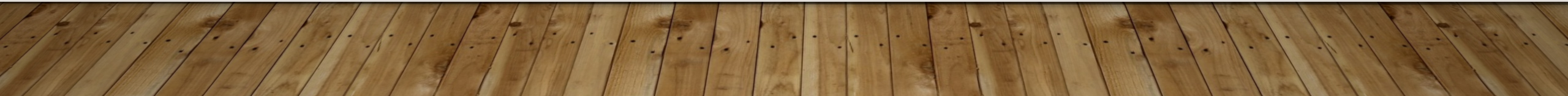


PHYSIOLOGICAL MEASURES OF PRESENCE IN STRESSFUL VIRTUAL ENVIRONMENTS

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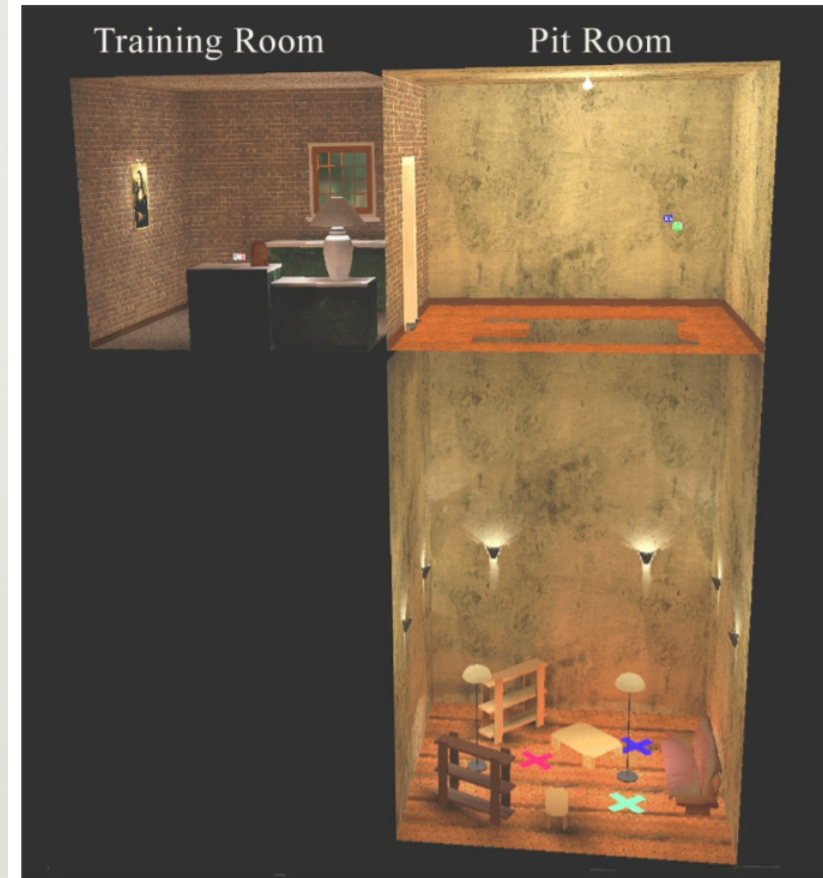
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EXAMPLE OF A STRESSFUL VIRTUAL ENVIRONMENT

- Training room
- Pit Room (with 20 ft. Hole)
- Living Room
- Three different experiments conducted



OUTLINE:

- Introduction
- The Environment and Measures
- Hypothesis
- Experimental Procedures
- Statistics
- Discussion
- Conclusion
- References

PRESENCE AND VIRTUAL ENVIRONMENTS (VE)

- A common measure of the quality and effectiveness of the VE is the amount of **presence** it evokes to the users
- *"Amount of Presence": The degree to which the VE creates in the user the subjective illusion or a sense of **being there** in the VE as opposed to the real one.*
- Presence is a subjective condition and has been so far measured by self-reporting (during the VE experience and immediately afterwards by filling in questionnaires)

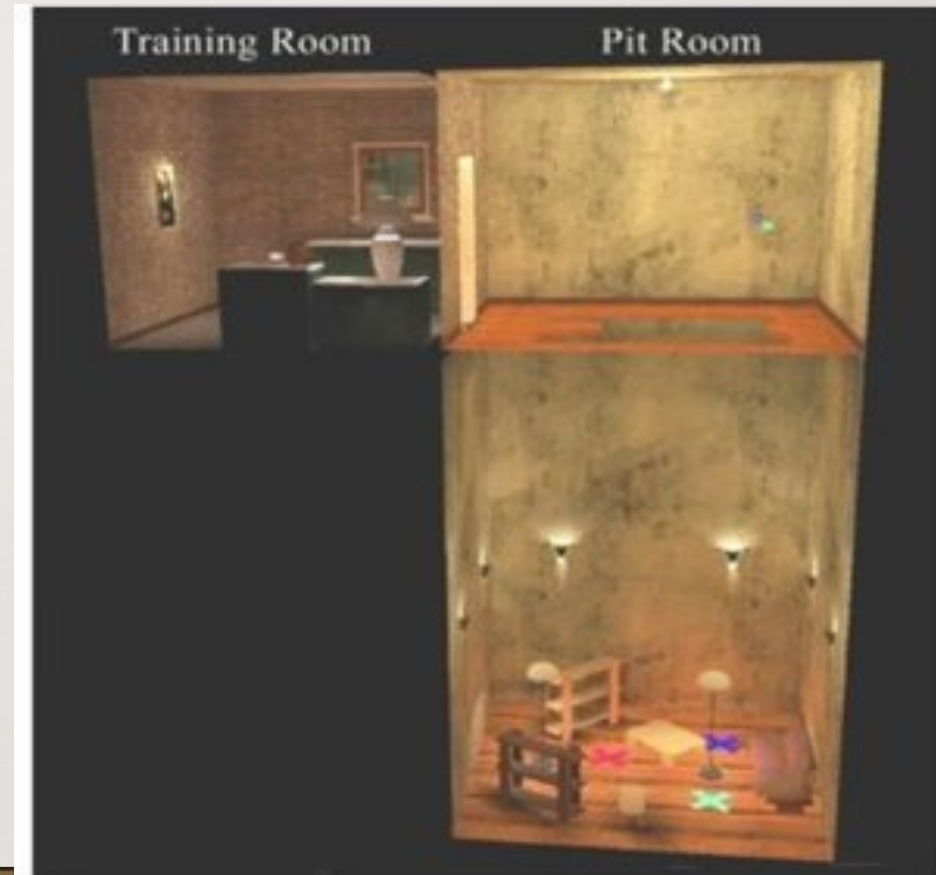
BEST WAY TO MEASURE PRESENCE?

Researchers have sought after a *presence measure* that is:

- **Reliable** – produces repeatable results, from trial to trial on same subject and across subjects
 - **Valid** – measures subjective presence, or at least correlates with well-established presence measures
 - **Sensitive** – discriminates among multiple levels of presence
 - **Objective** – is well shielded from subject and experimenter bias
- and ideally widely accepted and applicable.

THE ENVIRONMENT AND MEASURES

- Subjects start in the Training Room, practicing walking around and picking up and placing objects
- Later subjects are asked to enter the Pit Room



PHYSIOLOGICAL MEASURES AS ALTERNATE MEASURES OF PRESENCE IN STRESSFUL VE

Evaluation of three physiological measures:

- Change in Heart Rate

$$\Delta \text{ Heart Rate} = \text{mean HR}_{\text{Pit Room}} - \text{mean HR}_{\text{Training Room}}$$

- Change in Skin Conductance

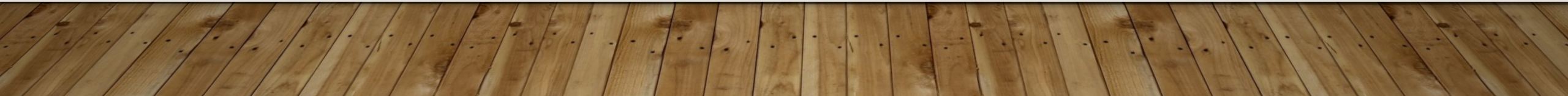
$$\Delta \text{ Skin Conductance Level} = \text{mean SC}_{\text{Pit Room}} - \text{mean SC}_{\text{Training Room}}$$

- Change in Skin Temperature

$$\Delta \text{ Skin Temperature} = \text{mean ST}_{\text{Pit Room}} - \text{mean ST}_{\text{Training Room}}$$

As alternative operational measures of presence in stressful virtual environments.

Each individual physiological measure was investigated for reliability, validity, sensitivity and objectivity.



REPORTED MEASURES

- **Reported Presence**

University College London (UCL) questionnaire with seven questions regarding presence

- **Reported Behavioral Presence** - does the user act as if in a similar real environment

UCL questionnaire with three questions regarding reported behavioral presence

*Responses for each question are on a scale from 1 to 7. Questions with responses $[\geq 5]$ were treated as "High Presence" and the rest as "Low Presence".

HYPOTHESIS

- *"... to the degree that a VE seems real, it will evoke physiological responses similar to those evoked by the corresponding real environment, and that greater presence will evoke a greater response. If so, these responses can serve as objective surrogate measures of subjective presence."*

EXPERIMENTAL PROCEDURES

Three experiments were conducted:

- Effects of Multiple Exposures on Presence (Multiple Exposures)
- Effects of Passive Haptics on Presence (Passive Haptics)
- Effects of Frame Rate on Presence (Frame Rate)

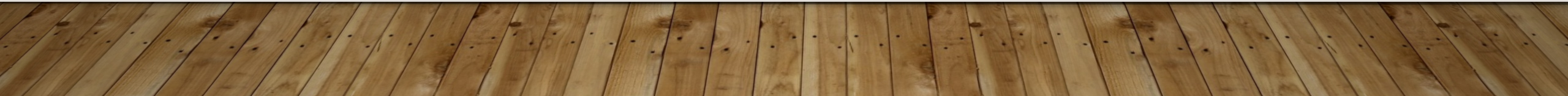
*Subjects who have experienced VE more than 3 times, are prone to motion sickness and had history with epilepsy and seizures were excluded from the experiments.

MULTIPLE EXPOSURES

- 10 subjects (average age 24.4; 7 female, 3 male)
- **Task:** Subjects were trained to pick up books and move around in the Training Room. Subjects then carried the virtual book to the Pit Room and placed it on the virtual chair on the far side of the Pit Room.
- **Number of times performed:** 3 times per day, on four separate days (12 times)
- **Question:** Does the presence in the VE decline with multiple exposures?

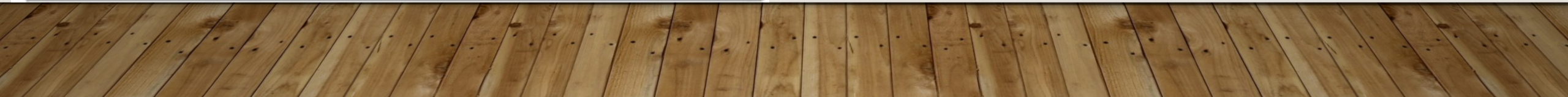
PASSIVE HAPTICS

- 52 subjects (average age 21.4, 16 female, 36 male) performed on 2 days
- Subjects experience the VE with 1.5-inch wooden ledge on one of their 2 days
- **Task:** Same as in Multiple Exposures, except subjects had to walk to the edge of the wooden platform, place their toes over the edge, and count to ten before they proceeded to the chair on the far side of the room to drop the book.
- **Question:** Does the 1.5-inch wooden ledge increase the presence in the VE?



Training Room

Pit Room

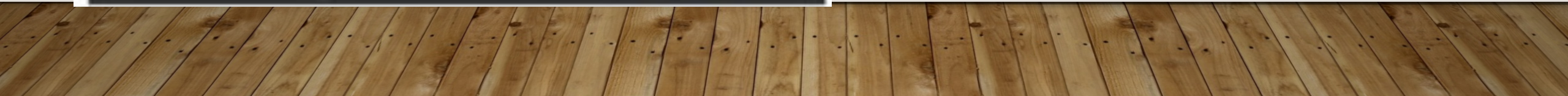


FRAME RATE

- 33 subjects (average age 22.3, 8 female, 25 male)
- **Number of times performed:** four times on one day each time same VE with a different frame rate (10, 15, 20 and 30 FPS)
- **Task:** Subjects had to pick up and drop blocks in the Training Room. They carried a red block to the Pit Room and dropped it on a red X-target. They plucked from the air two other blocks floating in the Pit Room and dropped each on the correspondingly colored Xs.
- **Question:** Does frame rate affect the presence in VE?

Training Room

Pit Room



STATISTICS

Study	Variable	All exposures				First Exposure Only (Between Subjects)			
		Mean	<i>P</i>	% > 0	N	Mean	<i>P</i>	% > 0	N
Multiple Exposures	ΔSkin Conductance	2.3 Δ mSiemens	< .001	99%	112	2.9 Δ mSiemens	.002	100%	9
	ΔSkin Temperature	0.6 Δ °F	< .001	77%	94	1.2 Δ °F	.015	100%	7
Passive Haptics	ΔHeart Rate	6.3 Δ BPM	< .001	89%	92	6.2 Δ BPM	< .001	85%	46
	ΔSkin Conductance	4.8 Δ mSiemens	< .001	100%	100	4.7 Δ mSiemens	< .001	100%	50
	ΔSkin Temperature	1.1 Δ °F	< .001	90%	98	1.1 Δ °F	< .001	94%	49
Frame Rate	ΔHeart Rate	6.3 Δ BPM	< .001	91%	132	8.1 Δ BPM	< .001	91%	33
	ΔSkin Conductance	2.0 Δ mSiemens	< .001	87%	132	2.6 Δ mSiemens	< .001	97%	33
	ΔSkin Temperature	0.8 Δ °F	< .001	100%	132	1.0 Δ °F	< .001	100%	33

STATISTICS

- Heart rate was **higher** in the Pit Room for 90% of the exposures to the VE
- Skin conductance was **higher** in the Pit Room for nearly 95% of the exposures to the VE
- Skin temperature was **lower** in the Pit Room for 90% of the exposures to the VE

- However, do the physiological reactions to the VE **diminish** over multiple exposures? Is habituation to the VE possible?

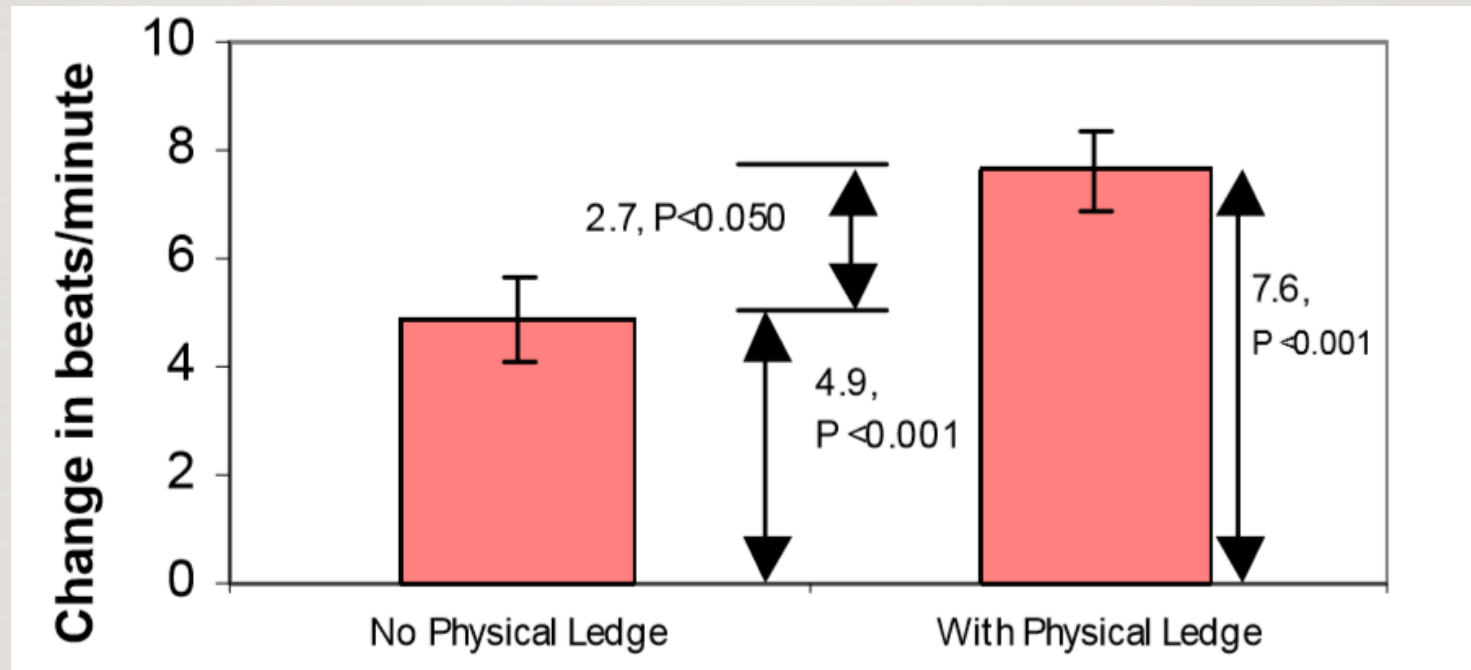
STATISTICS – MULTIPLE EXPOSURES

- Δ Skin Temperature, Reported Presence, Reported Behavioral Presence, and Δ Heart Rate each **decreased with multiple exposures** in every study (effect was not always statistically significant)
- Δ Skin Conductance **decreased** in *all but one* study.
- None decreased to zero even after 12 exposures.

Order Effects	Δ Heart Rate (Δ BPM)	Δ Skin Conductance (Δ mSiemens)	Δ Skin Temperature (Δ° F)	Reported Presence (Count “high”)	Reported Behavioral Presence (Count “high”)
Multiple Exposures	NA	-0.7 (1 st)	-0.9 (1 st)	-	-0.7 (1 st)
Passive Haptics	-	-	-	-0.8 (1 st)	-0.4 (1 st)
Frame Rate	-1.0 (Task)	-0.8 (1 st)	-0.3 (1 st)	-	-0.2 (Task)

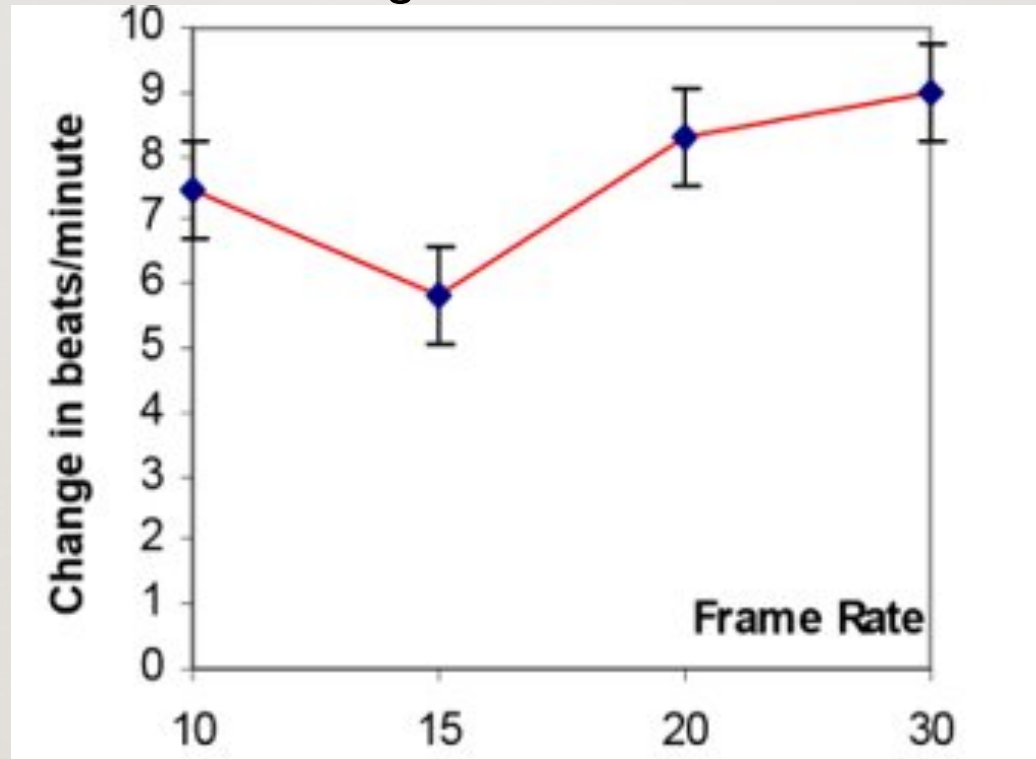
STATISTICS – PASSIVE HAPTICS

- Change in Heart Rate in the Passive Haptics experiment with and without physical ledge.



STATISTICS – FRAME RATE

- Change in Heart Rate after correcting loss of balance at 10, 15, 20 and 30 FPS



DISCUSSION

- Out of the 3 psychological measures Δ **Heart Rate** performed best.
- Δ Heart Rate significantly differed between the Training Room and the Pit Room
- After Multiple Exposures did not decrease to 0
- Distinguished the presence/absence of Passive Haptics
- Differentiated between Frame Rates
- Satisfies all requirements of a presence measure
- However it **may not** be a useful presence measure in less stressful environments

DISCUSSION

- Δ **Skin Conductance** did yield significant differentiation in some of the experiments but was not as consistent as the Δ Heart Rate. Namely, it did not differentiate between the Frame Rates.
- Δ **Skin Temperature**, despite having same response curves as Δ Heart Rate, is less sensitive, less powerful and slower.

CONCLUSION

- *Amount of Presence* as a quality measure of VE
- The physiological measures: Δ Heart Rate, Δ Skin Conductance , Δ Skin Temperature as alternate measures of presence in stressful VE
- The three experiments have shown:
 - Passive haptics increase presence in VE
 - Multiple exposures to the VE decreases presence, but does not lead to full habituation
 - Frame rate affects presence
- Δ Heart Rate as a consistent, reliable, valid, sensitive and objective measure of Presence in stressful VE

REFERENCES

All data, figures and tables were taken from:

- Michael Meehan, Brent Insko, Mary C. Whitton, Frederick P. Brooks Jr.:
Physiological measures of presence in stressful virtual environments. *ACM Trans. Graph.* 21(3): 645-652 (2002)