Physio and emotional signals for better Game Flow

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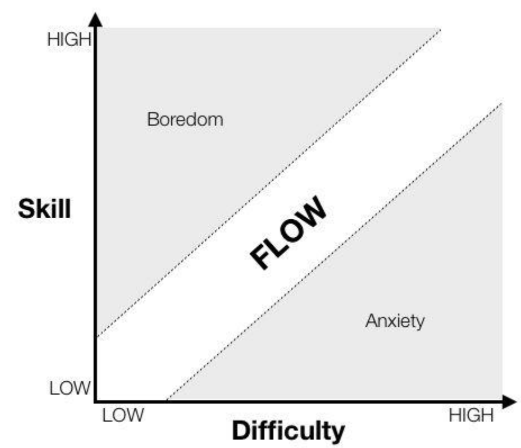
Introduction

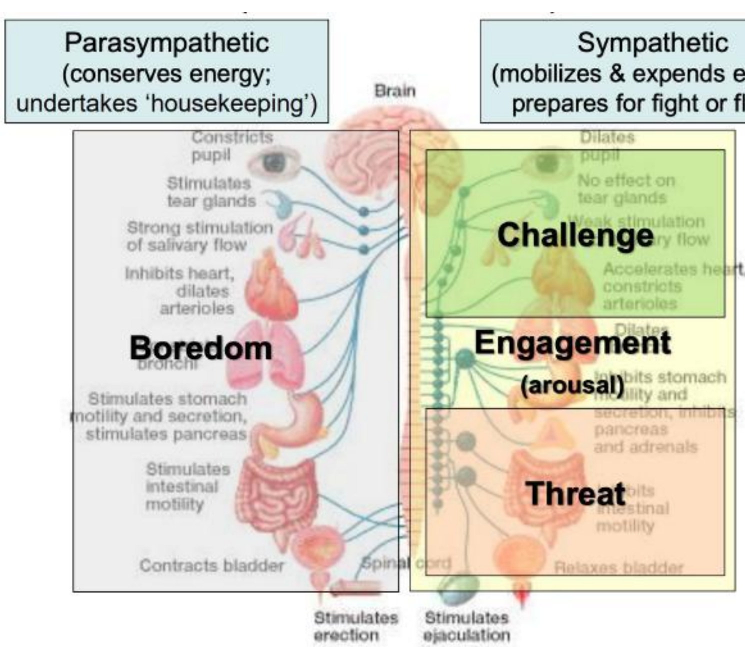
- **What**: make video-game more enjoyable
- **How**: Dynamic Difficulty Adjustment (DDA) based on affective signals
  - Flow: psychological state of being completely involved in an activity
  - Not too boring, nor too frustrating
- **Why:**
  - recreation is essential to a balanced life
  - Good video-games can be hindered by small details such as difficulty
  - Applicable to E-learning
  - Past studies on DDA do not involve facial expressions as feedback
  - Physio signals are relatively un-fakable

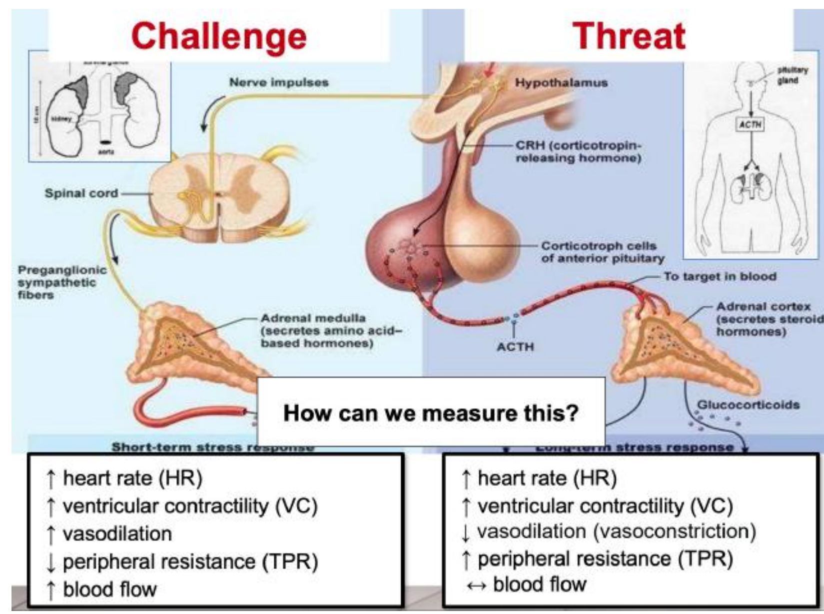


Theoretical perspectives built upon

- **General area:** affective feedback
- Basic emotions displayed through facial expressions
- Sympathetic and parasympathetic relation to arousal
- Increased blood flow = increased challenge

Emotion	Action Units
Happiness	6+12
Sadness	1+4+15
Surprise	1+2+5+26
Fear	1+2+4+5+7+20+26
Anger	4+5+7+23
Disgust	9+15+16

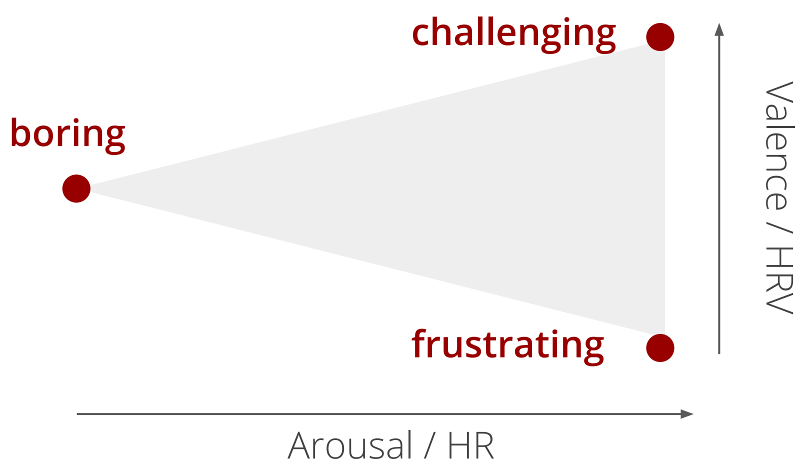




Gratch, Jonathan, CSCI534 Lecture 10

Hypothesis

- Players enjoy the game the most when they are engaged
- By adapting the game's difficulty we can impact valence and arousal
- Player is more aroused ⇒ higher heart-rate
- When aroused, more engaged ⇒ higher heart-rate variability
- Described adaptive version is more enjoyable
    - Than non-adaptive versions
    - Than adaptive versions without affective signals



Current state-of-the-art

Table 1. Properties of affective video games

N	References	Game name	Game purpose	Game genre	Delivery platform	Mode	Adapted game features
1	[92]	PhysiRogue (on Rogue Signals game)	applied	2D action	desktop, GPS-location-aware	multi-ple-player	Seekers' desirability of predators, player visual representation
2	[10]	Half-Life 2	entertain-ment	3D FPS	desktop	single-player	Avatar speed, sound volume, environmental density, gravity, and transparency; weapon damage; red and b/w filters; NPC creation
3	[63, 96]	EMO-Pacman (on Pac-Man game)	entertain-ment	2D arcade	desktop	single-player	Objects' speed
4	[83]	Tetris	entertain-ment	2D puzzle	desktop	single-player	Speed of falling Tetris blocks
5	[16, 97]	Bug-Smasher (a Playware ambient game)	entertain-ment	physical platform	Playware playground platform	single-player	Bugs' speed and the entropy of bug-visited tiles
6	[9]	Pong	entertain-ment	2D arcade	desktop	two-players	Speed and size of both ball and paddle; sluggish or overresponsive keyboard
7	[86, 93]	MindTactics (Unity3D game)	applied	3D strategy	desktop	single/ multi-player	Territorial control and distractors
8	[87]	A 3D games on TORCS[1]	entertain-ment	racing	desktop	single-player	Opponent skill
9	[32]	2D Xbox360 FPS game	entertain-ment	2D side-scrolling shooter	desktop with Microsoft Xbox 360 controller	single-player	Enemy target size, flame length, speed and jump height, weather conditions and boss speed
10	[20]	Tetris	entertain-ment	2D puzzle	desktop	single-player	Speed of falling Tetris blocks
11	[84]	Archery game	entertain-ment	shooting	desktop	single-player	Archery focus level
12	[88, 91]	VANISH	entertain-ment	3D FPS	desktop	single-player	Event probabilities, PCG and tunnel vision effects; character's movement speed, stamina, and sanity level
13	[34]	Car racing game	entertain-ment	3D racing	desktop, Logitech G27 racing wheel	single-player	Visibility, steering, and speed
14	[94]	BioPong (based on the Pong game)	entertain-ment	2D arcade	desktop	two-players	Ball speed, paddle size

Bontchev, Boyan. "Adaptation in affective video games: A literature review." *Cybernetics and Information Technologies*16.3 (2016

Current state-of-the-art

No	FT[2]	Measured signals	F[3]	Biofeed-back device	Rate (Hz)	Time win-dow (s)	Cali-bra-tion (min)	Signal filtering	Recognized emotions	Classifi-cation / estima-tion	Accu-racy (%)
1	+	Phasic EMG Phasic EDA Tonic EMG Tonic EDA	1 1 1 1	ProComp2 (Thought Techn.)	10 0,33 10 0,33	1 30 6 300		Kalman filter	Stress level	Direct mapping	
2	+	HRV (ECG) HR EDA	2 2 2	Lightstone (Wild Divine)		2	5	Average downsampling at 2 s	Horror	Direct mapping	
3	–	BVP EDA EMG RESP KEYB	4	NeXus and Biotrace+ (Mind Media)	128 32 1024 32 100	180		High-pass Chebyshev 20Hz filter; smoothing filter	Boredom, frustration and enjoyment	Direct mapping	
4	C	EDA BVP HR RESP TEMP	4 2 3 3 2	Biosemi Active 2	1024	20	1.5	Moving average filters	Boredom, anxiety, and engage-ment	SVM	53.33
5	+	HR BVP EDA	13 7 13	ProComp Inf. (Thought Techn.)	256	45	0	Discrete Fourier Transform (DFT) filter	Entertainment value	ANN	79.76
6	C	ECG PPG EDA EMG TEMP	17 3 5 16 3	Biopac (BIOPAC Systems)	1000	0.025 0.1		Low-pass filters, DFT, wavelets	Anxiety level	RT kNN BNT SVM	88.5 80.4 80.6 88.9
7	+	fNIR	4	Bespoke fNIR device	2048	16.5	0.33	Low-pass cut-off frequency filter (0.14 Hz)	Attention level	kNN NBC	73.77 57.37
8	+	BVP ECG EDA RESP TEMP	11 11 11 11 11	ProComp Infinity (Thought Techn.)	2048 2048 256 256 256	60	1	Horror	Preference level	LDA	74
9	+	BVP EDA ECG EMG RESP TEMP	1 1 1 1 1 1	Flexcomp Infinity (Thought Techn.), TTLAPI	2048		10	Chebyshev type II filters, downsampling by 64	Preference level	Direct mapping	
10	C	Alpha & theta (EEG)	2			2	2		Boredom, engage-ment, flow, overload	Linear estima-tion	
11	C	Alpha (EEG)	3	Bespoke device	256	2	3	FFT band-pass filter (0.5~50 Hz)	Focus level	Direct mapping	
12	C	BVP EDA EMG	2 2 1	Nexus-10 (Mind Media) and BioTrace+	32 32 1024	2 5 0.125	5	Smoothing filter (moving average)	Arousal and valence levels	Linear / nonlinear regre-sions	85
13	+	EDA	1	FlexComp (Thought Techn.)	1	30	8		Arousal	Direct mapping	
14	C	EDA HR	1 1	Arduino			0		Arousal	Direct mapping	

Bontchev, Boyan. "Adaptation in affective video games: A literature review." *Cybernetics and Information Technologies*16.3 (2016

Methodology

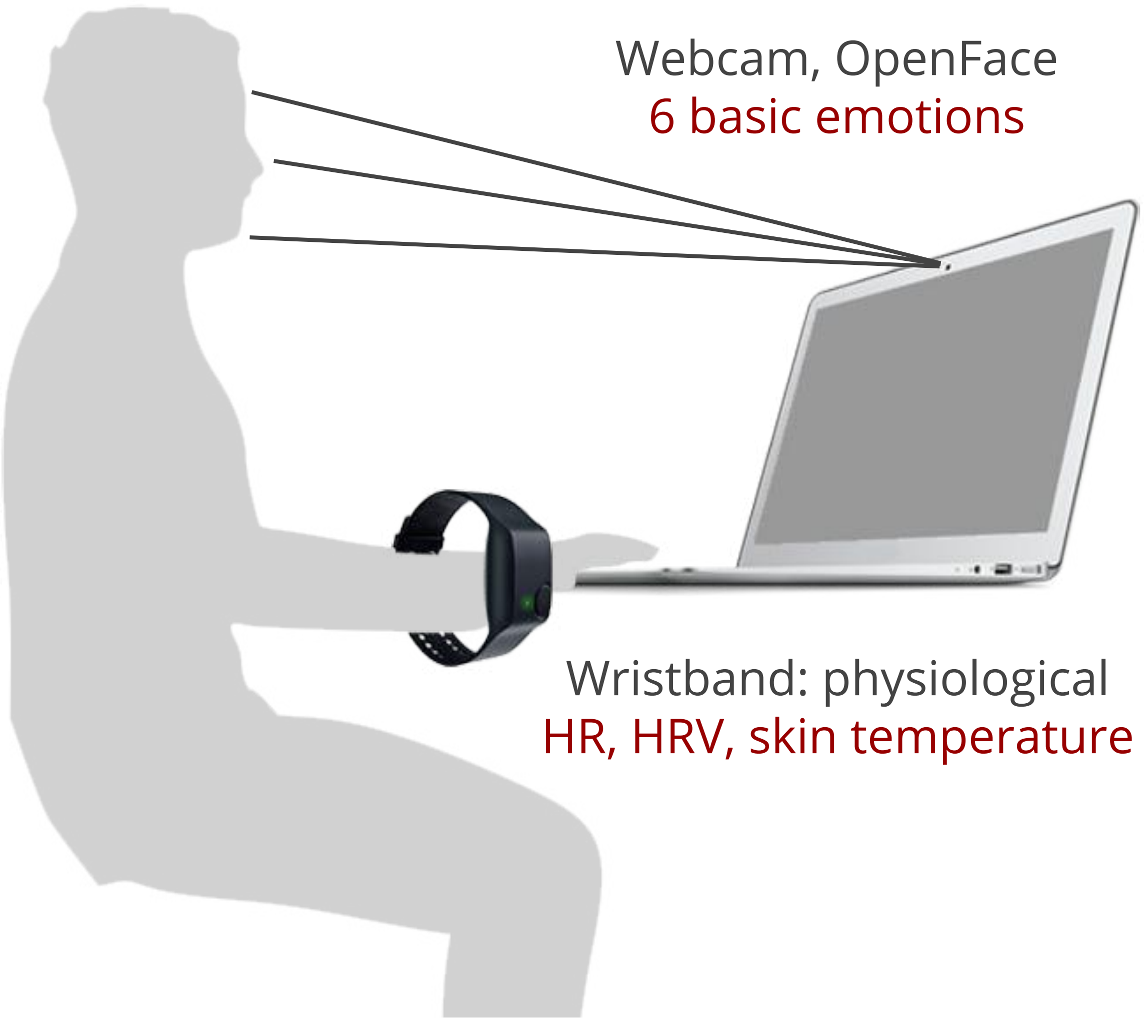
Study design

- Ask basic info about competitiveness/video game skill
    a. For baseline and later analysis
- Play four versions of the game
    a. Two for baseline: very easy, very hard
        - System baseline and participants accommodation
    b. Two adaptive ones: using a classic strategy and using our strategy
        - Counterbalanced design: ordered randomly
- Each version replayed multiple times (because it is very short)
    a. Last two versions can be played for as long as desired
- After each version, participant rates it (out of five stars):
    a. Difficulty: easy to hard
    b. Valence: frustrating to challenging — whether it was hard in an enjoyable way
    c. Enjoyment: how much they liked it overall
- After playing all versions, participants are asked to pick their favorite
- Participants don't know what the game adapts to
    a. But are (obviously) aware that they wear a measurement watch
    b. And that they are being recorded

Variables

Independent variable	Whether to adjust difficulty based on affective feedback
Dependent variable	User enjoyment: ratings, favorite version, play duration
Measurements	Affective feedback: - emotions through facial expressions - HR, HRV, skin temperature Supplementary info: - participant's video game skill / competitiveness - self-reported difficulty perception - self-reported valence (frustrating vs challenging)

Capturing affective signals



Affective signals

- Emotion signals
  - OpenFace: generate facial Action Units
  - Subtract each participant's AU baseline
  - Compute the 6 Basic Emotions by summing AUs

- Physiological signals
  - Heart rate
  - HRV = inter-beat interval standard deviation
  - Skin temperature
  - Baseline collected during first variant

Classic adaptive strategy

Goal: maintain player performance at below peak level

After every turn

- Adjust the difficulty based on performance of **previous turn**
- Increase/decrease **base difficulty** using percentage overlap
  - > 50% : increase difficulty scaled by % overlap (maximum 5)
  - < 50% : decrease difficulty scaled by % overlap (maximum -5)
- The maximum change is also affected by reported user skill

Every 500 ms

- Add **random fluctuations** ±3 (constrained by base ±13)

Guy Hawkins, Keith Nesbitt, and Scott Brown, “Dynamic Difficulty Balancing for Cautious Players and Risk Takers,” *International Journal of Computer Games Technology, 2012*

Affective adaptive strategy

Goal: maintain player affective at a certain level of anxiety

- Physiological signals (cardiovascular and skin temperature):
  - Adapt difficulty in order to increase physio values
  - If any drop below the user's baseline: **harder**

- Emotional signals
  - Adapt difficulty in order to invoke emotions (measured through facial expressions)
  - If player displays happiness, surprise or sadness: **harder**
  - If player displays disgust, anger or fear: **easier**
  - (emotions in order of magnitude)

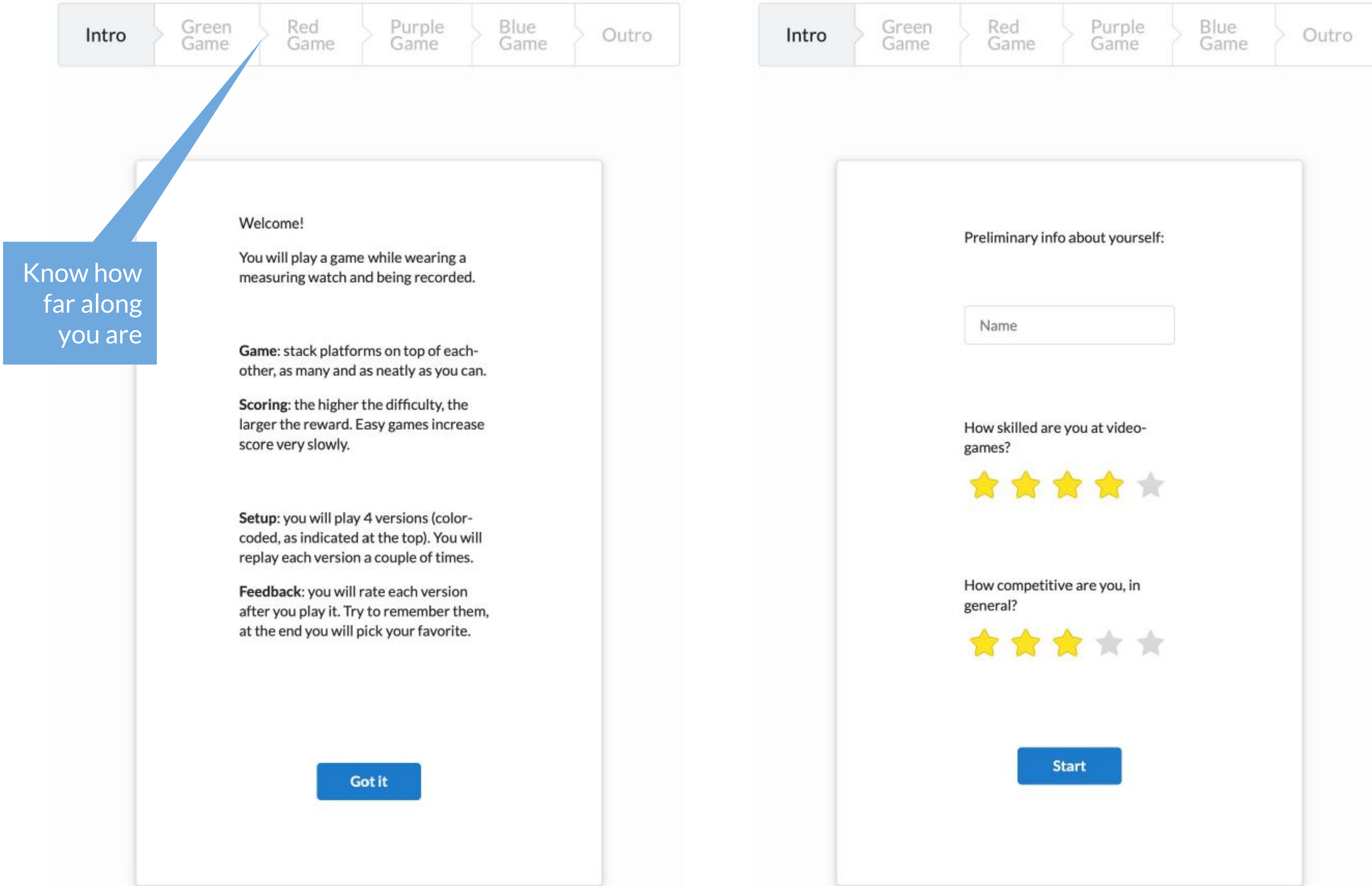
Rohrmann, Sonja, Jürgen Hennig, and Petra Netter. "Changing psychobiological stress reactions by manipulating cognitive processes." *International Journal of Psychophysiology* 33.2 (1999)

Liu, Changchun, et al. "Dynamic difficulty adjustment in computer games through real-time anxiety-based affective feedback." *International Journal of Human-Computer Interaction* 25.6 (2009)

Experiment

Study Phases

- Participants: USC students
- Participants don't know
  - Hypothesis
  - If/how the difficulty is adjusted
- Phase I
  - 10 participants
  - Discarded: used for learning lessons
- Phase II
  - 13 participants
  - Improve UI and mechanics
  - Analyzed and reported on


Intro
Green Game
Red Game
Purple Game
Blue Game
Outro
Know how far along you are
Welcome!
You will play a game while wearing a measuring watch and being recorded.
Game: stack platforms on top of each-other, as many and as neatly as you can.
Scoring: the higher the difficulty, the larger the reward. Easy games increase score very slowly.
Setup: you will play 4 versions (color-coded, as indicated at the top). You will replay each version a couple of times.
Feedback: you will rate each version after you play it. Try to remember them, at the end you will pick your favorite.
Got it
Intro
Green Game
Red Game
Purple Game
Blue Game
Outro
Preliminary info about yourself:
Name
How skilled are you at video-games?
How competitive are you, in general?
Start

Game: Stack

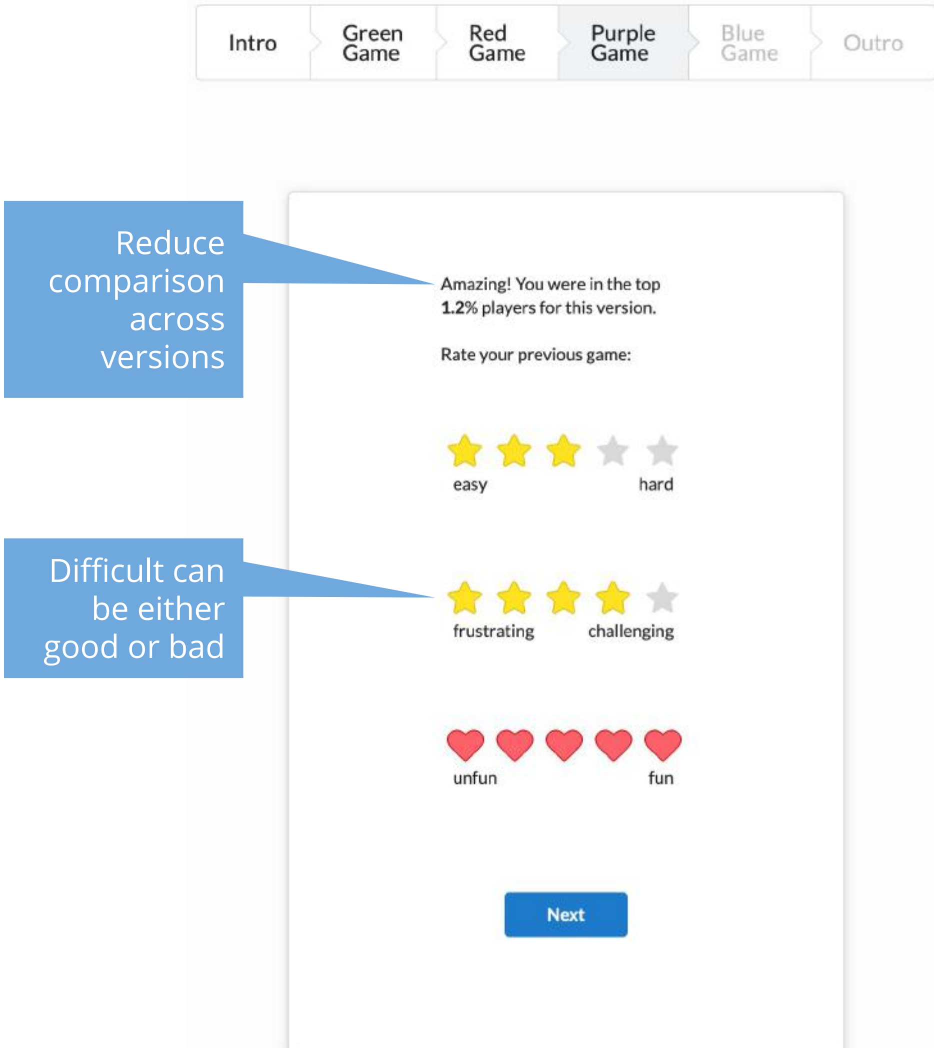
- Mechanics
    - Stack platforms on top of eachother
    - Platform moves horizontally, tap to drop it
    - The less precise your drop, the harder it'll be
    - Game ends if you drop the platform outside the tower

- Difficulty adjustments
    - Platform lateral movement
    - Higher drop position

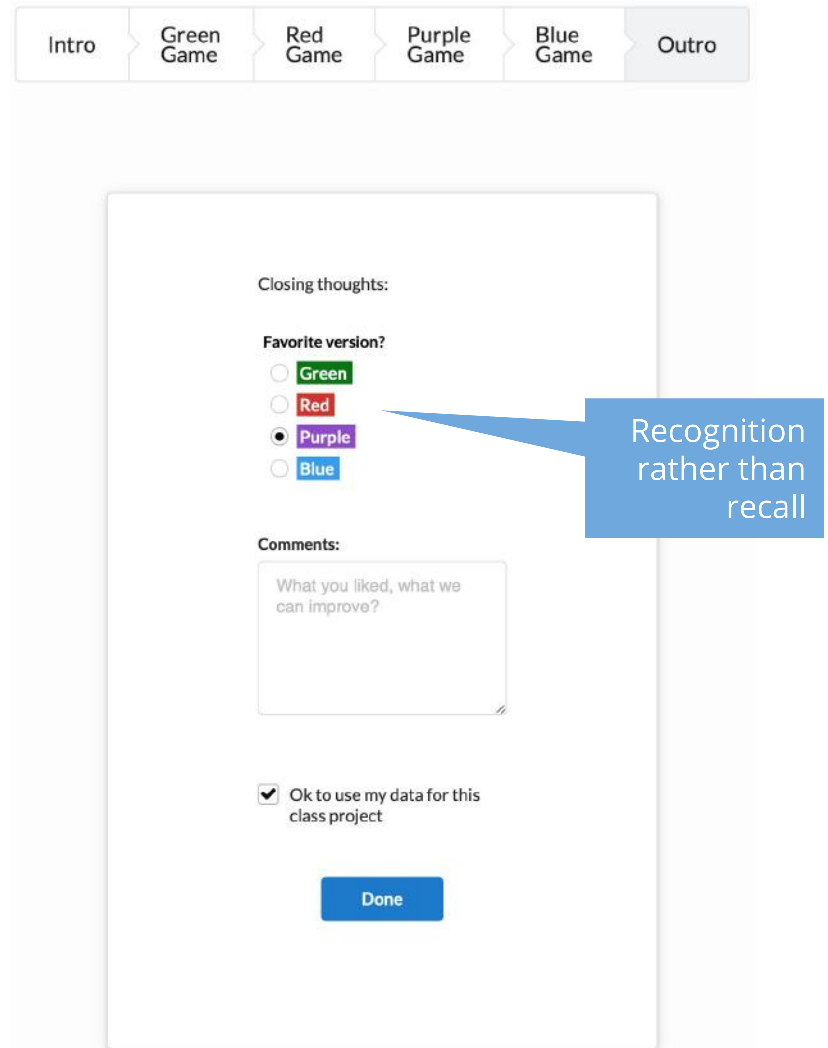
Score accounts for difficulty to reduce "easy-is-best" bias

Play as long as you wish

After every version



At the end

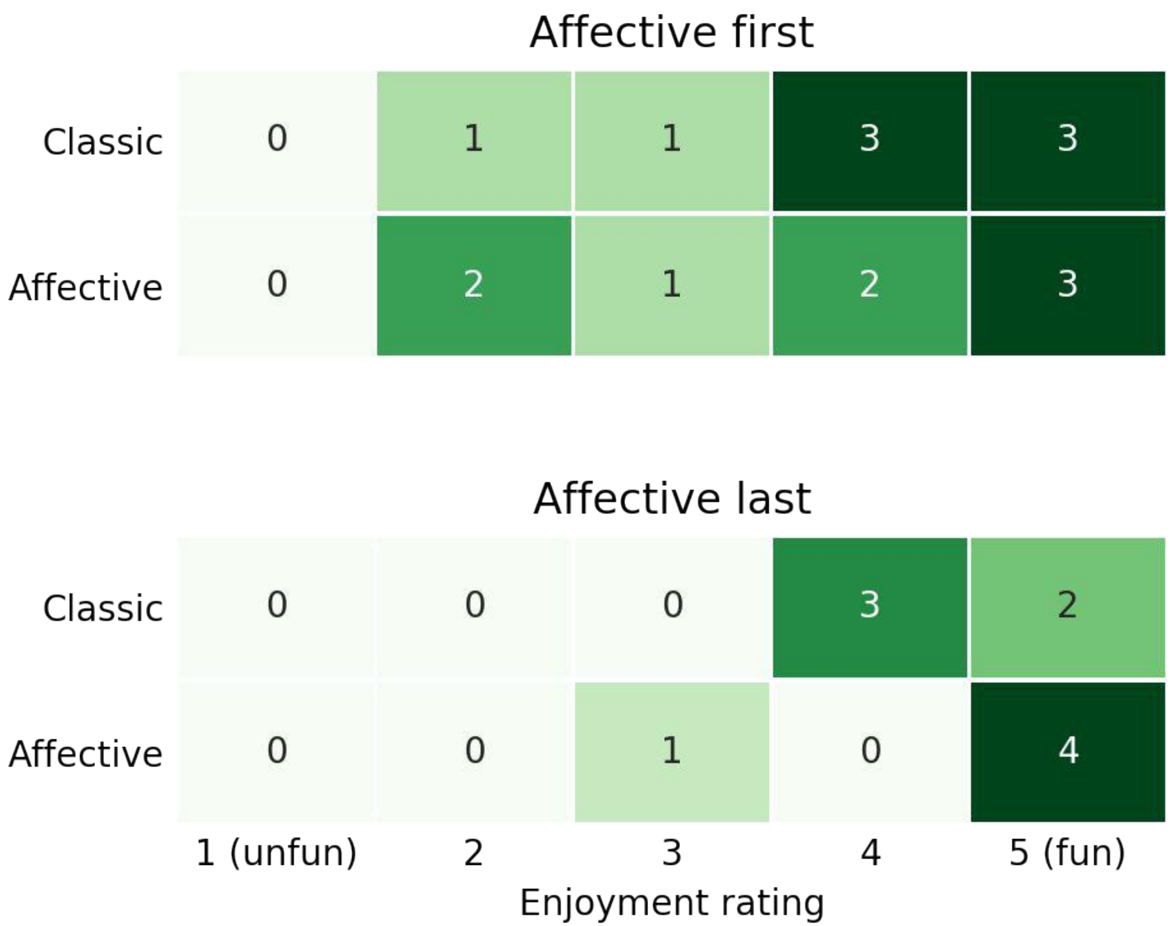


Results

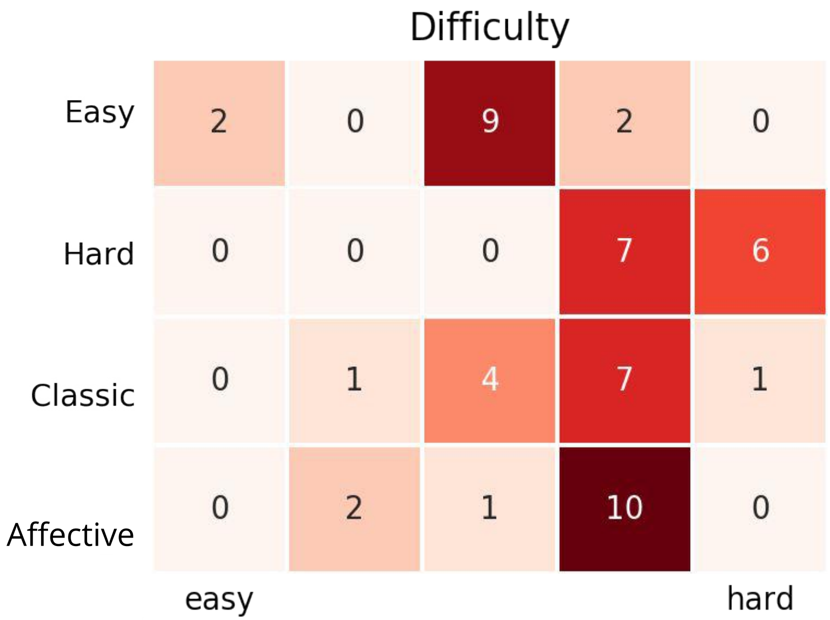
Versions ratings

85% of participants rated it higher or equal to the classic version
77% of participants rated it (their) highest out of all versions

Order bias


Affective first
Classic 0 1 1 3 3
Affective 0 2 1 2 3
Affective last
Classic 0 0 0 3 2
Affective 0 0 1 0 4
1 (unfun)
2
3
4
5 (fun)
Enjoyment rating

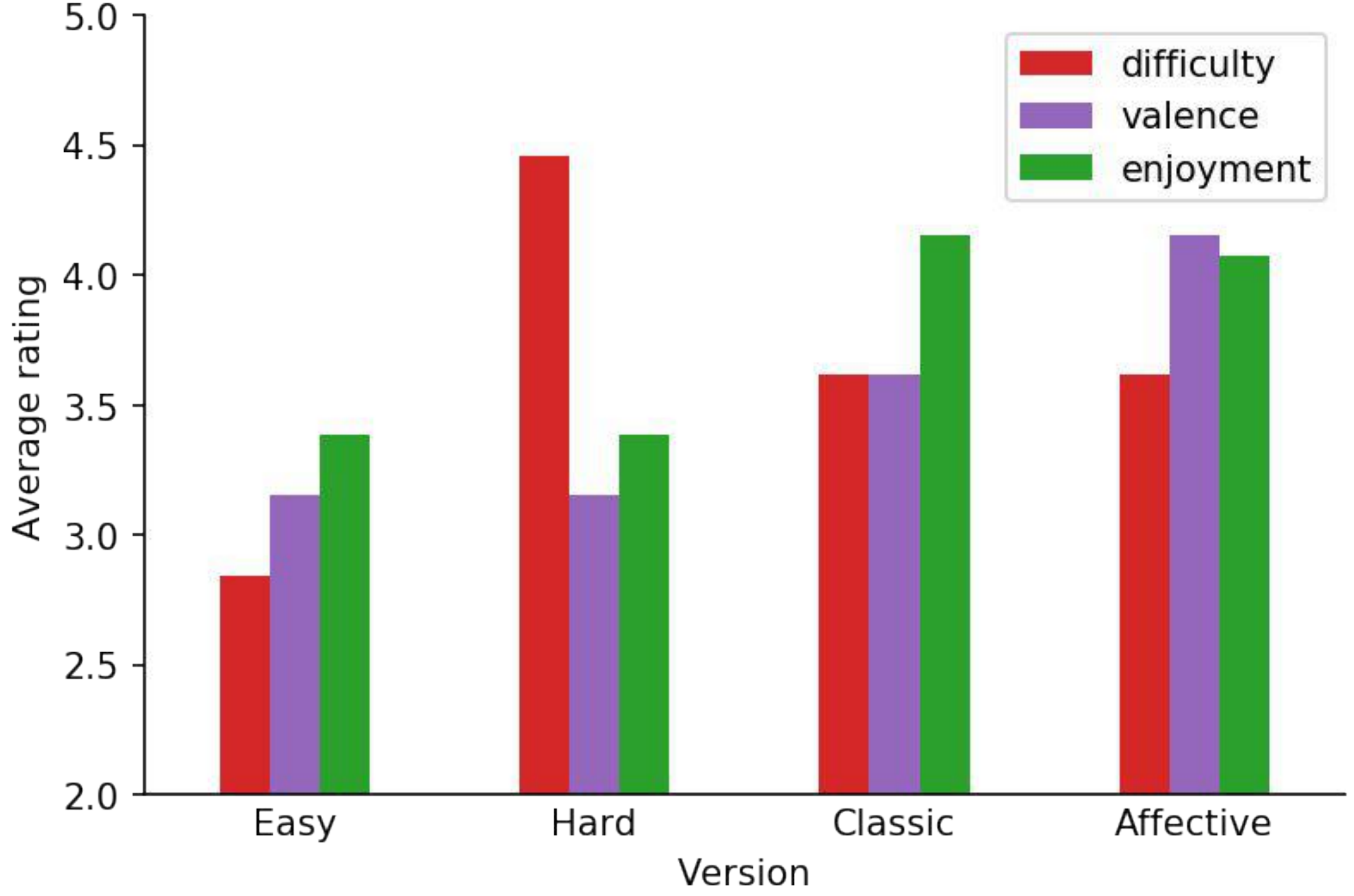
Specialized ratings

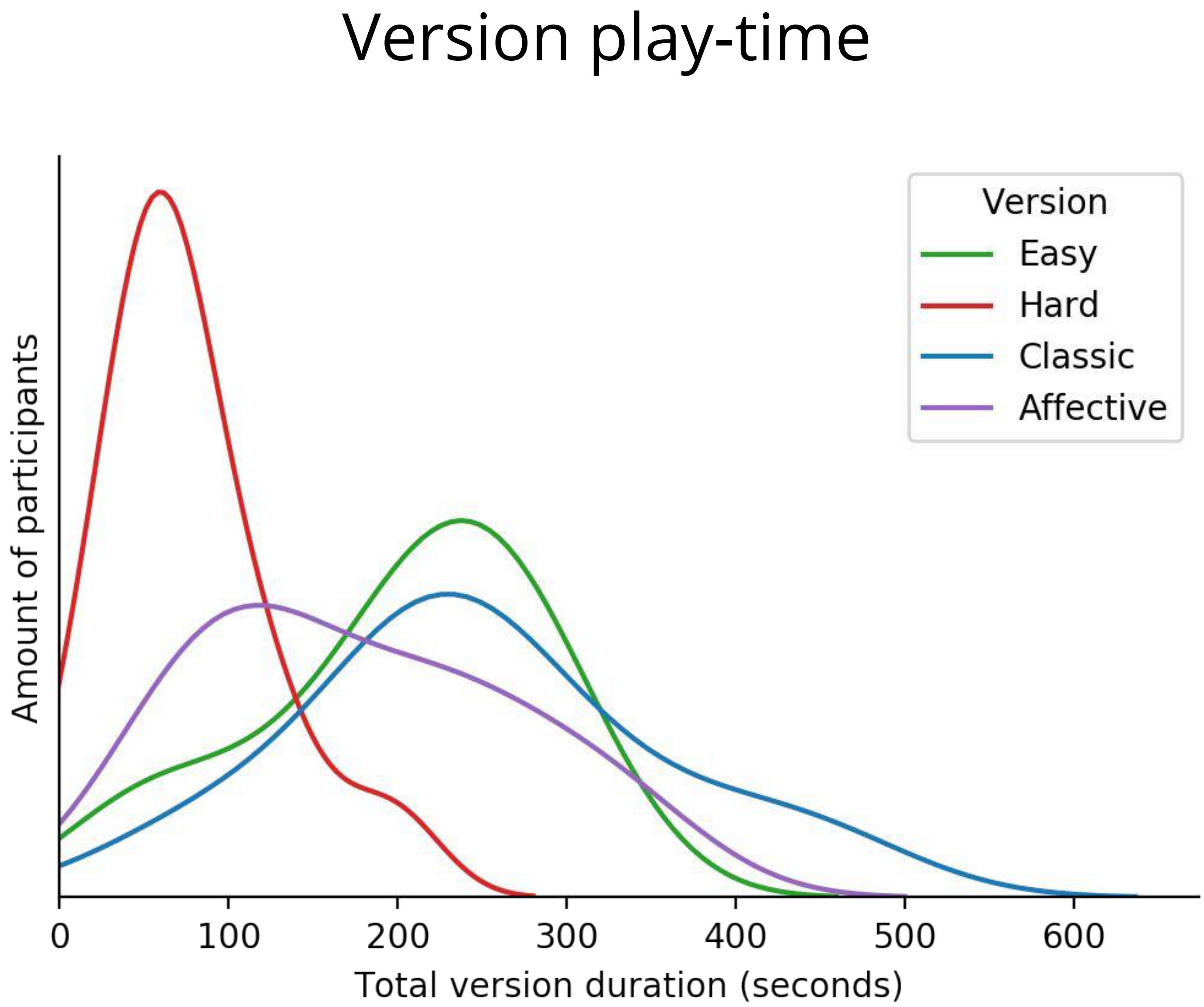


Ours was harder…

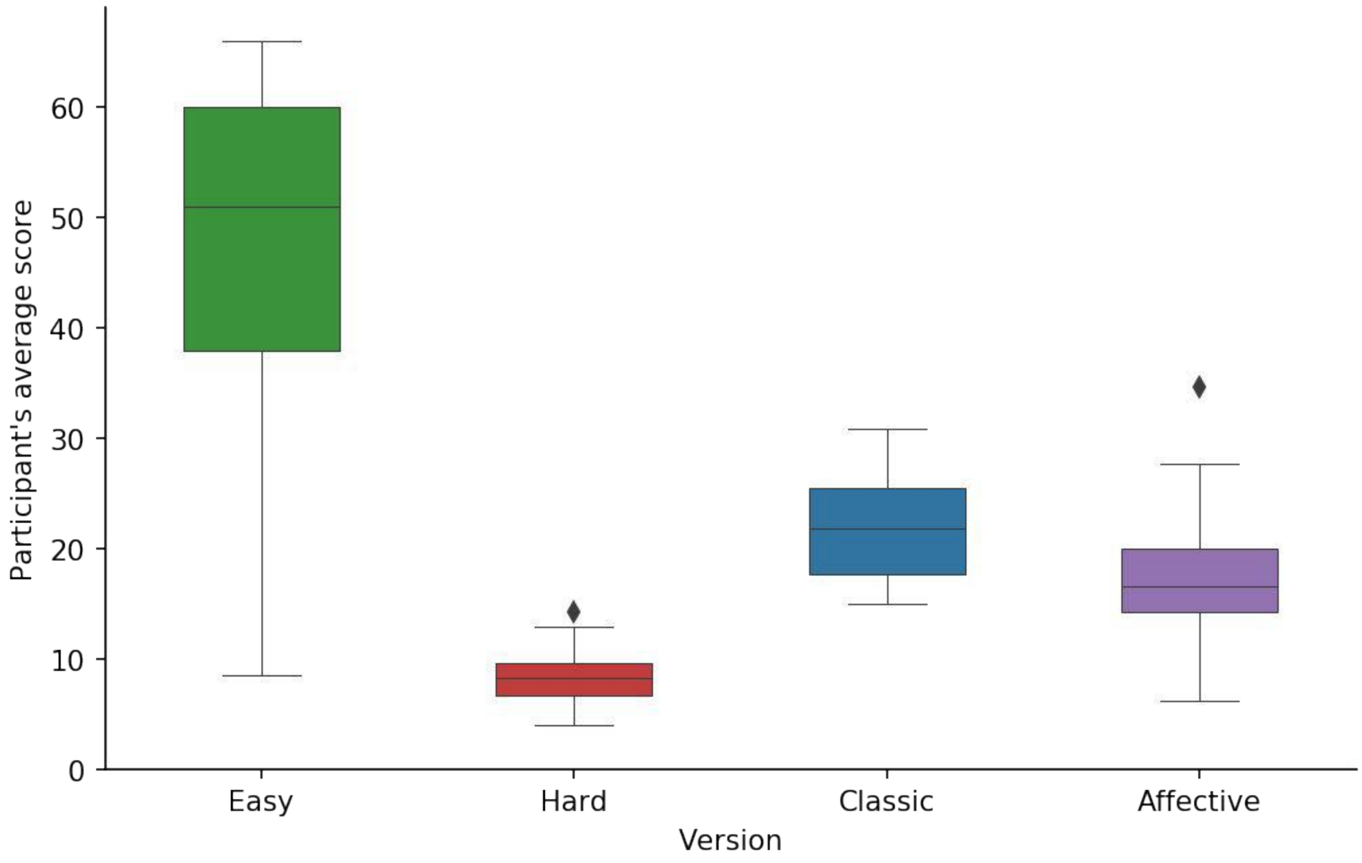
… but in a pleasant way

Rating Averages

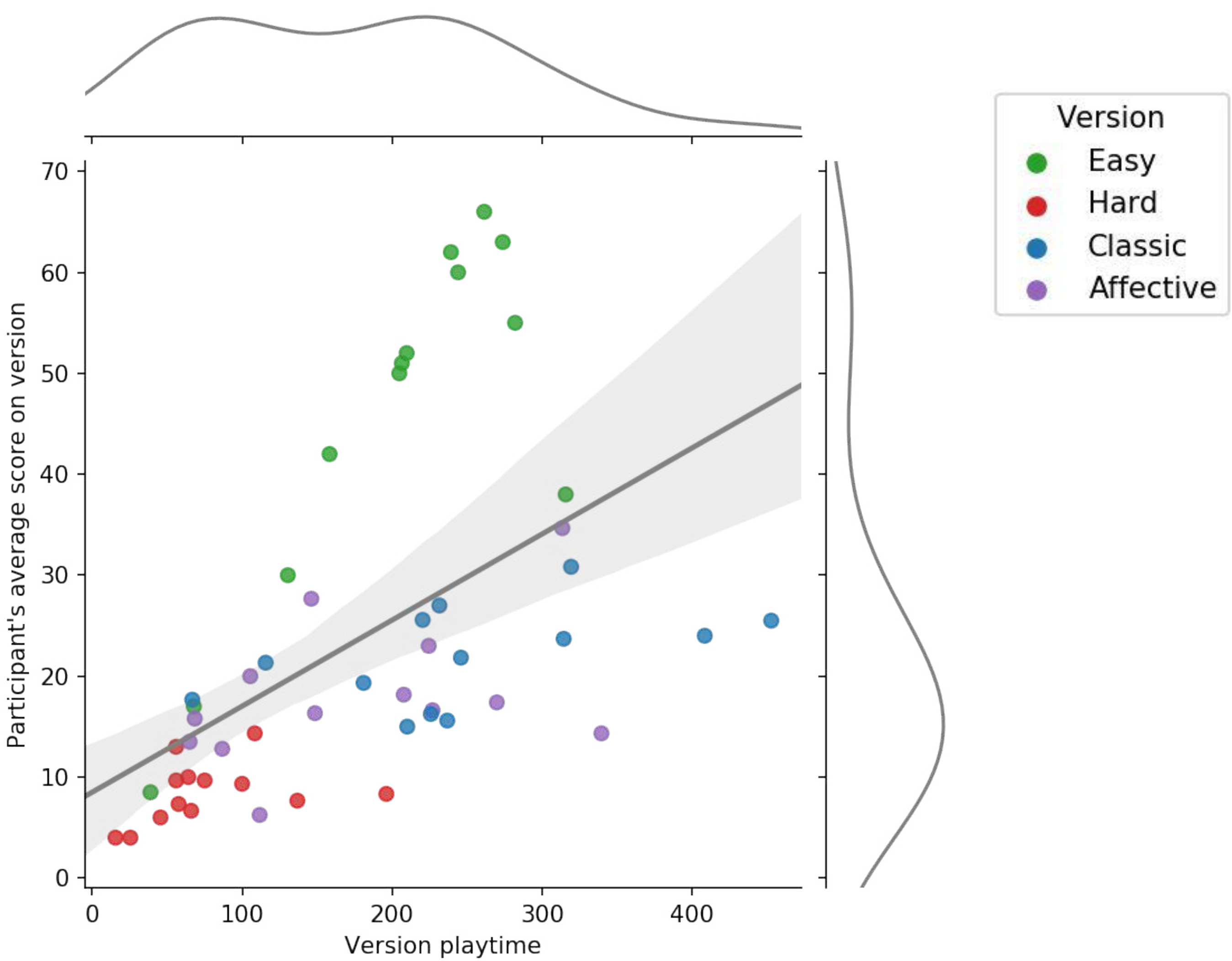



Version play-time
Version
Easy
Hard
Classic
Affective
Amount of participants
0
100
200
300
400
500
600
Total version duration (seconds)

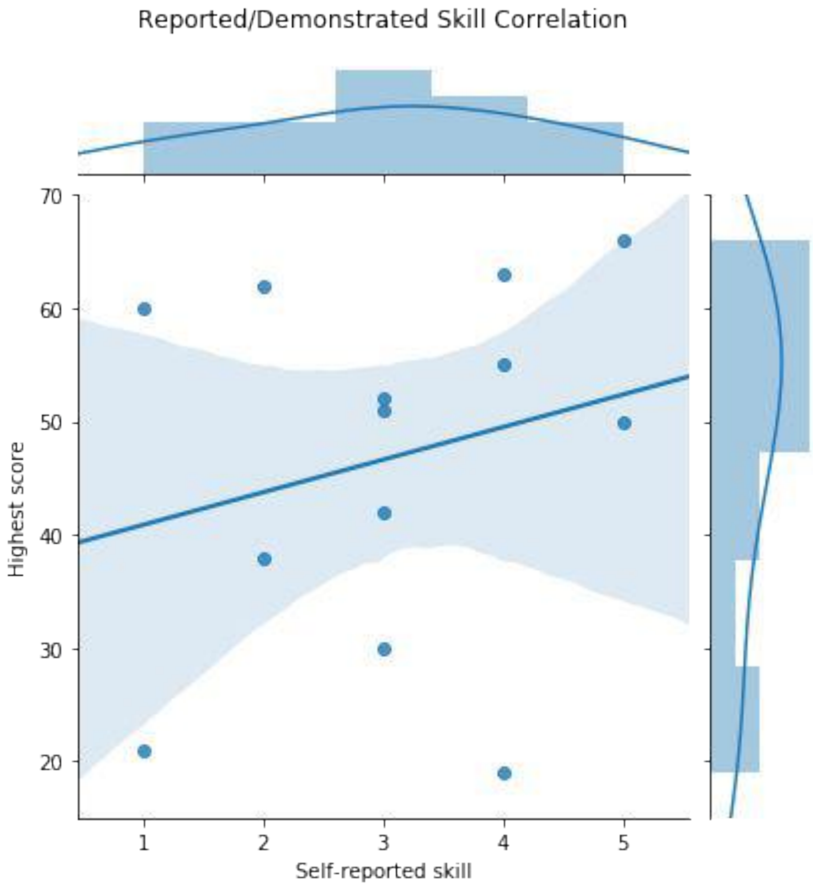
Scores across versions

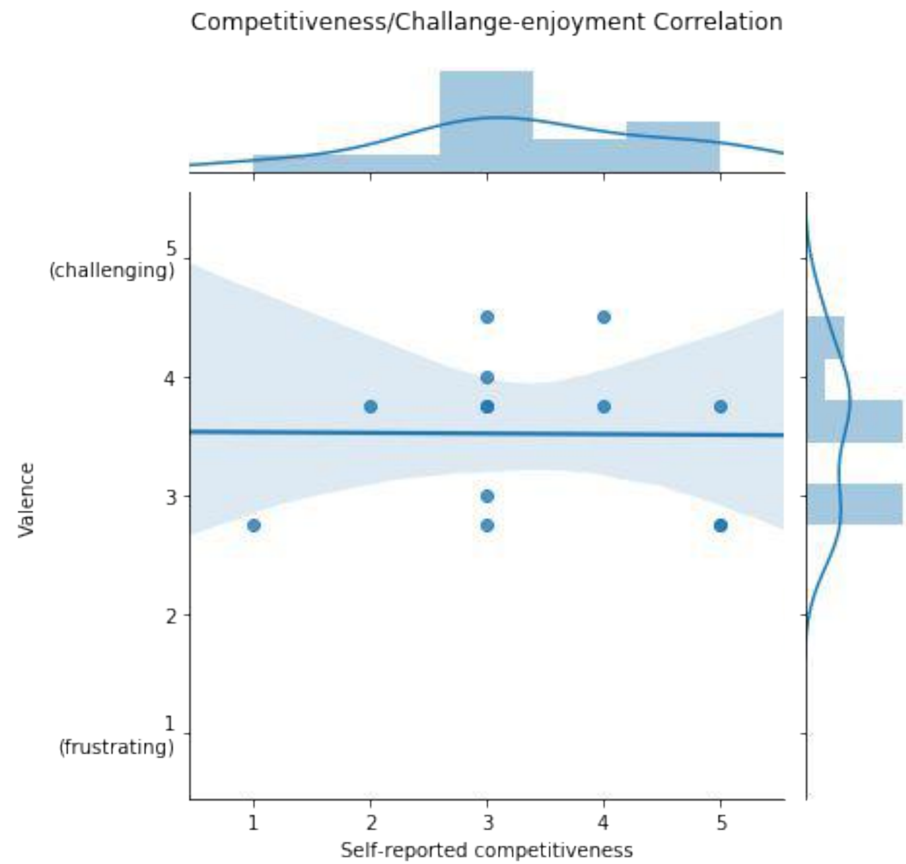


Practice makes perfect

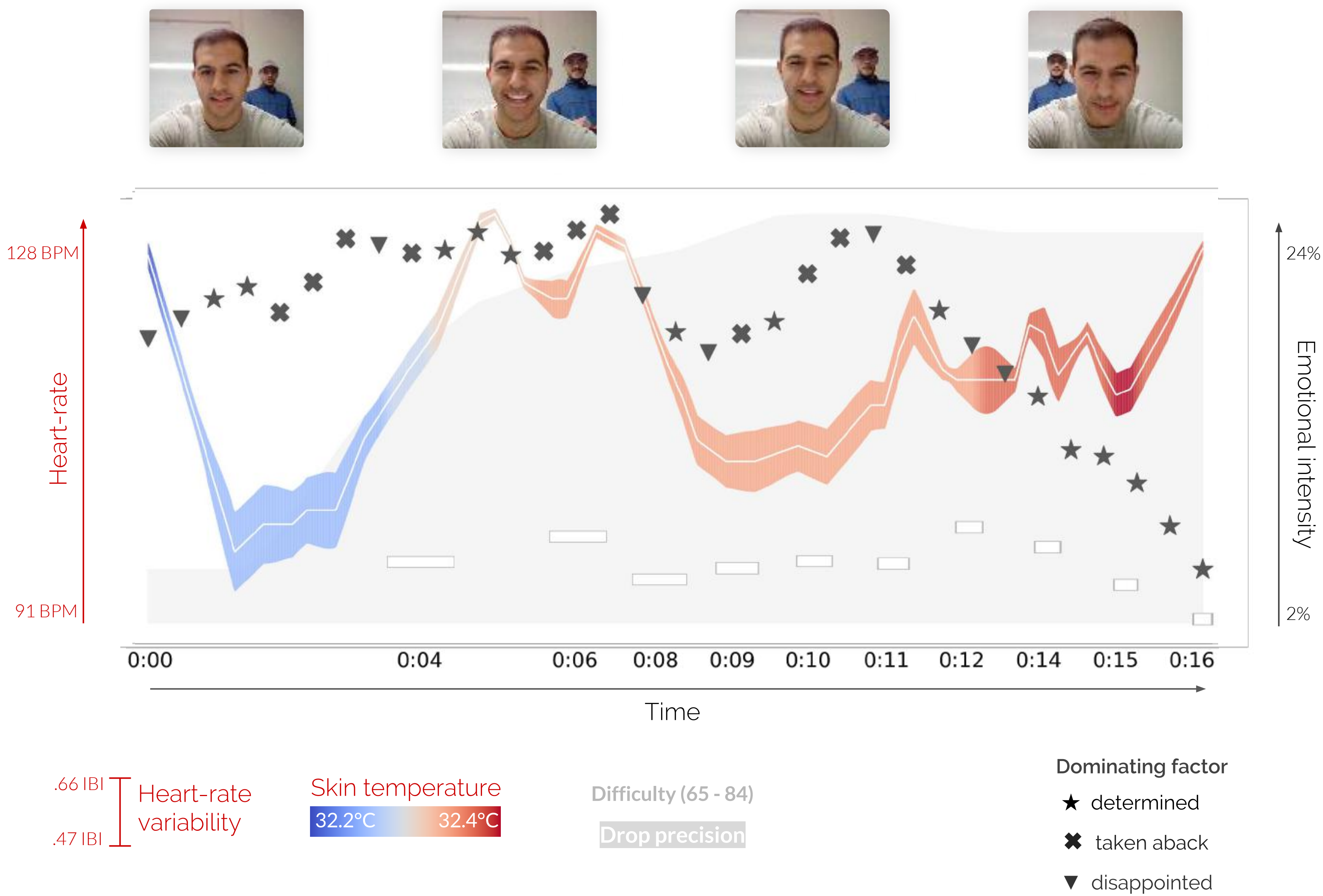


Self-reported measures accuracy





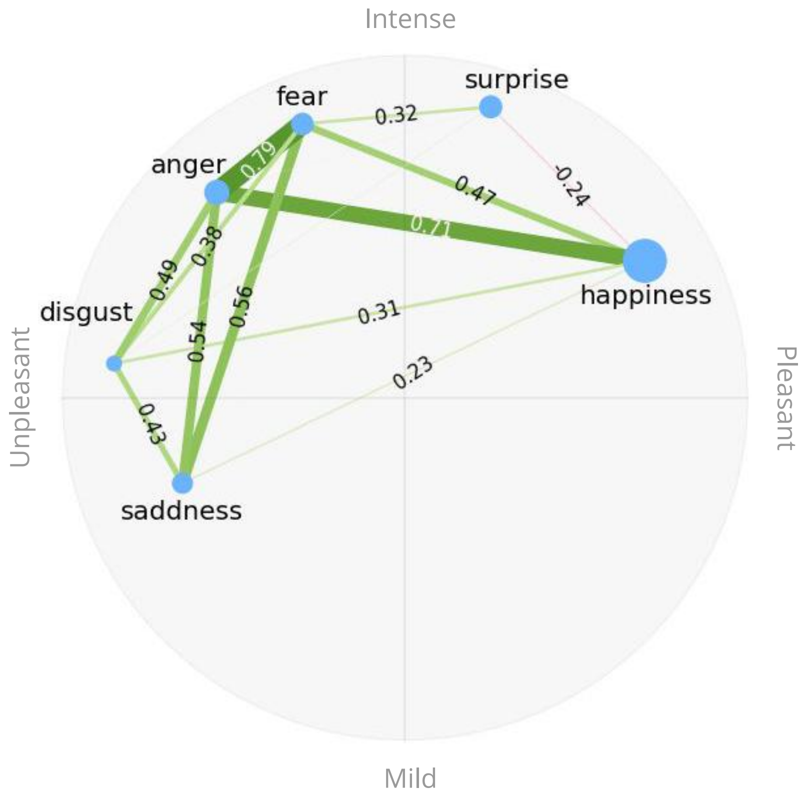
Analysis



128 BPM
91 BPM
Heart-rate
24%
2%
Emotional intensity
0:00
0:04
0:06
0:08
0:09
0:10
0:11
0:12
0:14
0:15
0:16
Time
.66 IBI
.47 IBI
Heart-rate variability
Skin temperature
32.2°C
32.4°C
Difficulty (65 - 84)
Drop precision
Dominating factor
determined
taken aback
disappointed

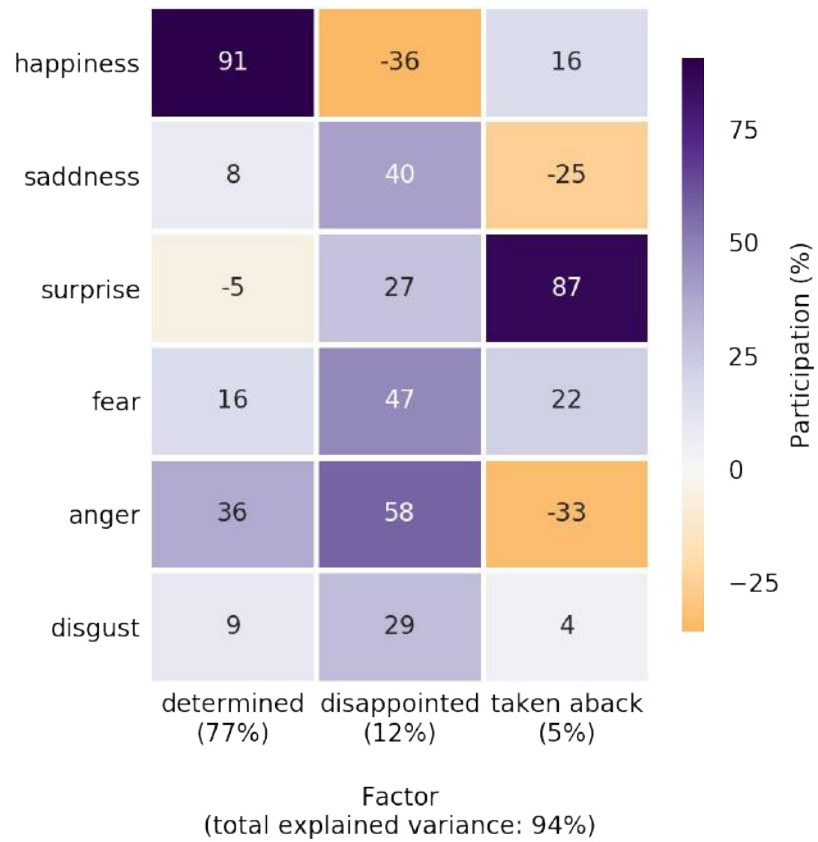
Emotion aggregation

Linear correlation



Node position: valence/arousal
Node size: average intensity
Edge width: pair-wise correlation

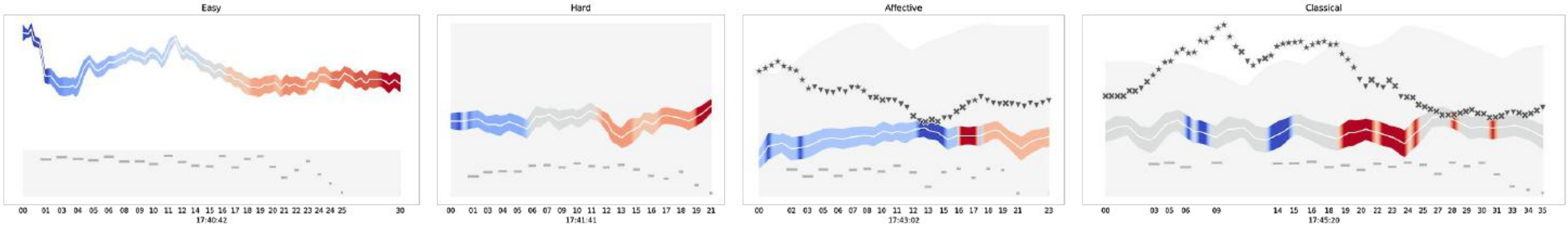
Linear dependencies



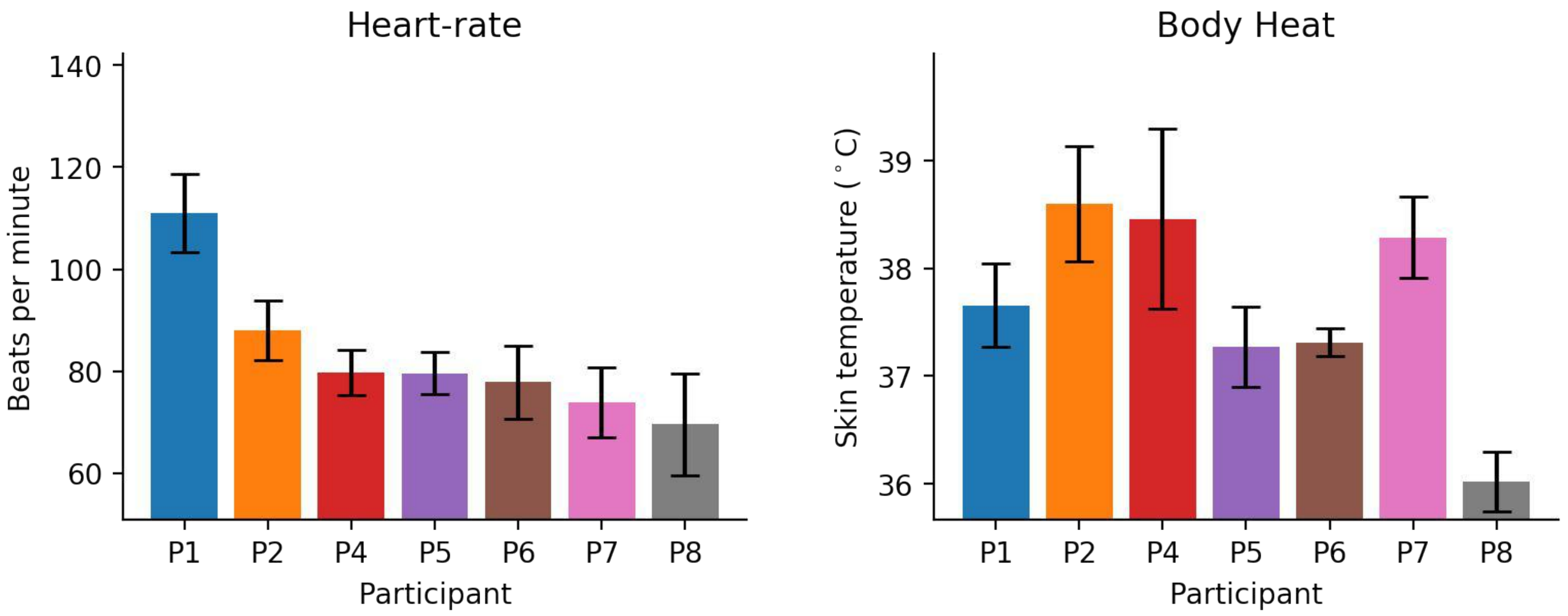
Yet more dimensions

- Version
- Overall time and order (human body does not reset)
- Replay: one with max score plotted below here
- User preferences and ratings

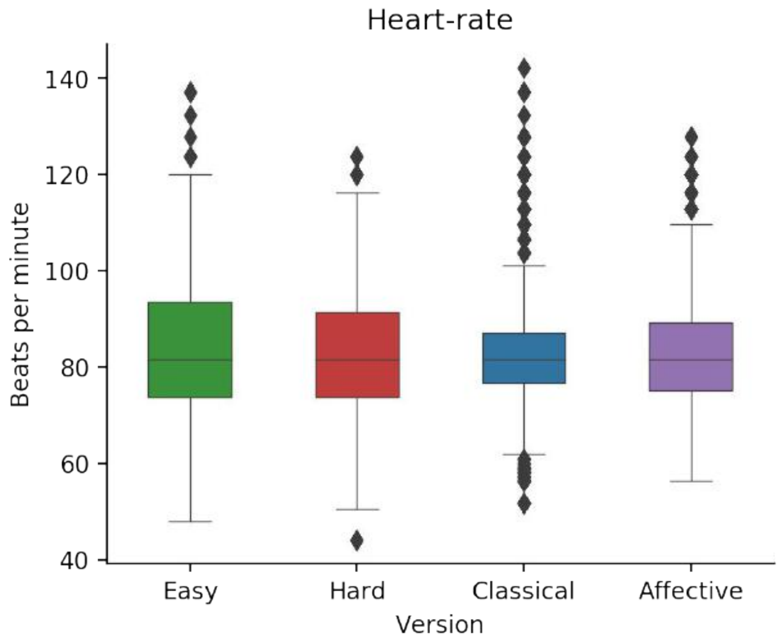
⇒ affective signals unalignable across users, have to look at averages

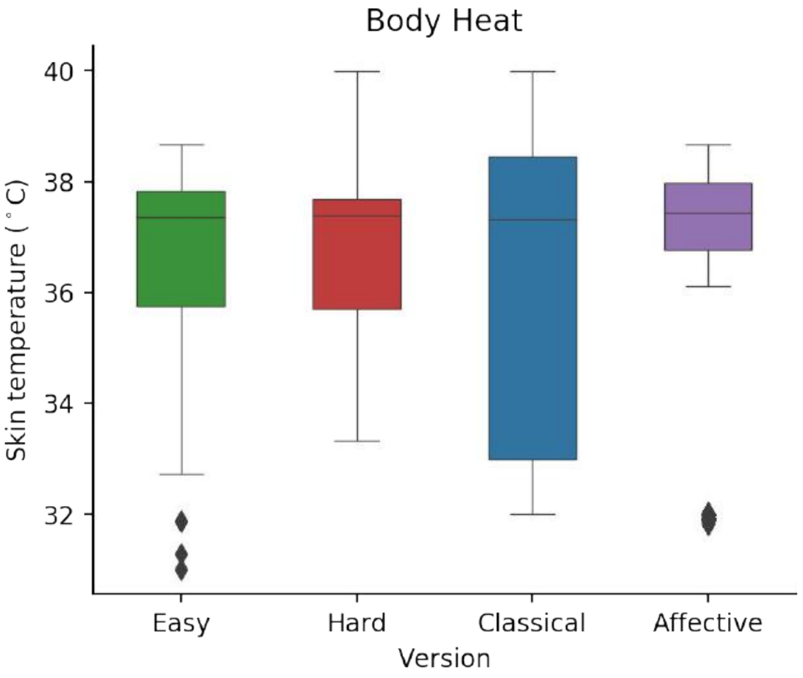


Physio variation among participants

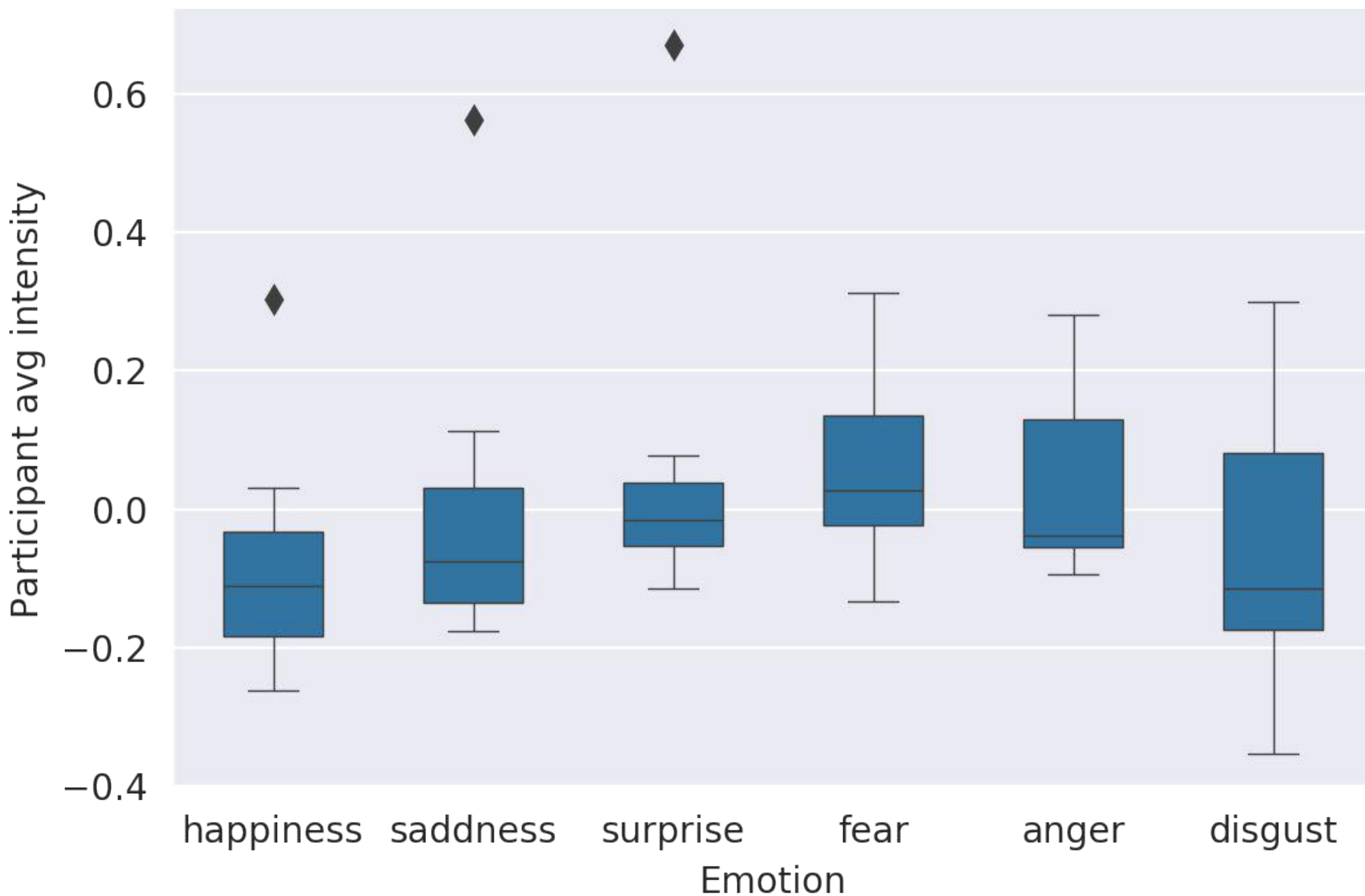


Physio variation across versions



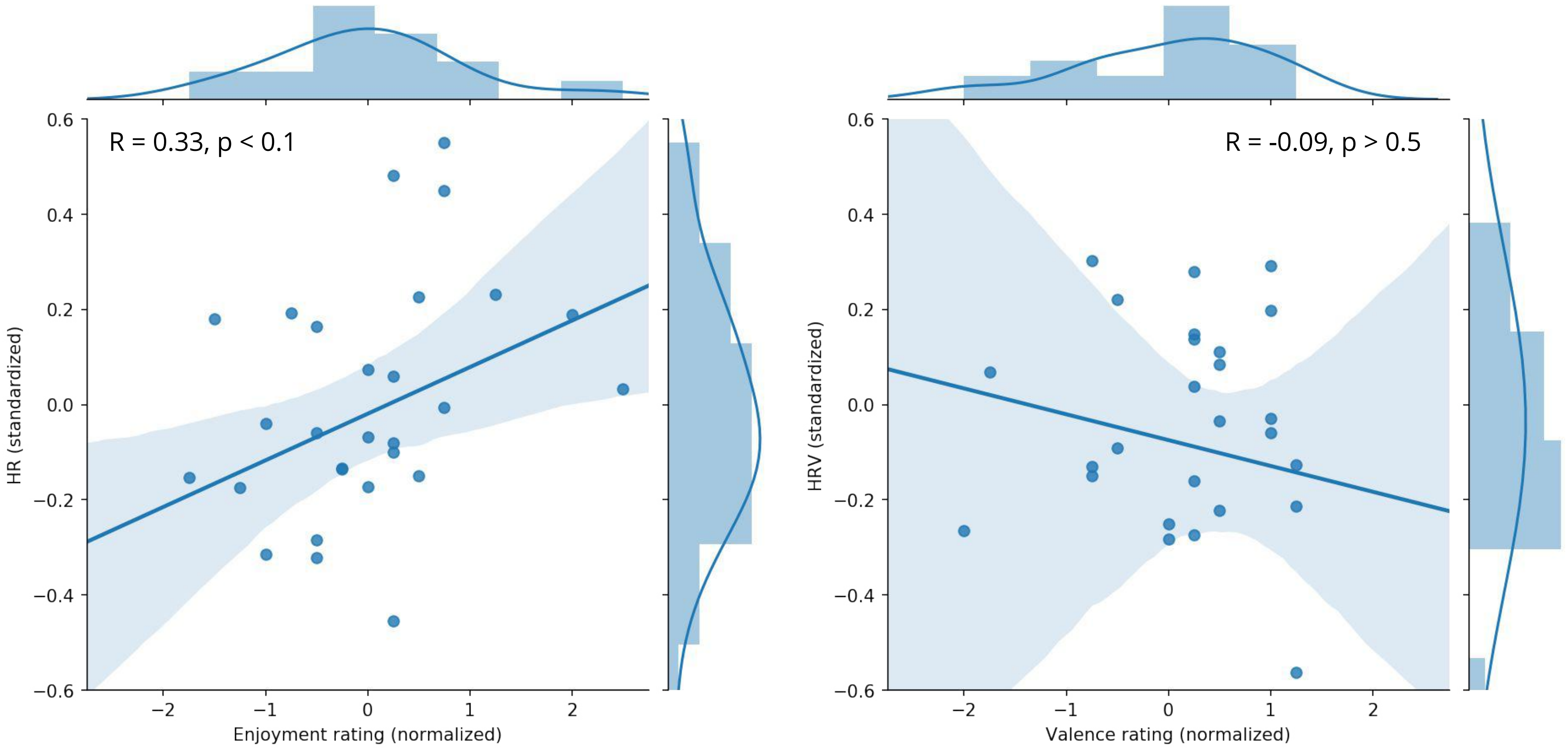


Emotional variation among participants



Emotional variation across versions

Cardiovascular/rating correlation



Conclusions

Conclusions

- Affective version at least as enjoyable as the classically-adaptive one, but more challenging, pleasant way
- Positive correlation between heart rate and game enjoyment
- Physio, emotional, and their combination is valuable (express complementary information)

Study design lessons learned

1. Correct incentives
    a. “Try to get a high score” => focus on absolute value & cross-version comparison
    b. Fix: larger rewards for more difficult drops
    c. Further isolate versions: version-wise “leaderboard”
2. Participants don’t pay attention (unless specifically instructed)
    a. Name and color code versions
    b. Tell from beginning what’s required of them
3. System performance is critical
    a. Lag: makes it harder, unintentionally
    b. Interpretation
4. Participant’s ratings are unreliable
    a. Rate (nearly) everything the same
    b. Not much agreement between highest rating and favorite (or play time)
5. Affective data is hard to isolate
    a. Climb stairs before coming to experiment room => high HR
    b. Emotions from one version/replay carry over to the next
    c. Measurements need to be fixed in post-processing

Possible next steps

- Less intrusive: HR & HRV from video
- More affective signals:
  - galvanic skin response
  - eye gaze
  - voice tone
  - Sentiment analysis on comments
- More “real” incentives: global scoreboard, monetary reward
- Modeling of player type: risk-takers, high-scorers, fast-players etc.
- Transparency to participants
  - More enjoyment if they understand the mechanics
  - (without being able to game the system)
- Immersion:
  - sound effects, VR
  - large scale game
- Machine Learning for adaptive difficulty

Demo:

cetus.usc.edu/physio-difficulty

(Firefox only, no physio)

Division of labor

Dillon Stefan Shaoyen Qinyi

Signal collection	Application	Experiment
Physiological	Difficulty adaptation strategy	Design, participants
Emotional	Game, form, UI	Analysis

Q & A

Moments from our journey...

Validating frameworks

Eliciting physio responses

Meeting ad-hoc

Running studies

Backup : Detailed Affective Dynamic Difficulty

```
Δ-difficulty = baseInc + physioInc + emoInc

int baseInc:
   if (cur_difficulty >= 85) return -3
   if (cur_difficulty >= 60) return -2
   if (cur_difficulty <= 15) return 3
   if (cur_difficulty <= 40) return 2


int physioInc:
   diff=0
   foreach physio_signal
      if (ph < baseline)   diff++
   return diff
```

Backup : Detailed Affective Dynamic Difficulty

```
int emoInc:
switch(emotion)
case HAPPINESS:return math.floor((100-cur_difficulty) / 10 )

case SADNESS:  return math.floor((100-cur_difficulty) / 10 * 0.5)

case SURPRISE: return math.floor((100-cur_difficulty) / 10 * 0.75)

case FEAR :    return math.floor(cur_difficulty / -10 * 0.5)

case ANGER :   return math.floor(cur_difficulty / -10 * 0.75)

case DISGUST : return math.floor(cur_difficulty / -10 * 0.8)
```