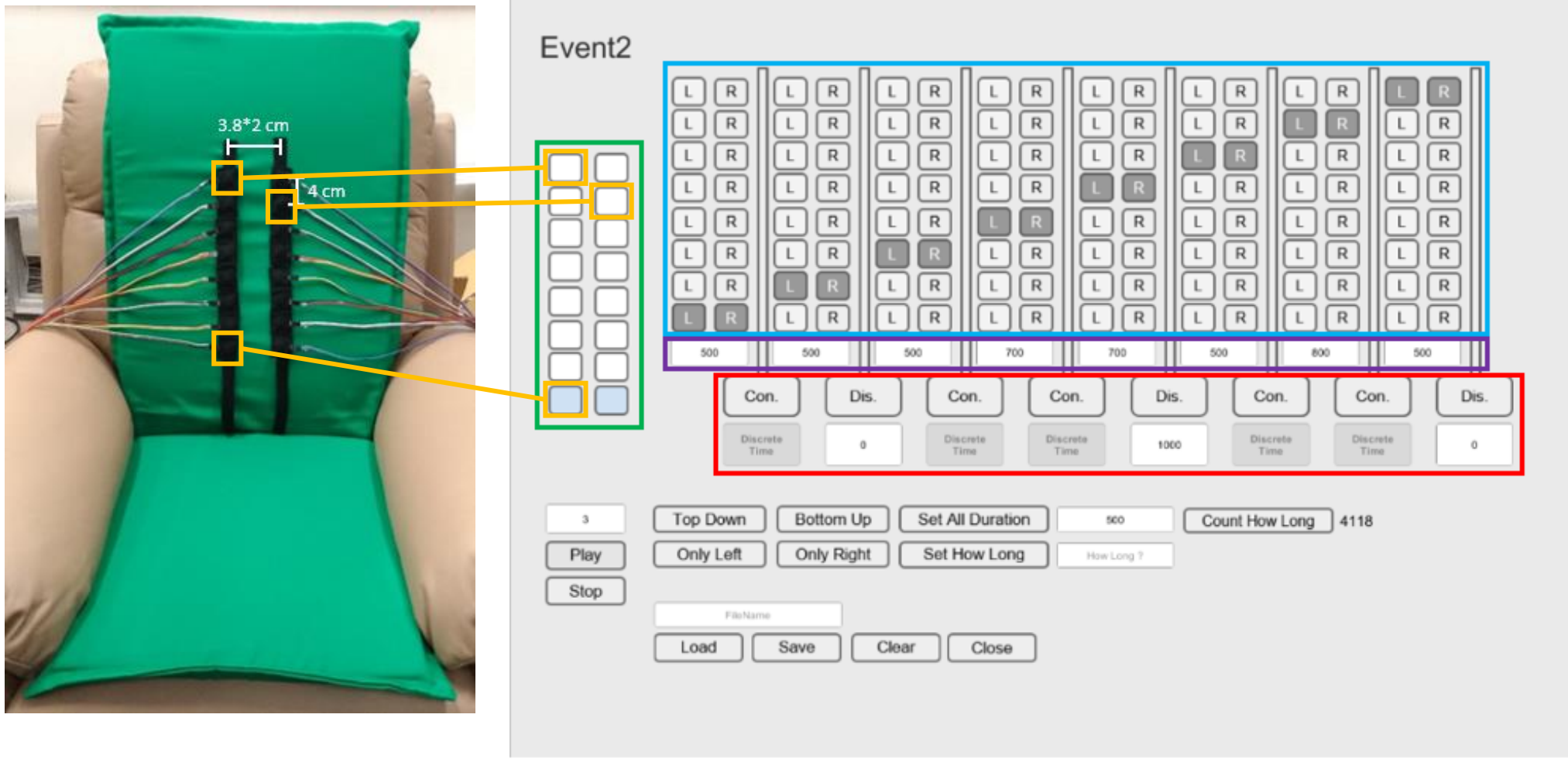
TIP Design Interface



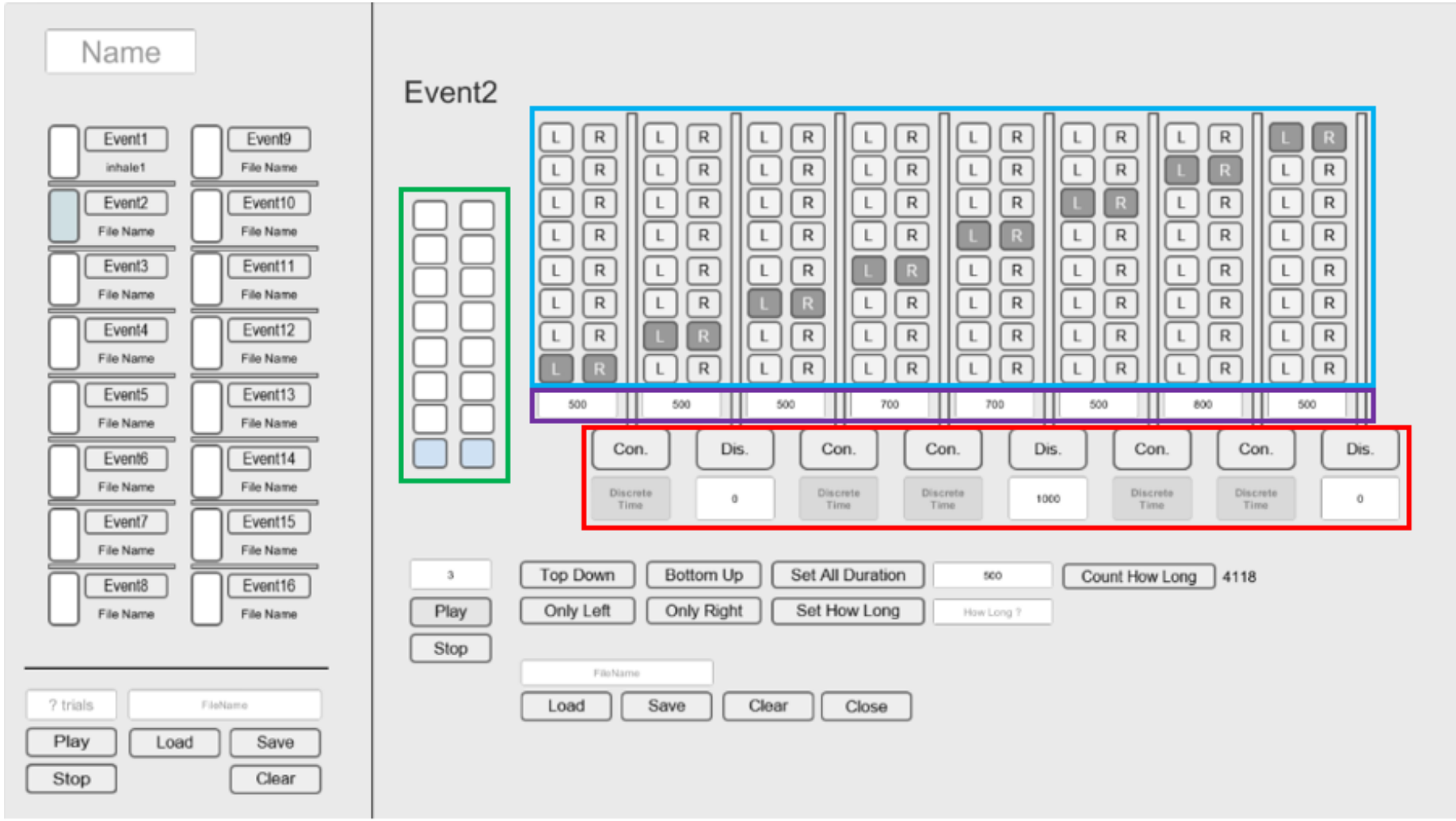
TIP Design Interface (cont.)



TIP Design Interface (cont.)



TIP Design Interface (cont.)



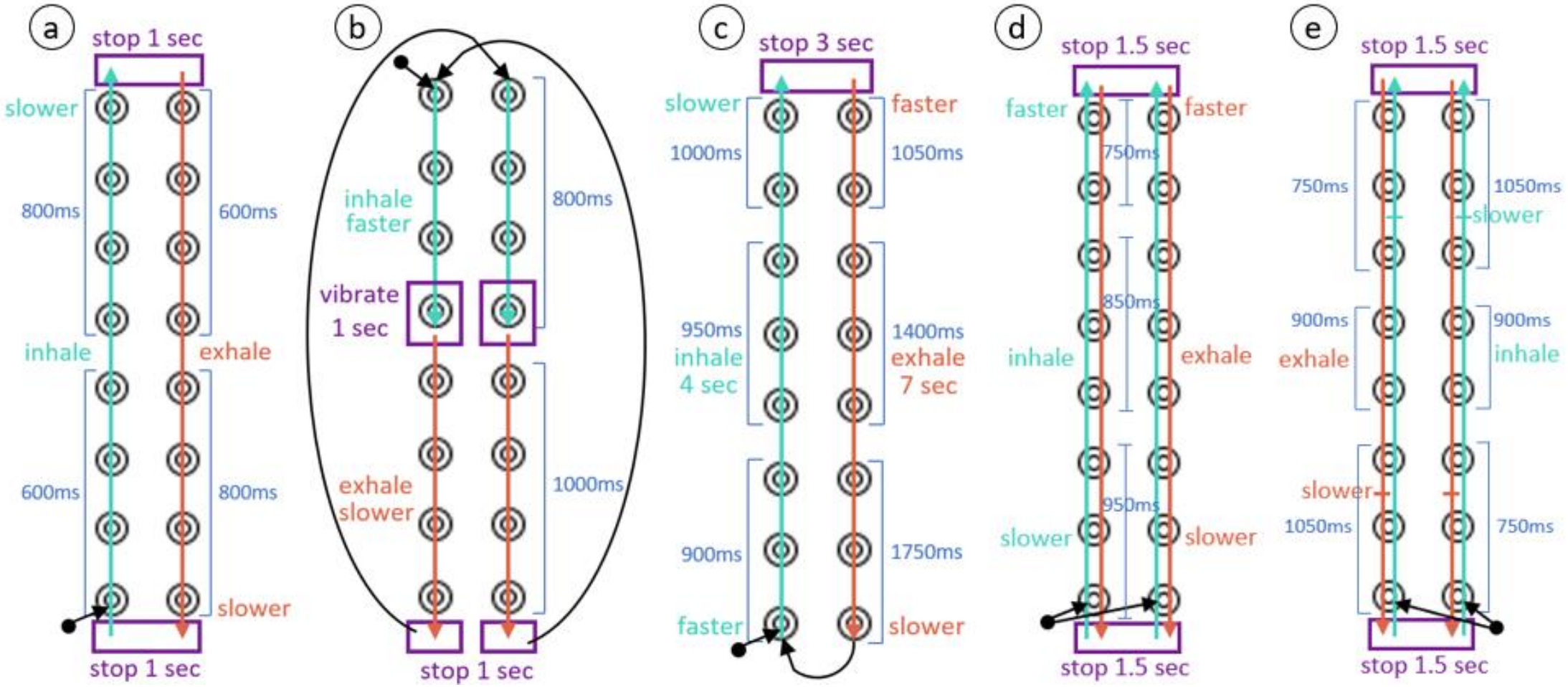
Outline

- Introduction
- Related Work & Design Consideration
- Implementation
- Exploration Study
  - Exploration Study 1: User Defined Pattern
  - Exploration Study 2: Expert Defined Pattern
  - Exploration Study 3: Find Intuitive Tactile Instruction Pattern
  - Exploration Study 4: Find the Preference of Multi-modal Instruction
- Evaluation
- Conclusion & Future Work

Exploration Study 1: User Defined Pattern

- Participants
  - 3 males and 2 females.
  - They only know that when doing diaphragmatic breathing, the belly expands when inhale, and the belly shrinks when exhale.
- Task
  - Design TIP for each step of diaphragmatic breathing.

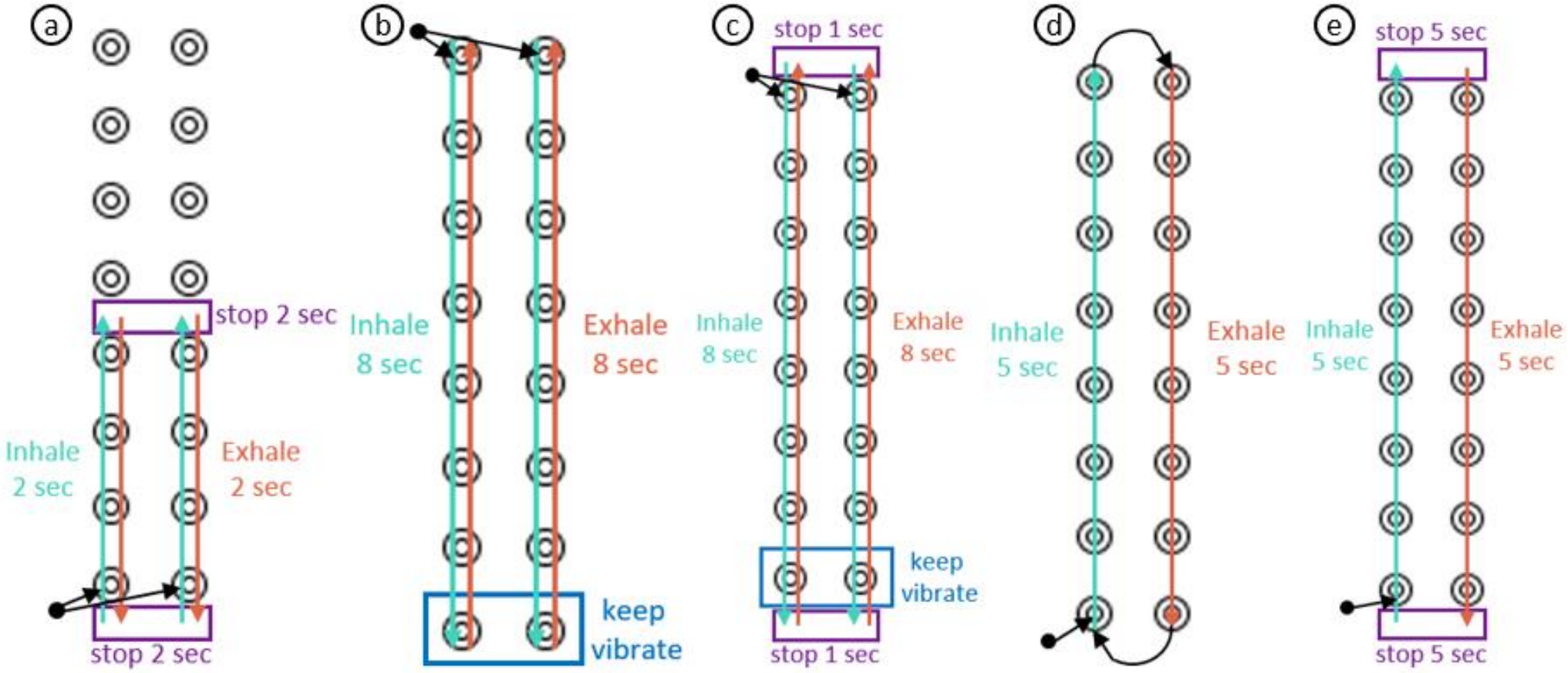
Results


a
stop 1 sec
slower
800ms
600ms
inhale
exhale
600ms
800ms
slower
stop 1 sec
b
inhale
faster
800ms
vibrate
1 sec
exhale
slower
1000ms
stop 1 sec
c
stop 3 sec
slower
faster
1000ms
1050ms
950ms
inhale
4 sec
1400ms
exhale
7 sec
900ms
1750ms
faster
slower
d
stop 1.5 sec
faster
faster
750ms
850ms
inhale
exhale
950ms
slower
slower
stop 1.5 sec
e
stop 1.5 sec
750ms
1050ms
slower
900ms
exhale
900ms
inhale
slower
1050ms
750ms
stop 1.5 sec

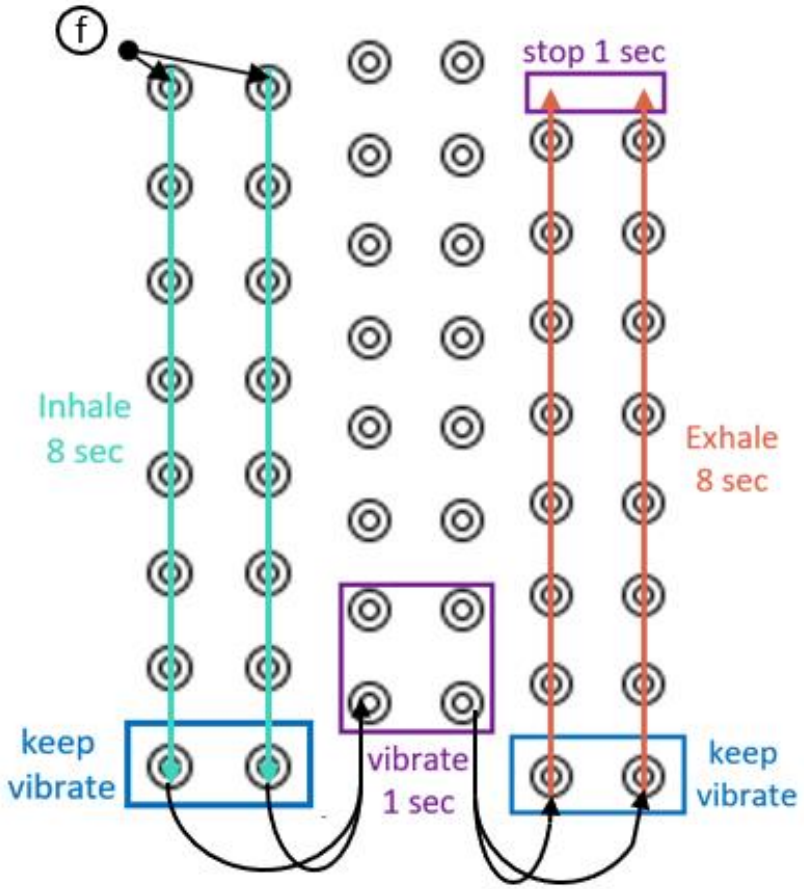
Exploration Study 2: Expert Defined Pattern

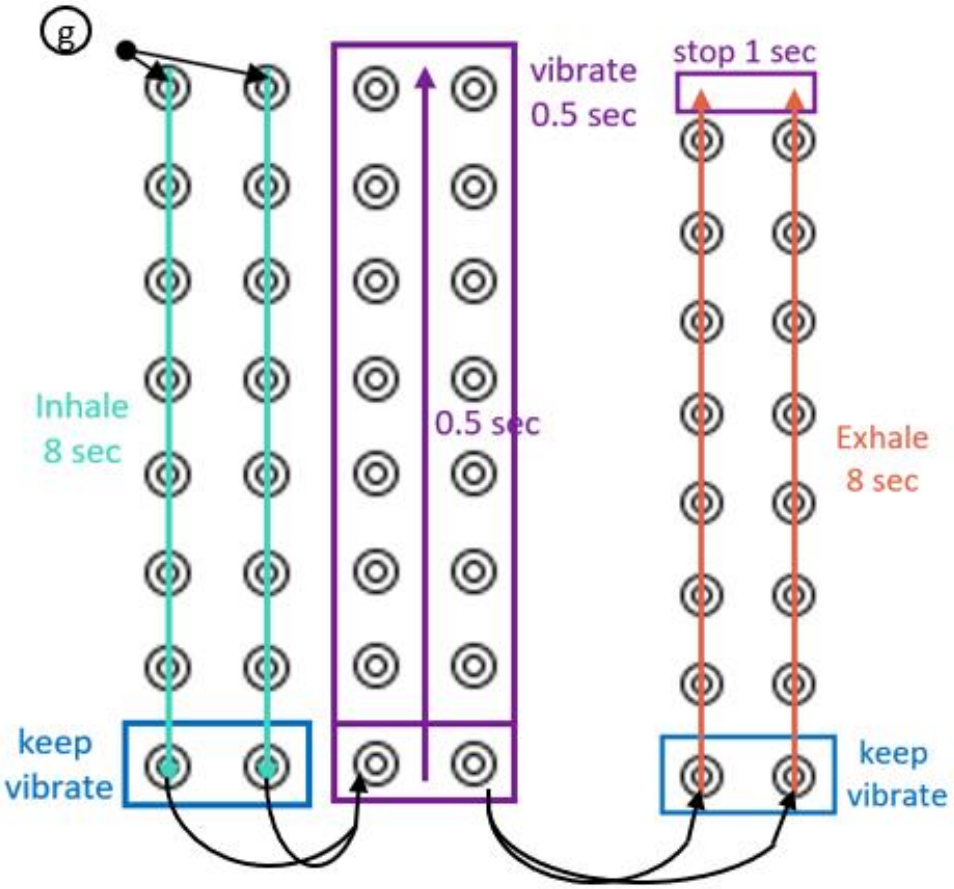
- Participants
  - 3 yoga teachers.
  - 1 male and 2 females.
- Task
  - Design TIP for each step of diaphragmatic breathing and Nadi Shodhana Pranayama.

Results of diaphragmatic breathing

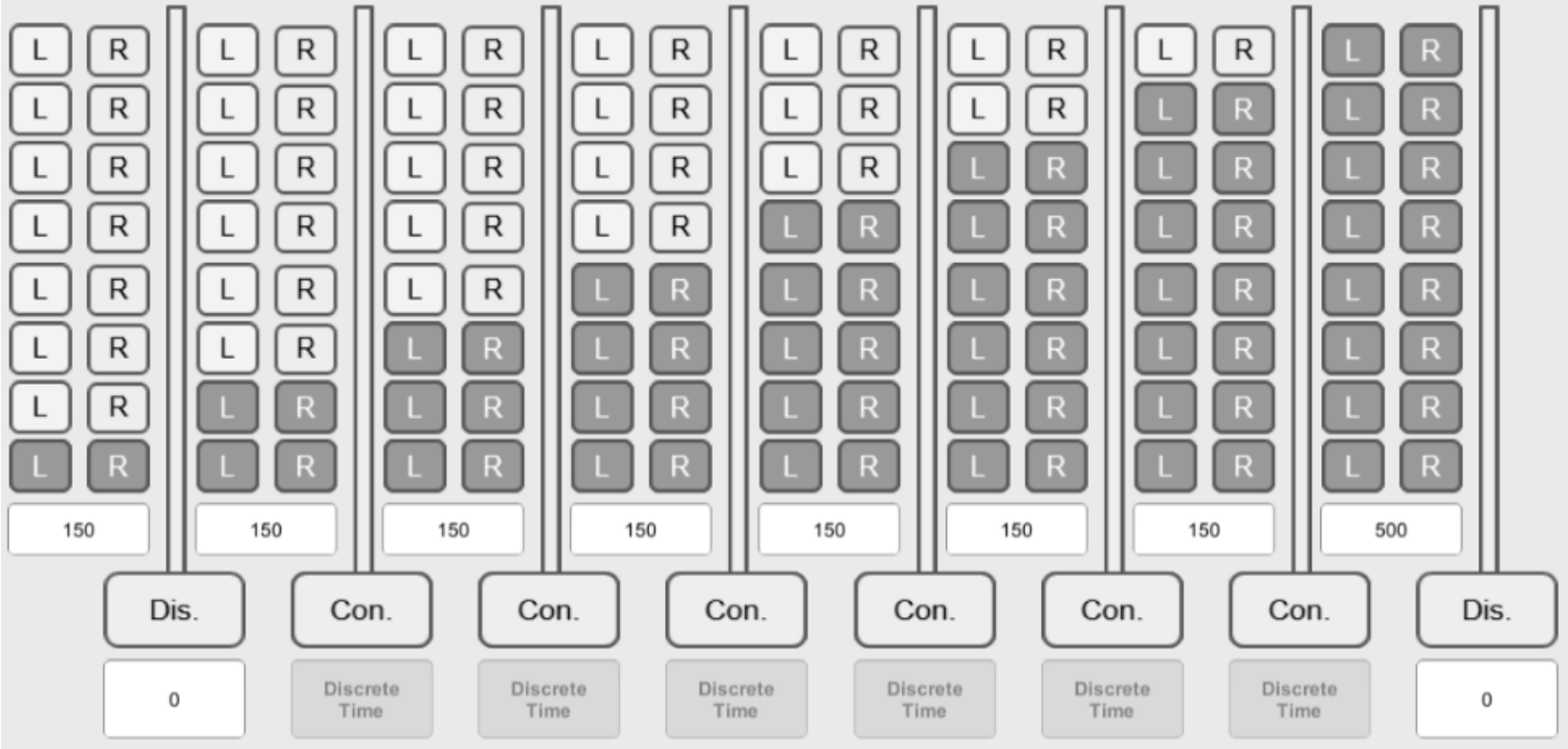


Results of diaphragmatic breathing (cont.)

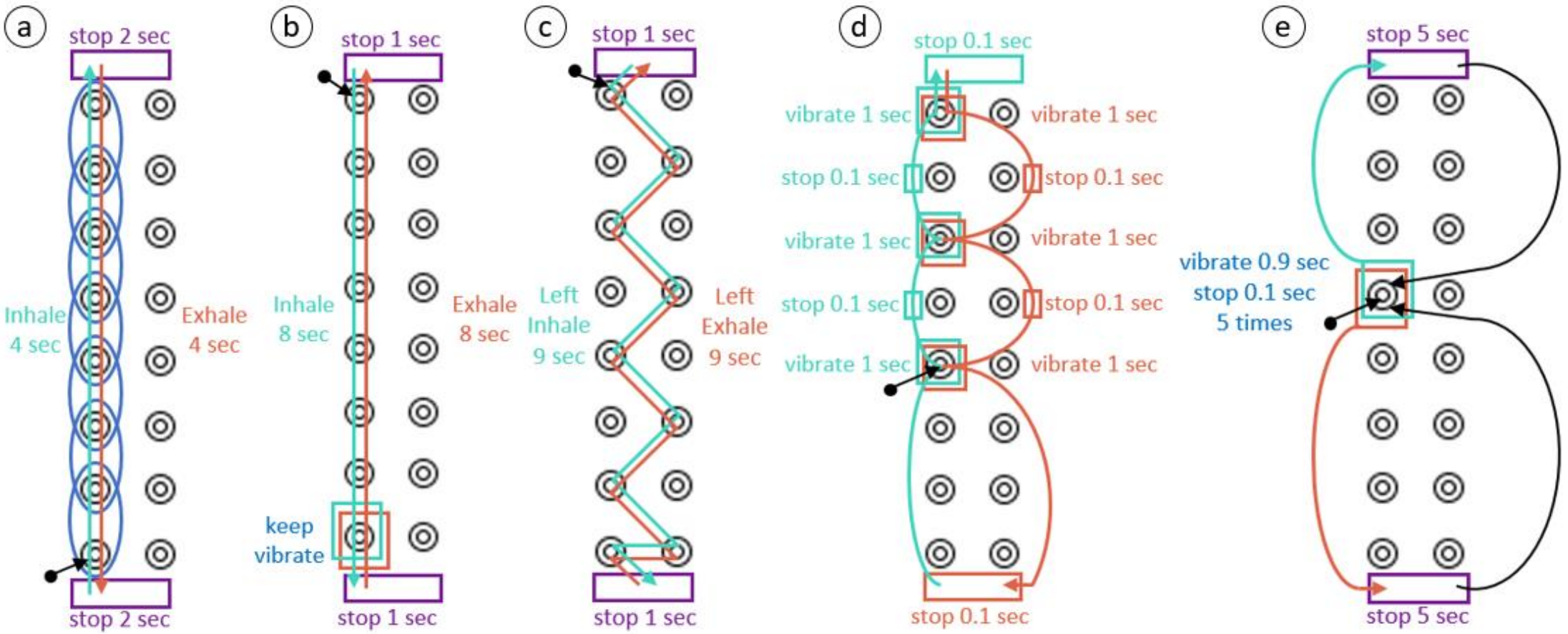




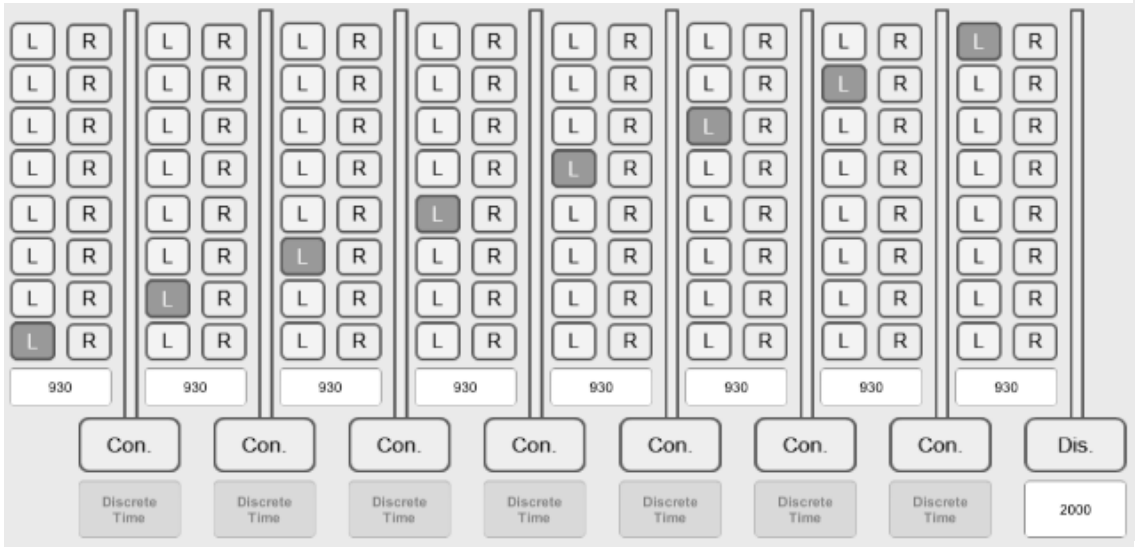
Results of diaphragmatic breathing (cont.)

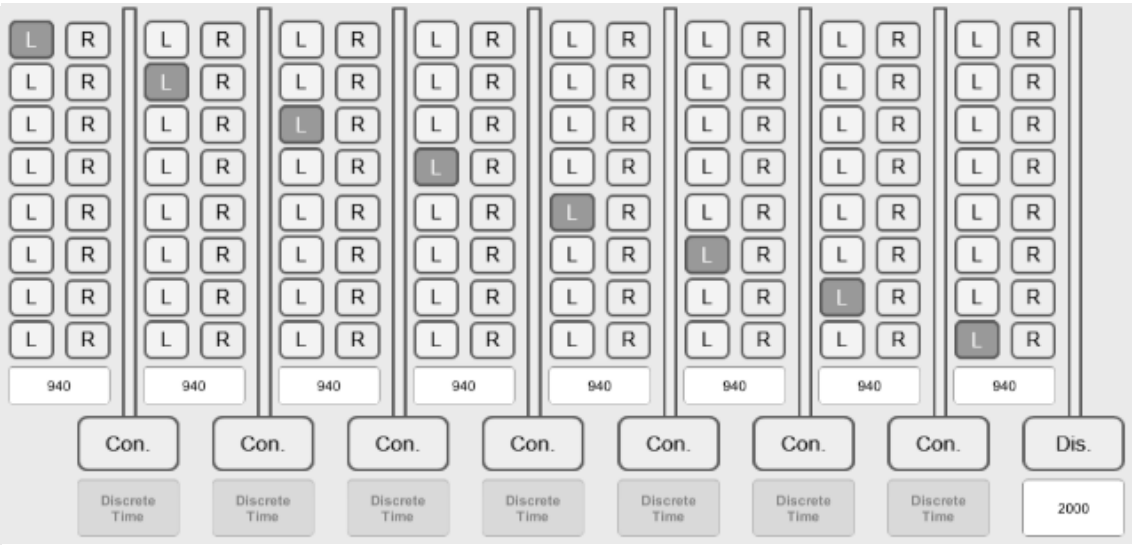


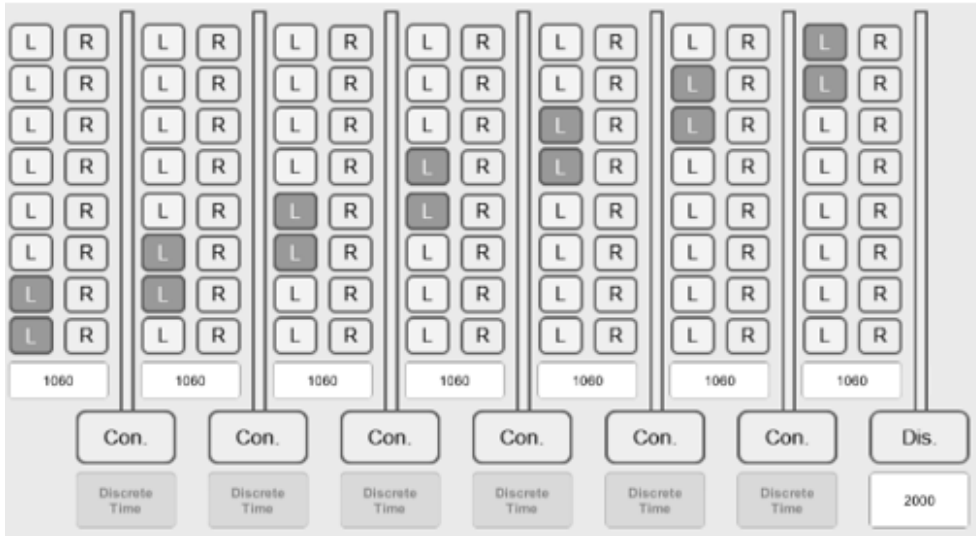
Results of Nadi Shodhana Pranayama

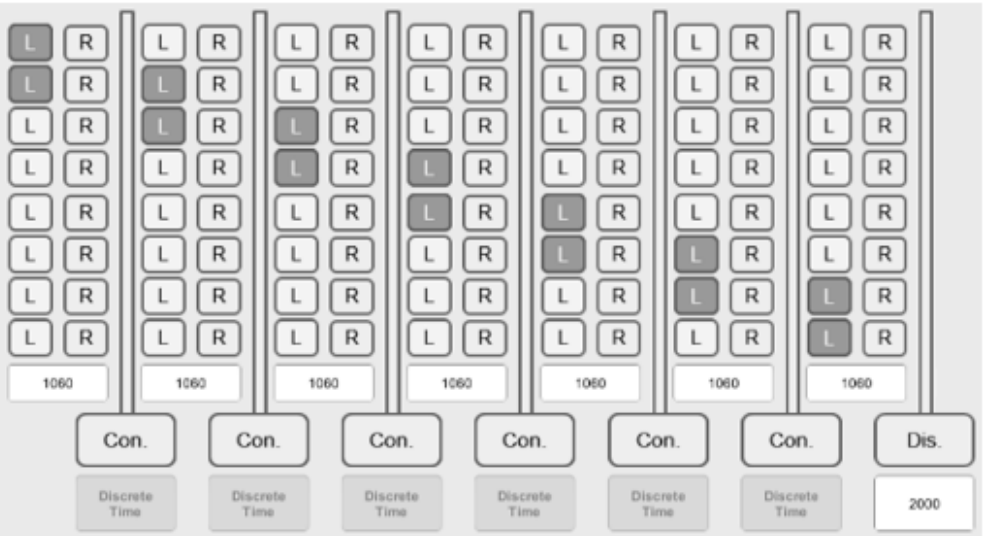


Results of Nadi Shodhana Pranayama (cont.)







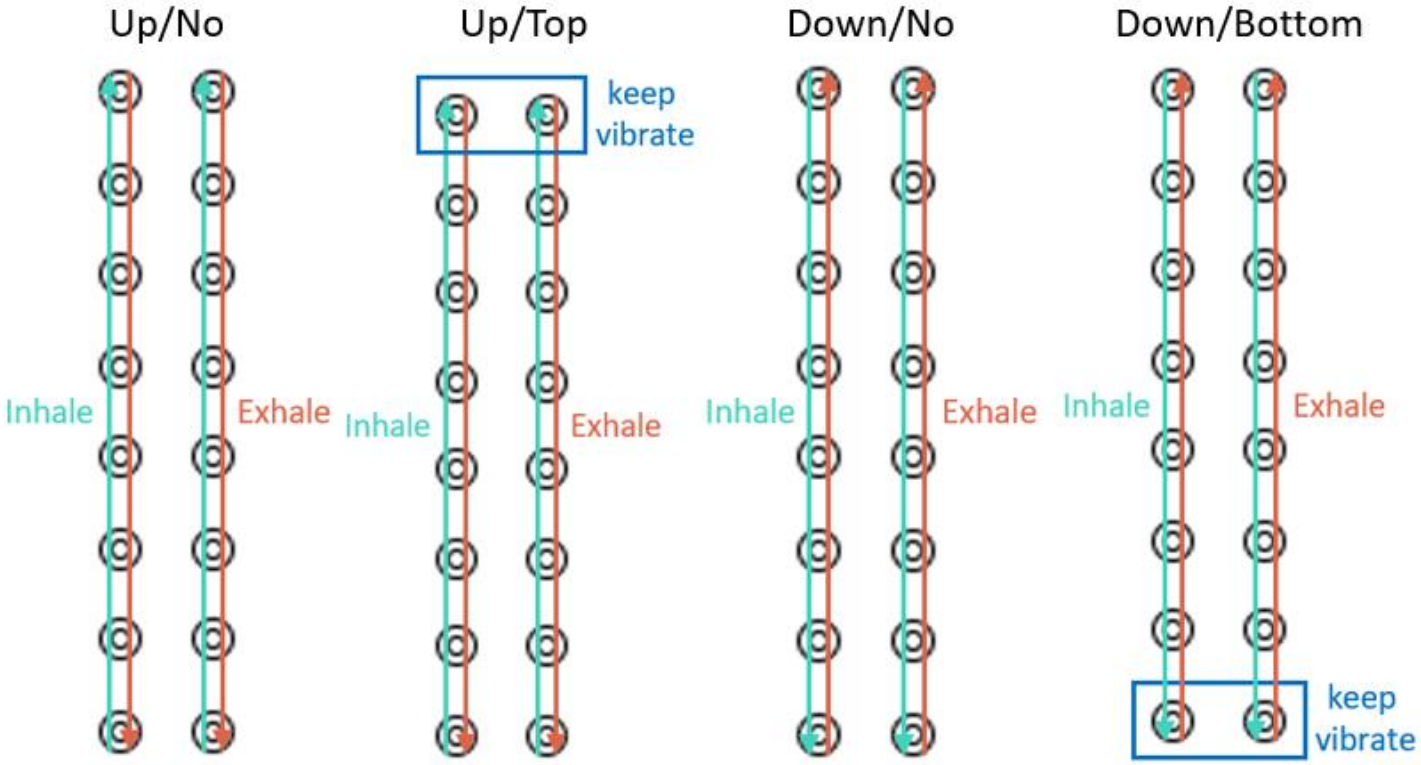


Exploration Study 3: Find Intuitive Tactile Instruction Pattern

- Diaphragmatic breathing
  - The abdominal expands when inhale
  - The abdominal shrinks when exhale

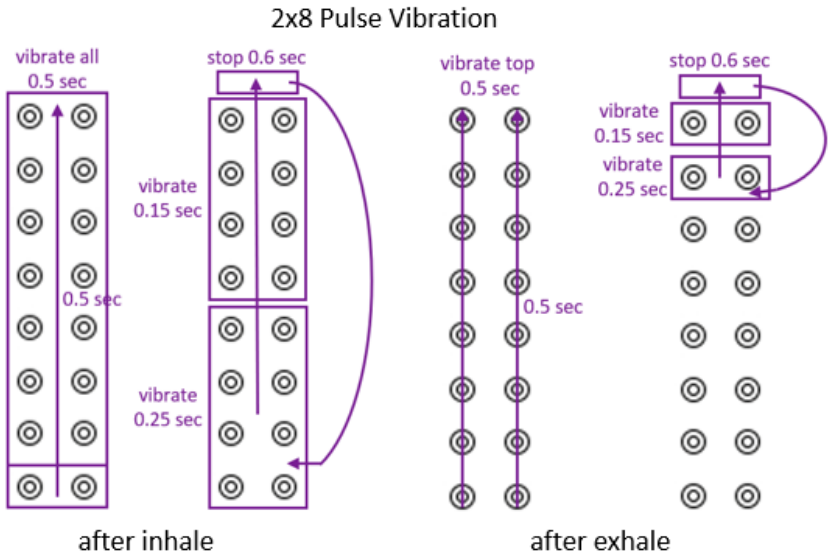
Exploration Study 3: Find Intuitive Tactile Instruction Pattern (cont.)

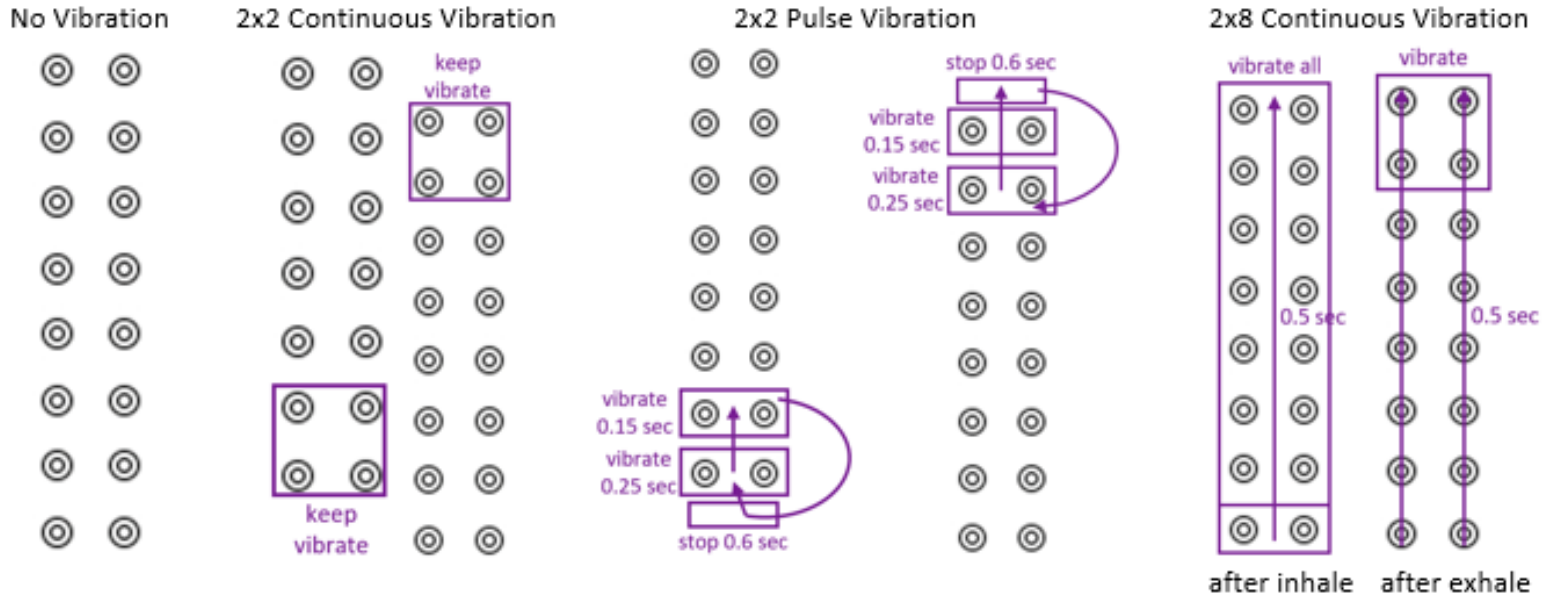
- Inhale Direction / Keep Vibrate Row (4040)
  - Up/No
  - Up/Top
  - Down/No
  - Down/Bottom
- Basic Vibration Range (4040)
  - One Row
  - Two Rows



Exploration Study 3: Find Intuitive Tactile Instruction Pattern (cont.)

- Breath-Holding (4444,4848)
  - No Vibration
  - 2x2 Continuous Vibration
  - 2x2 Pulse Vibration
  - 2x8 Continuous Vibration
  - 2x8 Pulse Vibration





Exploration Study 3: Find Intuitive Tactile Instruction Pattern (cont.)

- Participants
  - 12 participants (9 males and 3 females)
  - 21 to 26 years old (mean = 23.08 years old, std = 1.38)
  - Only one participant have never used massage chairs before.
    - 7 of them like to use massage chairs
    - 5 of them have no special feeling for massage chairs
  - Nobody practices breathing on their daily basis.
- Task
  - Score preference on a 7-point scale (1: Dislike it very much, 7: Like it very much)
  - Sort the options by preference

Results

- Inhale Direction / Keep Vibrate Row

	Up / No	Up / Top	Down / No	Down / Bottom	ANOVA
Order	2.17 (1.27)	2.42 (0.9)	2.83 (1.03)	2.58 (1.31)	F=0.55, P=0.65
Preference	3.67 (1.23)	3.67 (0.89)	4.17 (1.03)	3.92 (1)	F=0.64, P=0.6
How many people like the most	3	1	4	4	N/A
Order	2.29 (1.08)		2.71 (1.16)		F=1.2, P=0.28
Preference	3.67 (1.05)		4.04 (1)		F=1.26, P=0.27

- Basic Vibration Range

	One Row	Two Rows	ANOVA
Order	1.33 (0.49)	1.67 (0.49)	F=1.38, P=0.27
Preference	5.17 (0.83)	5.25 (0.97)	F=0.08, P=0.78
How many people like the most	4	8	N/A

Results

- 4 Second Breath-Holding

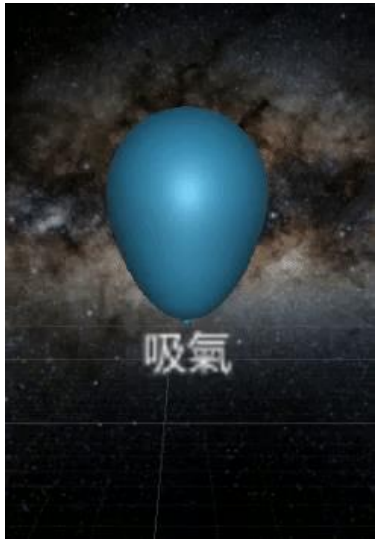
	No Vibration	2x2 Continuous Vibration	2x2 Pulse Vibration	2X8 Continuous Vibration	2x8 Pulse Vibration	ANOVA
Order	3 (1.13)	3.67 (1.44)	3.17 (1.4)	2.5 (1.57)	2.67 (1.5)	F=1, P=0.42
Preference	4.33 (0.89)	4.92 (1.51)	4.33 (1.3)	3.83 (1.53)	4.08 (1.78)	F=1.24, P=0.31
How many people like the most	1	5	3	2	1	N/A

- 8 Second Breath-Holding

	No Vibration	2x2 Continuous Vibration	2x2 Pulse Vibration	2X8 Continuous Vibration	2x8 Pulse Vibration	ANOVA
Order	2.42 (1.24)	3.58 (1.51)	3.42 (1.16)	2.83 (1.64)	2.75 (1.42)	F=1.15, P=0.35
Preference	4.17 (0.94)	5.08 (1.73)	4.33 (1.56)	4.08 (1.44)	4.08 (1.78)	F=1.29, P=0.29
How many people like the most	0	5	3	3	1	N/A

Exploration Study 4: Find the Preference of Multi-modal Instruction

- Visual Instruction



- Audio Instruction
  - 吸氣、屏息、吐氣、屏息
- Tactile Instruction
  - Their favorite TIP chose in exploration study 3

Exploration Study 4: Find the Preference of Multi-modal Instruction (cont.)

- Interfaces (4 breaths each)
  - Audio
  - Visual
  - Tactile
  - Audio + Visual
  - Audio + Tactile
  - Visual + Tactile
  - Audio + Visual + Tactile (Always first)

Exploration Study 4: Find the Preference of Multi-modal Instruction (cont.)

- Participants
  - 12 participants (9 males and 3 females)
  - 21 to 26 years old (mean = 23.08 years old, std = 1.38)
  - Only one participant have never used massage chairs before.
    - 7 of them like to use massage chairs
    - 5 of them have no special feeling for massage chairs
  - Nobody practices breathing on their daily basis
  - All of them have used VR before

Exploration Study 4: Find the Preference of Multi-modal Instruction (cont.)

- Task
  - Do diaphragmatic breathing (4444)
  - Score preference on a 7-point scale (1: Dislike it very much, 7: Like it very much)
  - Questions
    - Have you keep up with the breathing guidance?
    - Have you forgotten what to do at any of the instructions?
  - Sort the interfaces by preference

Results

- One instruction

	(1) Audio	(2) Visual	(3) Tactile	ANOVA
Order	2 (0.74)	1.67 (0.78)	2.33 (0.89)	N/A
How many people like the most	3	2	7	F=1.38, P=0.27

- Two instructions

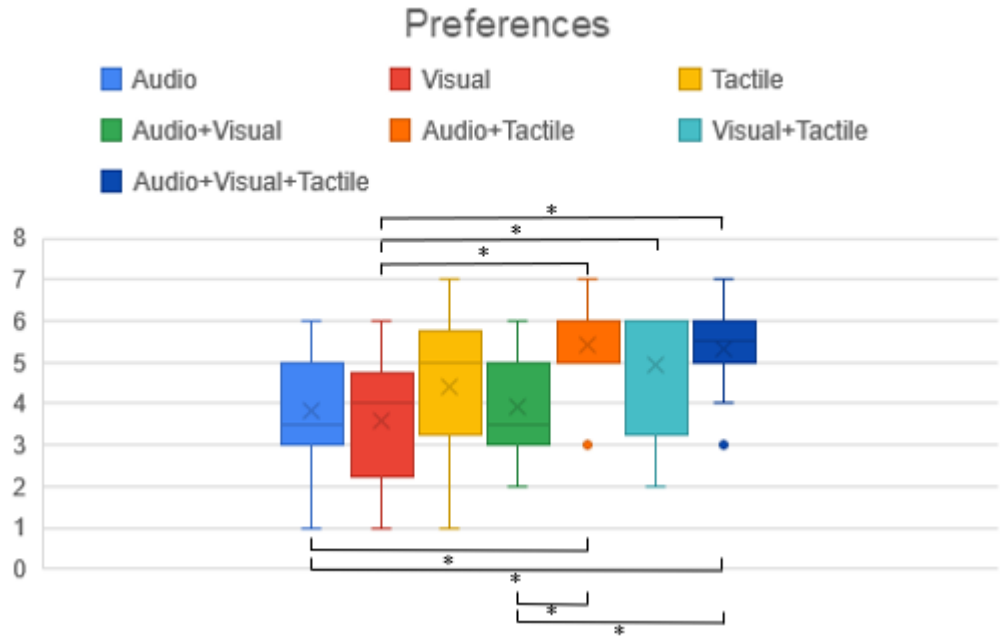
	(1) Audio+Visual	(2) Audio+Tactile	(3) Visual+Tactile	ANOVA	Tukey Post-hoc
Order	1.33 (0.65)	2.42 (0.67)	2.25 (0.75)	N/A	-
How many people like the most	1	6	5	F=5.67, P<0.05	1-2, 1-3

- Different amount of instructions

	(1) One	(2) Two	(3) Three	ANOVA	Tukey Post-hoc
Order	1.5 (0.8)	2.58 (0.67)	1.92 (0.67)	N/A	-
How many people like the most	2	8	2	F=4.68, P<0.05	1-2

Results (cont.)

	(1) Audio	(2) Visual	(3) Tactile	(4) Audio+Visual	(5) Audio+Tactile	(6) Visual+Tactile	(7) Audio+Visual+Tactile	ANOVA	Tukey Post-hoc
Preferences	3.83 (1.47)	3.58 (1.44)	4.42 (1.73)	3.92 (1.24)	5.42 (1.08)	4.92 (1.51)	5.33 (1.07)	F=8.13, P<0.001	1-5,1-7, 2-5, 2-6, 2-7, 4-5, 4-7
Order	3.33 (1.78)	2.17 (1.47)	3.67 (2.1)	5.42 (1.83)	2.83 (1.4)	4.75 (1.6)	5.83 (0.83)	F=7.34, P<0.001	1-7, 2-5, 2-6, 2-7, 4-5, 4-7
How many people like the most	1	0	1	0	6	2	2	N/A	-
Relation	31% (0.32)	8% (0.23)	9% (0.43)	26% (0.37)	30% (0.32)	21% (0.3)	-0.3% (0.19)	F=2.08, P=0.07	-
Attention	1% (0.39)	-1% (0.39)	-13% (0.34)	-36% (0.23)	-16% (0.42)	-12% (0.37)	-16% (0.24)	F=1.85, P=0.1	-



Outline

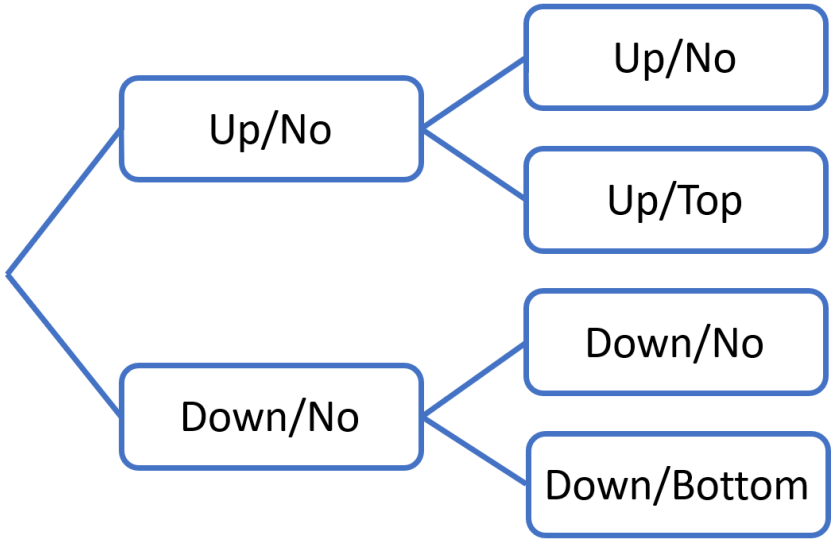
- Introduction
- Related Work & Design Consideration
- Implementation
- Exploration Study
- Evaluation
  - User Study 1: Determine Personalize TIP for Inhale and Exhale
  - User Study 2: Determine Personalize TIP for Breath-Holding
  - User Study 3: Evaluate Effectiveness of Personalize TIP for Guiding 4-7-8 Breathing
  - User Study 4: Evaluate Effectiveness of Personalize TIP for Guiding Nadi Shodhana Pranayama
- Conclusion & Future Work

Evaluation

- Participants
  - 16 participants (11 males and 5 females)
  - 21 to 31 years old (mean = 23.88 years old, std = 2.53)
  - Only 4 participants have never used massage chairs before.
    - 7 of them like to use massage chairs
    - 9 of them have no special feeling for massage chairs
  - Nobody practices breathing on their daily basis
  - All of them have used VR before

User Study 1: Determine Personalize TIP for Inhale and Exhale

- Inhale Direction / Keep Vibrate Row (4040)
  - Up/No
  - Up/Top
  - Down/No
  - Down/Bottom



- Basic Vibration Range : Two Rows

User Study 1: Determine Personalize TIP for Inhale and Exhale

- Task
  - 7-point scale (1: Negative, 7: Positive)
    - Effectiveness (Can it successfully guide breathing)
    - Efficiency (How much effort and resource need to learn and remember)
    - Satisfaction
  - Choose the favorite one

Results

	Up / No	Down / No	Up / No	Up / Top	Down / No	Down / Bottom
Effectiveness	4.06 (1.48)	4.13 (1.82)	4.5 (1.77)	3.5 (1.77)	5 (1.51)	4.63 (1.19)
Efficiency	4.75 (1.65)	4.75 (1.61)	4.88 (1.96)	4.25 (1.67)	5.38 (1.3)	5 (0.93)
Satisfaction	3.94 (1.29)	3.88 (1.75)	4.38 (1.19)	3.38 (1.3)	4.75 (1.58)	4.5 (1.51)
How many people like the most	8	8	7	1	5	3

User Study 2: Determine Personalize TIP for Breath-Holding

- Breath-Holding (4848)
  - No Vibration
  - 2x2 Pulse Vibration

User Study 2: Determine Personalize TIP for Breath-Holding

- Task
  - 7-point scale (1: Negative, 7: Positive)
    - Effectiveness (Can it successfully guide breathing)
    - Efficiency (How much effort and resource need to learn and remember)
    - Satisfaction
  - Choose the favorite one

Results

	No Vibration	2x2 Pulse Vibration
Effectiveness	4.13 (1.54)	4.69 (1.35)
Efficiency	4.81 (1.28)	5 (1.55)
Satisfaction	4 (1.55)	4.44 (1.41)
How many people like the most	5	11

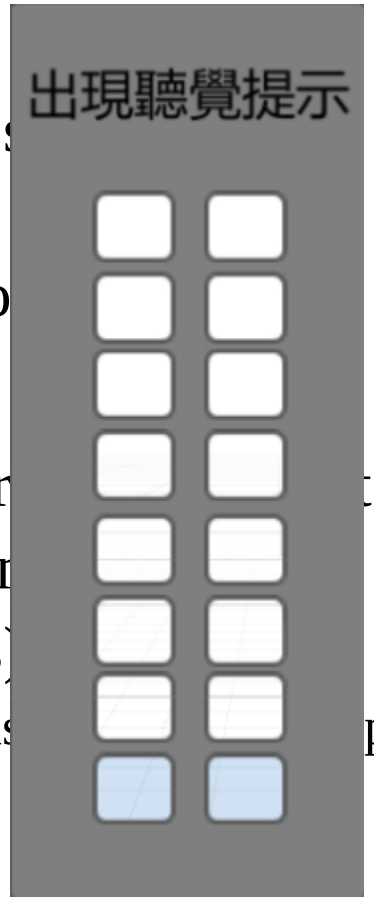
User Study 3: Evaluate Effectiveness of Personalize TIP for Guiding 4-7-8 Breathing

- 4-7-8 Breathing
  - Inhale through the nose for 4 seconds
  - Hold the breath for 7 seconds
  - Exhale from mouth for 8 seconds
- System
  - Visual + Audio + Tactile (3 breaths, 1 minute)
  - Audio + Tactile (3 breaths, 1 minute)
  - Tactile (24 breaths, 8 minutes)
    - When forget what the tactile instruction means, press space to call back the audio instruction

Weil, Andrew. *Breathing: The master key to self healing*. Sounds True, 1999.

User Study 3: Evaluate Effectiveness of Personalize TIP for Guiding 4-7-8 Breathing

- 4-7-8 Breathing
  - Inhale through the nose for 4 s
  - Hold the breath for 7 seconds
  - Exhale from mouth for 8 seco
- System
  - Visual + Audio + Tactile (3 br te)
  - Audio + Tactile (3 breaths, 1 r
  - Tactile (24 breaths, 8 minutes)
    - When forget what the tactile ins press space to call back the audio instruction



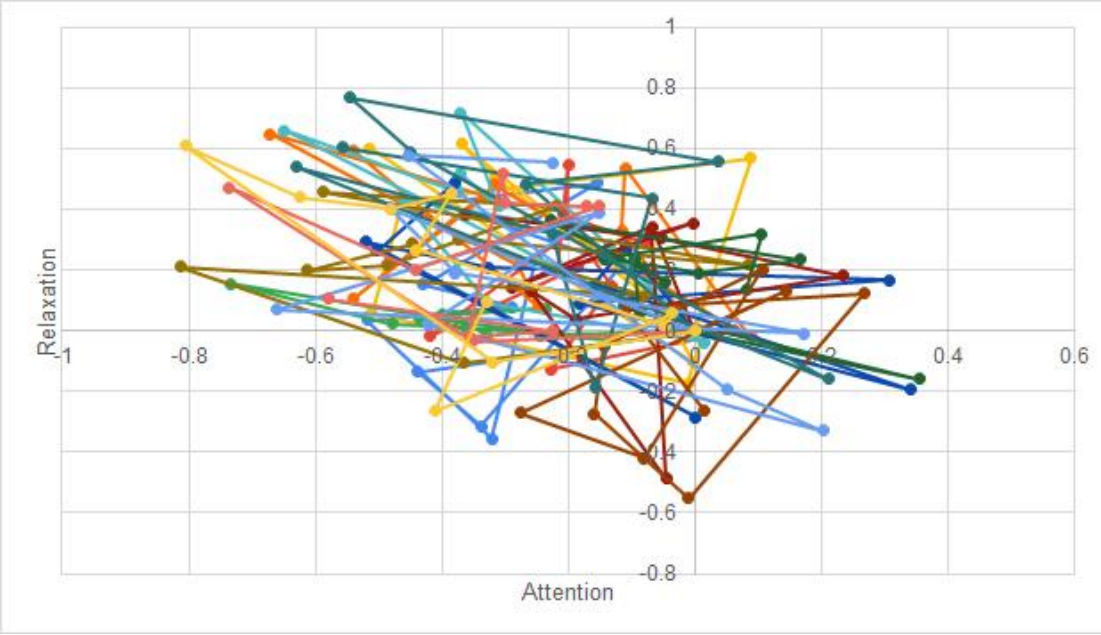
User Study 3: Evaluate Effectiveness of Personalize TIP for Guiding 4-7-8 Breathing

- Questions
  - Have you keep up with the breathing guidance?
  - Have you forgotten what to do at any of the instructions?
  - Do those instructions disturb you?

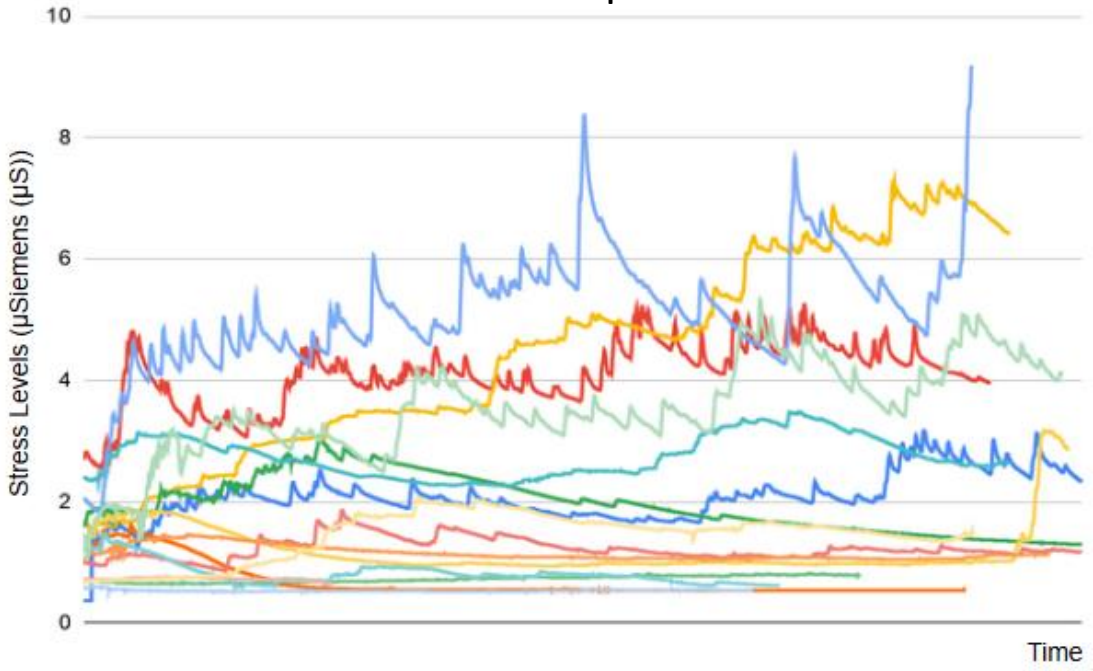
Results

- 2 participants called back the audio instruction.
  - 1 and 2 times

Brainwave



Skin Response



Results (cont.)

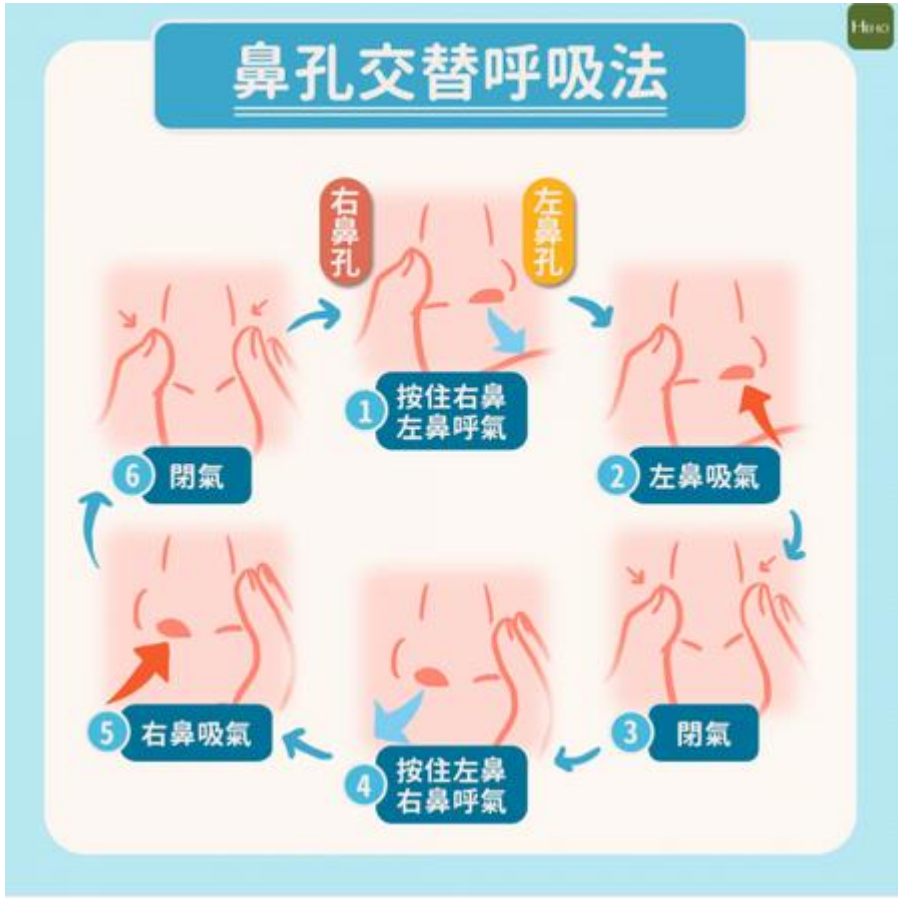
- Have you keep up with the breathing guidance?
  - Cannot keep up with the guidance because the length for breath-holding and exhale is too long.
  - Want to sleep so didn’t keep up all.
- Have you forgotten what to do at any of the instructions?
  - Can call back audio instruction, so no.
- Do those instructions disturb you?
  - The audio instruction disturb a little and is a little bit too long.
  - The visual instruction is useless.

Results (cont.)

- It is good to only left the tactile instruction and can call back audio instruction when needed, because the audio instruction interfere with relaxation, but still need the audio instruction when forget what the tactile instruction is about.

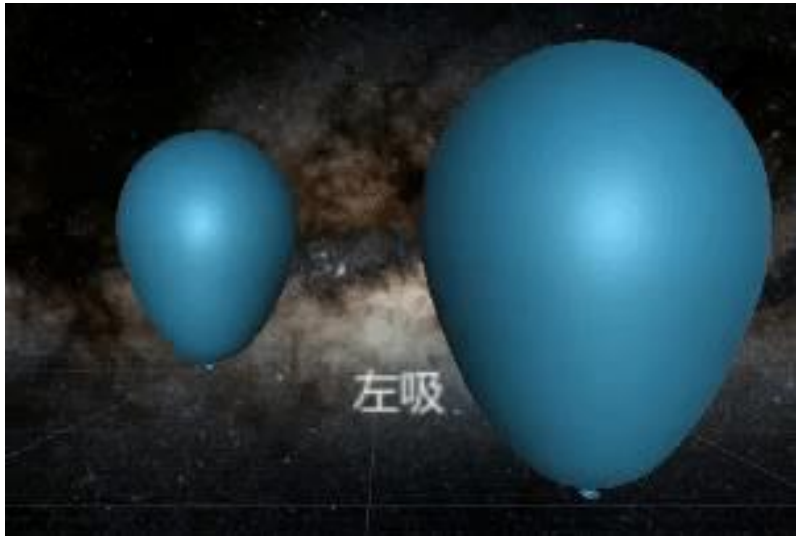
User Study 4: Evaluate Effectiveness of Personalize TIP for Guiding Nadi Shodhana Pranayama

- Nadi Shodhana Pranayama
  - Time ratio: 4:16:8:0
  - We use 2840
    - Use a finger to block the nose that is not for breathing
    - Inhale with left nose for 2 seconds
    - Hold the breath for 8 seconds
    - Exhale with right nose for 4 seconds
    - Inhale with right nose for 2 seconds
    - Hold the breath for 8 seconds
    - Exhale with left nose for 4 seconds



User Study 4: Evaluate Effectiveness of Personalize TIP for Guiding Nadi Shodhana Pranayama (cont.)

- Visual Instruction



- Audio Instruction
  - 左吸、屏息、右吐、右吸、屏息、左吐
- Tactile Instruction
  - Their favorite TIP chose in user study 1 and 2.
  - It is divided into left side and right side.

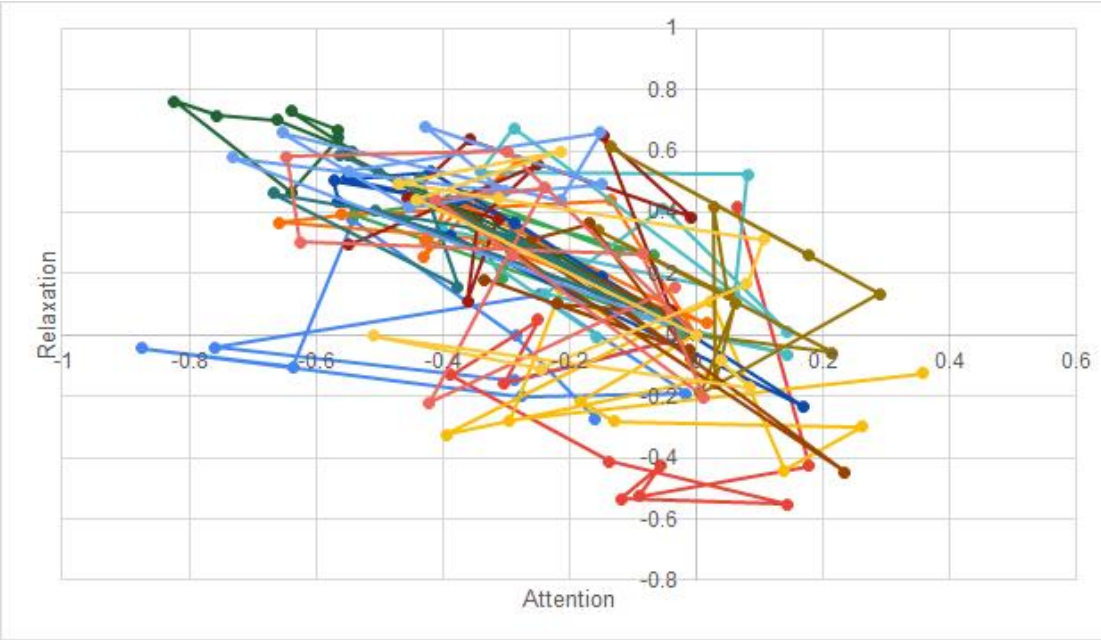
User Study 4: Evaluate Effectiveness of Personalize TIP for Guiding Nadi Shodhana Pranayama (cont.)

- Questions
  - Have you keep up with the breathing guidance?
  - Have you forgotten what to do at any of the instructions?
  - Do those instructions disturb you?
- System Usability Scale (SUS)
  - Experience in user study 3 should also be considered.

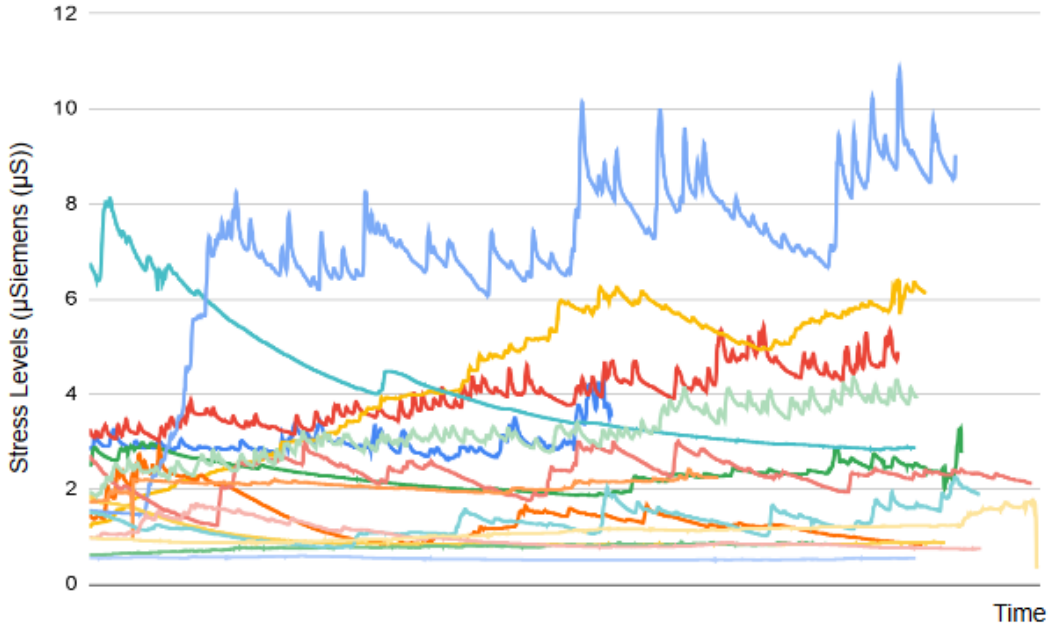
Results

- 4 participants called back the audio instruction.
  - 1, 1, 2 and 3 times

Brainwave



Skin Response



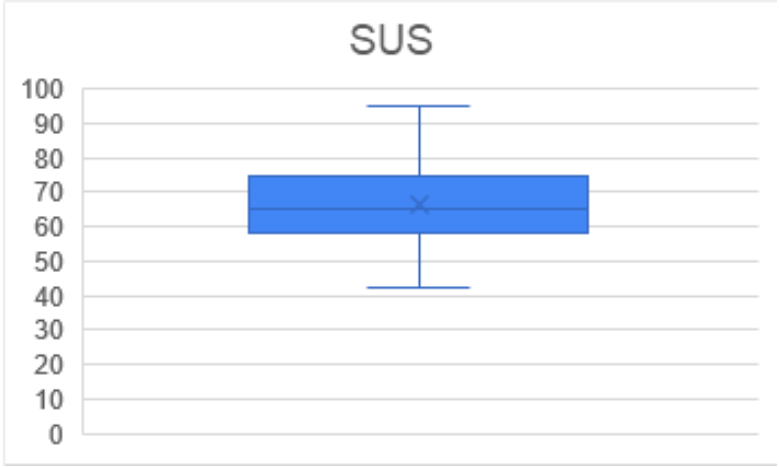
Results (cont.)

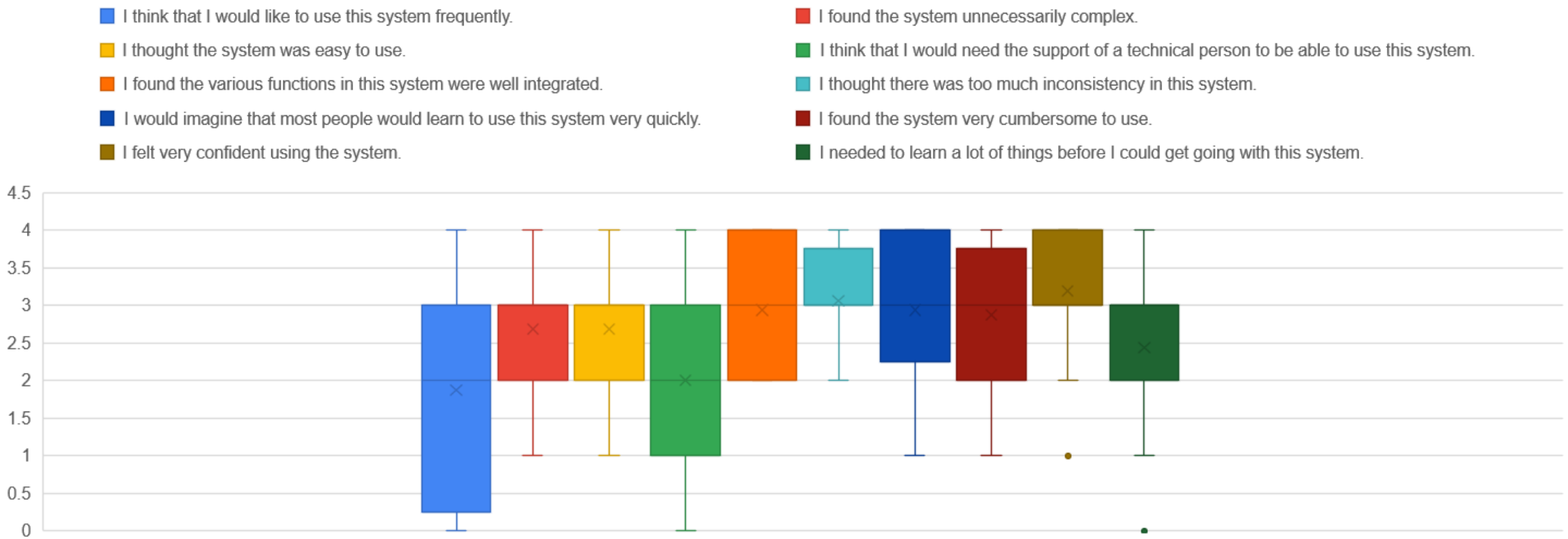
- Have you keep up with the breathing guidance?
  - Cannot keep up with the guidance because the length for breath-holding and only have 2 seconds to inhale, the air is not enough for following steps.
  - Cannot do it properly due to stuffy nose.
- Have you forgotten what to do at any of the instructions?
  - To press the space while doing this breathing is not that easy, only concentrate on breathing is hard enough.
- Do those instructions disturb you?
  - Due to the relatively short inhalation time, the interval between each step of TIP feels small, which is a little bit unclear.

Results (cont.)

- Vibrate on the side of the nostril used for breathing is very intuitive.

Results (cont.)





Outline

- Introduction
- Related Work & Design Consideration
- Implementation
- Exploration Study
- Evaluation
- Conclusions & Future Works

Conclusions

- We design a tactile chair cushion
- We design an interface for designing tactile instruction pattern (TIP).
- We explore on TIPs that can guide users breathing.
- We find the preference of multi-modal instruction.
- We propose a system that can guide users breathing with the least interference.

Future Works

- Change the vibration motor modules to speaker modules.
- Find a more suitable TIP for relatively short breathing step.
- Conduct a study that the participants do the breathing exercise for several days and see when can we see the effectiveness of the breathing technique.
- Explore the design of TIPs on other breathing techniques.

Thank you for your attention.