Haptic Feedback for Virtual Reality

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Introduction

- Background
  - Virtual Reality
  - Haptic Feedback
- ImpactVest (Tsai et al.)
  - Detailed walkthrough of design
  - Outcomes
- Other haptic technologies (Force Jacket, Delazio et al.)
- Future

Background

Virtual Reality

- Uses headsets, controllers, and motion tracking cameras for user interaction
- Speculated about since 1995[3], technology not capable then
- More and more commercially available and a viable technology
- Can be used for games, education, and therapy

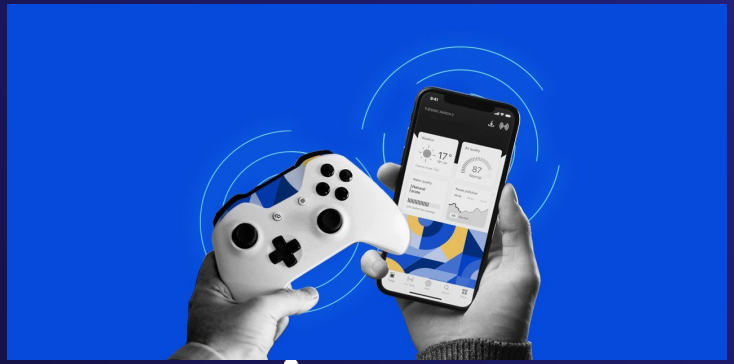
Background

Haptic Feedback

- Haptic feedback, as it relates to VR, is the usage of devices that render touch-related effects from the virtual environment in the natural

- Most often is vibrotactile (buzzing, small motors)

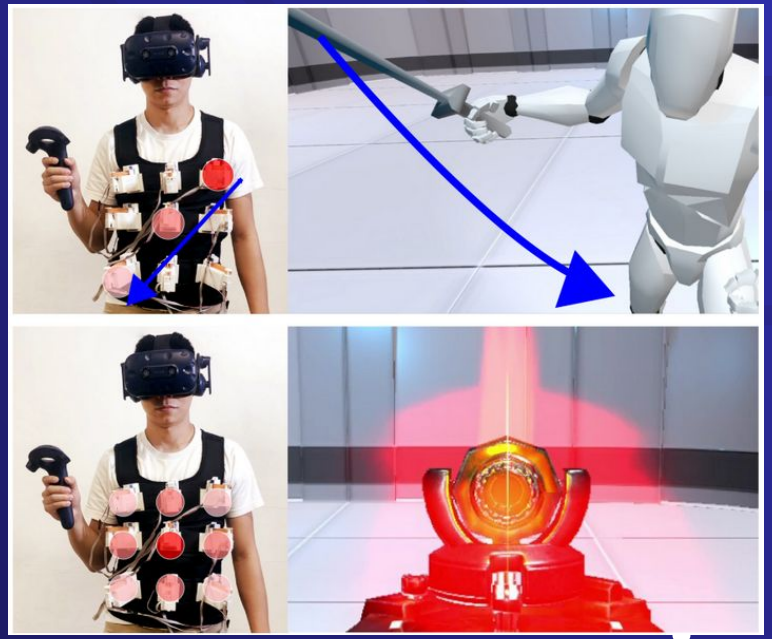
- Other forms include: pneumatics, instant impactors, etc.



ImpactVest[1]

(Tsai et al.)

- Inspired by previous work such as *Force Jacket* [2]
- “Instant impactors” -> shoots a rubber ball attached to rubber band wound by electric motor
- For use in games, render shots, slashes, explosions, punches, etc.



Design Considerations

Realism

Is the experience believable?

Elastic force for quick, high impact

Versatility

Can this method render more than one type of experience?

Independent controllers for timings, levels, positions

Comfort and Safety

Is there a balance in impact forces?

Placement and maximum force study

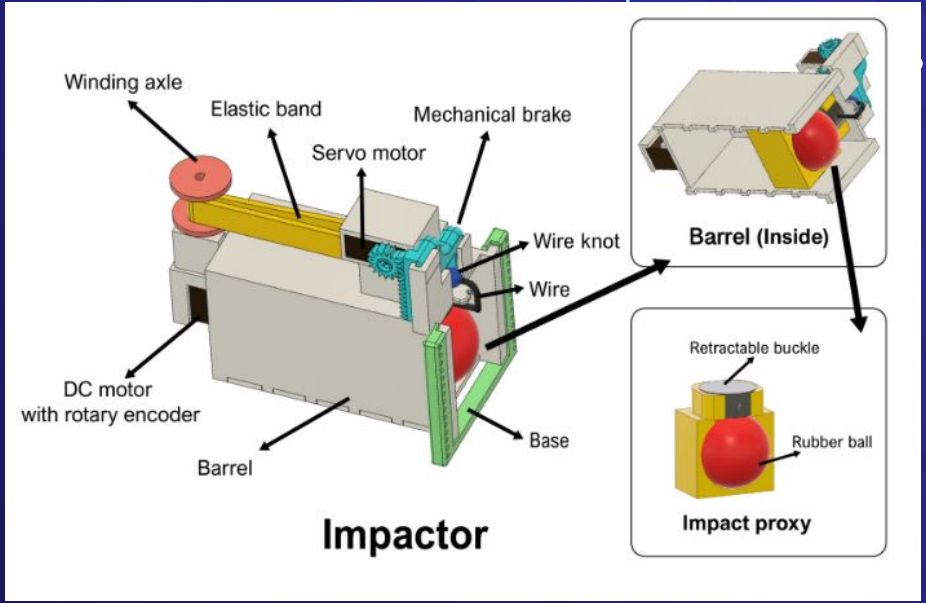
Mobility

Is the equipment bulky or a hindrance?

As light and compact as possible

Impactors

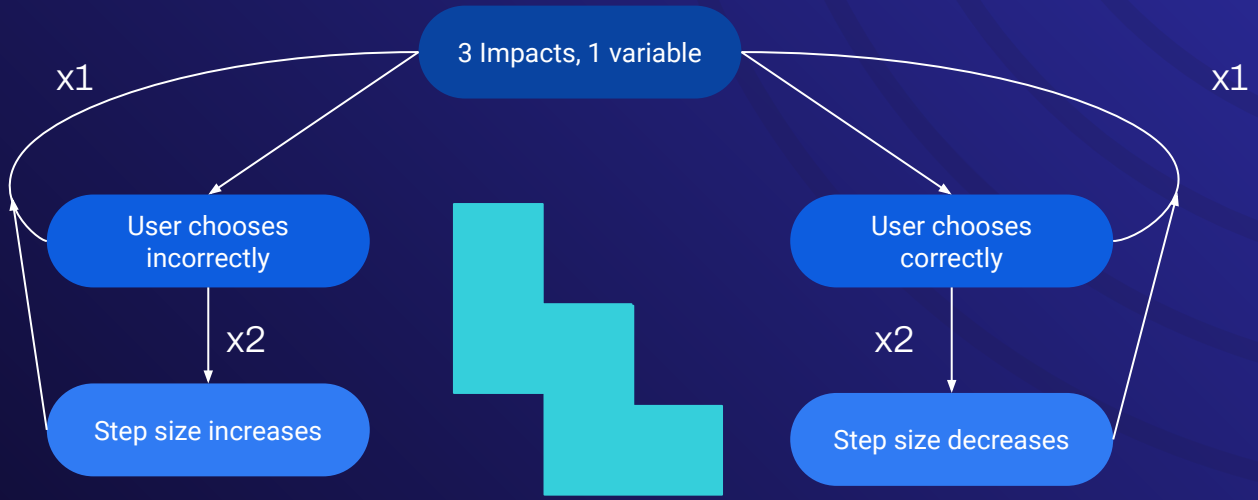
- Precise impactor (proxy)
- Small impact area -> higher perceived impact force
- Elastic band wound by DC motor



Just-Noticeable Difference (JND) Study

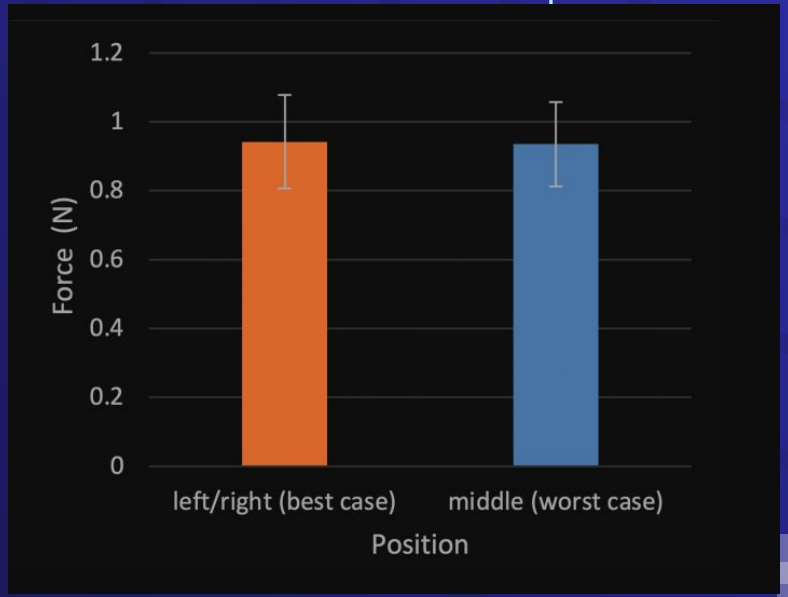
- Differentiate Impact Forces
- Adaptive staircase design
- 12 participants

- Base step size: 0.2 N
- Adjusted to 0.1 N
- Worst case, best case



JND Study

- Two results - ‘best case’, ‘worst case’ - based on location
- Results indicate *minimum difference required*
- ‘Best case’ - 0.935 N*
- ‘Worst case’ - 0.942 N



** Forces measured in Newtons (N)*

Time Interval Threshold Study

Goal:

Identify the time thresholds that separate users perceptions between discrete and simultaneous impacts

- Impacts too close together => same impact (simultaneous)
- Impacts too far apart => discrete impacts

Procedure:

- Same staircase design as JND study
- Base upper/lower bounds = 0 ms/160 ms
- Base step size = 20 ms
- Decreased by 5 ms after two reversals

Results:

- Lower bound = 32.57 ms
- Upper bound = 61.87 ms
- Averaged = 47.22 ms

VR Experience Study

Goal

Test the ImpactVest versus existing vibrotactile motors

Apparatus and Participants

- One trial with ImpactVest, one with vibrotactile motors (same layout)
- 12 participants

VR Environment (tests)

- Soldiers
- Swordsmen
- Boxer
- Cannon

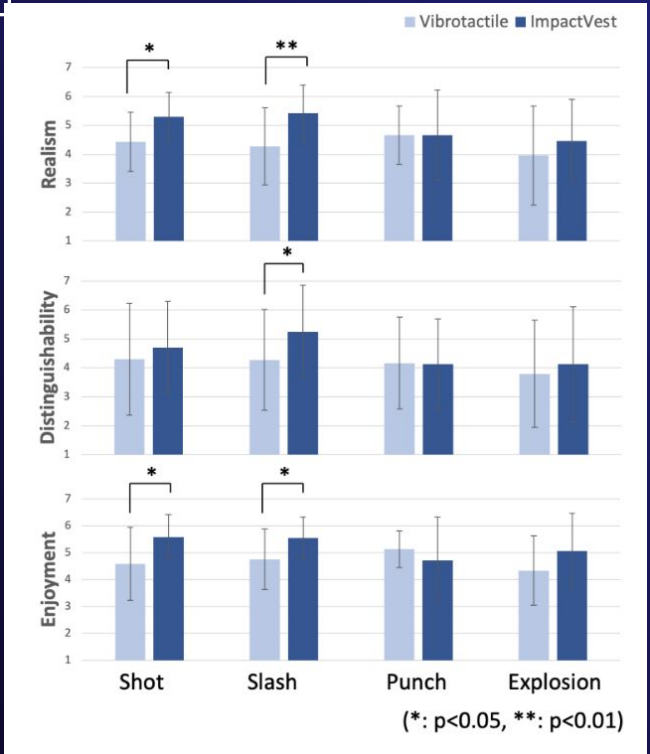
Procedure

- Users put in env, subject to different impacts
- Repeated with vibrotactile motors
- Survey, open-ended feedback

Results

Survey Results

7-point Likert scale



What does this mean?

- ImpactVest scored higher in all three categories for shot and slash
- No significant difference for punch and explosion
- Accomplishes realism and versatility goals

Open-ended feedback revealed:

- No mobility issues (design goal)
- Requests for *higher* force (comfort and safety)
- Vibro better at simulating ‘after effects’, i.e. numbness
- Speculation of combining

Force Jacket (Delazio et al.)

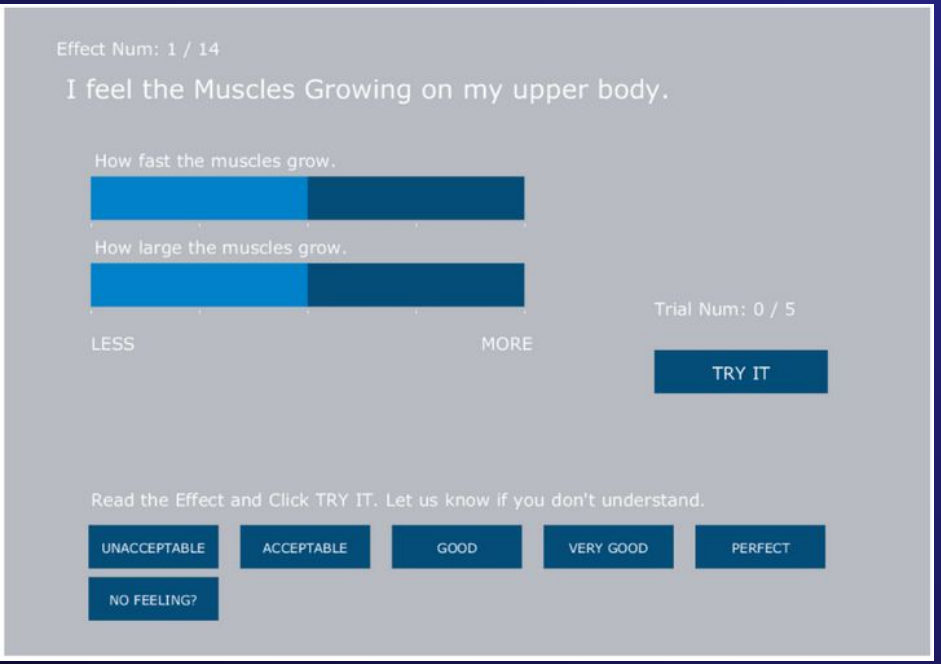
- Similar idea
  - Pneumatics
  - 26 distributed airbags
- Algorithms
  - Inflation/Deflation
  - ‘Fluttering’
- Preliminary Study
  - Localization Study
  - Free Magnitude Study
    - Some areas more sensitive

Force Jacket - Results

- Feel Effect User Study
  - Procedure
    - Parameters
    - Survey
  - ‘Feel Effect’
  - Goodness Ratings
  - Pay attention to icons
- Implications
  - Limitations
  - Future?

FEEL EFFECT	LIKE	DIS-LIKE	GOODNESS RATING
Motorcycle Vibration	14	2	4.39
Muscle Enhancement	8	4	4.18
Calm Heartbeat	9	2	4.12
Adult Hug	6	5	3.76
Snake Slithering around Body	12	1	3.71
Bug Crawling Up Arm	9	4	3.47
Snowball Hit on Chest	3	11	3.29
Fist Punch on Side	1	13	3.12
Heavy Rain	6	6	2.94
Slime Dripping on Back	6	5	2.94
Light Rain	7	7	2.65
Child Hug	9	2	2.65
Hand Tap on Shoulder	1	11	2.47
Racing Heartbeat	10	3	1.29

Force Jacket - Results cont.



FE	*Inflation Pressure (psi)*	*Time per Cycle (ms)*	*Target Force (N)*	*Duration (ms)*	*Target Frequency (Hz)*	*Motion Speed (in/s)*	Impact Dispersion (in)
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Future Prospects

- Different kinds of haptics and tactile feedback mechanisms
- Combinations
  - Tsai et al: “... we envision that impactors and vibrotactile actuators can be combined and complement each other to render more realistic and versatile feedback”
  - Downsizing

References

[1] Hsin-Ruey Tsai, Yu-So Liao, and Chieh Tsai. 2022. ImpactVest: Rendering Spatio-Temporal Multilevel Impact Force Feedback on Body in VR. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (New Orleans, LA, USA) (CHI '22). Association for Computing Machinery, New York, NY, USA, Article 356, 11 pages. https://doi.org/10.1145/3491102.3501971

[2] Alexandra Delazio, Ken Nakagaki, Roberta L. Klatzky, Scott E. Hudson, Jill Fain Lehman, and Alanson P. Sample. 2018. Force Jacket: Pneumatically-Actuated Jacket for Embodied Haptic Experiences. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (Montreal QC, Canada) (CHI '18). Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3173894

[3] Lawrence W. Stark. 1995. How virtual reality works: illusions of vision in "real" and virtual environments. In Human Vision, Visual Processing, and Digital Display VI, Bernice E. Rogowitz and Jan P. Allebach (Eds.), Vol. 2411. International Society for Optics and Photonics, SPIE, 277 – 287. https://doi.org/10.1117/12.207546

Questions!