We Know More than We Can Tell: How Game-based Learning Assessments Help Students Demonstrate their Knowledge

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Today’s Perspectives

- Characterizing *implicit learning*
- Exemplar: Implicit Learning in a Physics Game
- On the horizon

Disclaimer

These opinions are our own, they are not the opinions of MIT, any of the project funders, nor (with the exception of co-authored previously published work) our collaborators

Secondary disclaimer:

“It’s tough to make predictions, especially about the future!”

-- Attributed to Woody Allen, Yogi Berra, Niels Bohr, Vint Cerf, Winston Churchill, Confucius, Disreali [sic], Freeman Dyson, Cecil B. Demille, Albert Einstein, Enrico Fermi, Edgar R. Fiedler, Bob Fourer, Sam Goldwyn, Allan Lamport, Groucho Marx, Dan Quayle, George Bernard Shaw, Casey Stengel, Will Rogers, M. Taub, Mark Twain, Kerr L. White, etc.

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Related Publications

- Alstad Z, Dahlstrom-Hakki I, Asbell-Clarke J, Rowe E, Altman M. The Use of Multidimensional Biopsychological Markers to Detect Learning in Educational Gaming Environments. Working Paper.
- Asbell-Clarke J, Rowe E, Dahlstrom-Hakki I, Alstad Z, Altman M. (Poster) Revealing the Invisible, in Washington, D.C.: Cyberlearning PI Meeting 2016; 2016.

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Combining Education-, Cognitive- & Information- Sciences

IDEAS LAB

Characterizing Implicit Learning

Implicit Learning

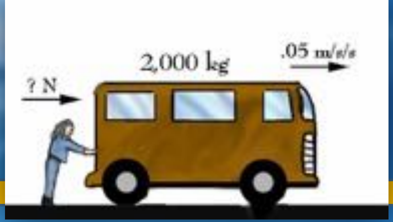
What Lies Below?

We know more than we can say - Polanyi (1966)

Explicit Knowledge
- What we can say

Behaviors
- What we do
- How we respond

Implicit Knowledge
- What we know



External Assessments

Explicit Knowledge

Bridging

Neurophysical Sensors

Data Mining Game Behaviors

Implicit Knowledge

Mining Digital Games

Why?

- Games are sticky
- Digital games create digital footprints
- Reveal implicit learning through behaviors
- Inclusive assessments

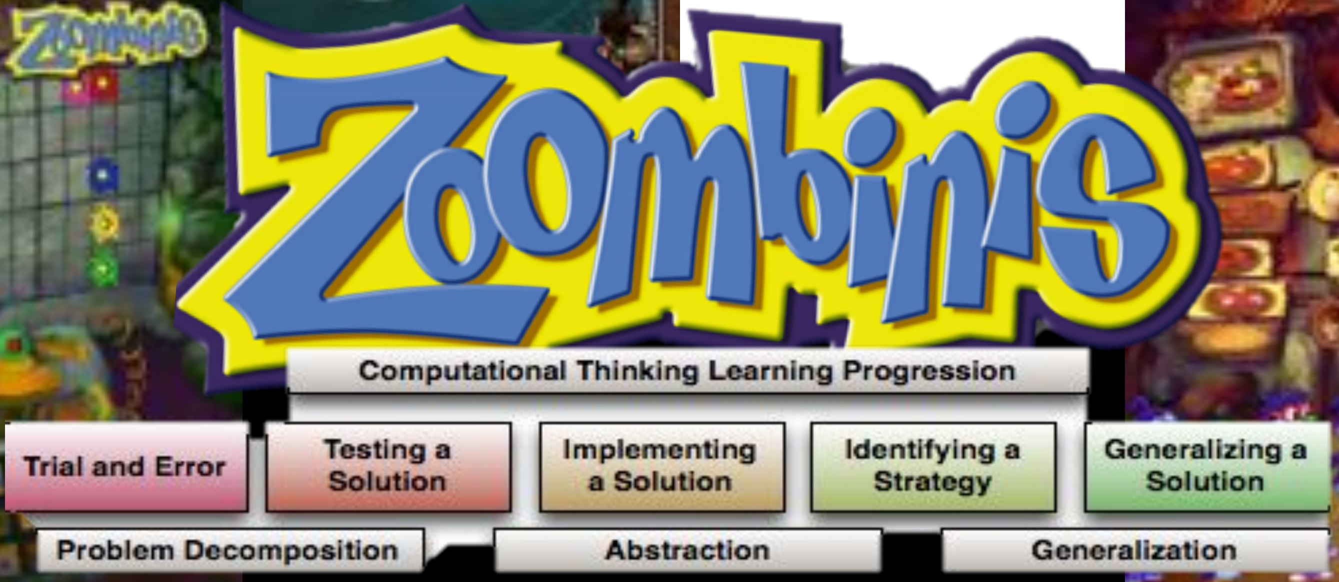
How?

1. Ground games in salient phenomena
2. Use data analytics to watch implicit learning
3. Provide support for educators to bridge implicit to explicit

and Development Organization

Newton's Laws of Motion

Optics



Implicit Learning in a Physics Game

Revealing the Invisible

Welcome to IMPULSE

Evidence of Learning

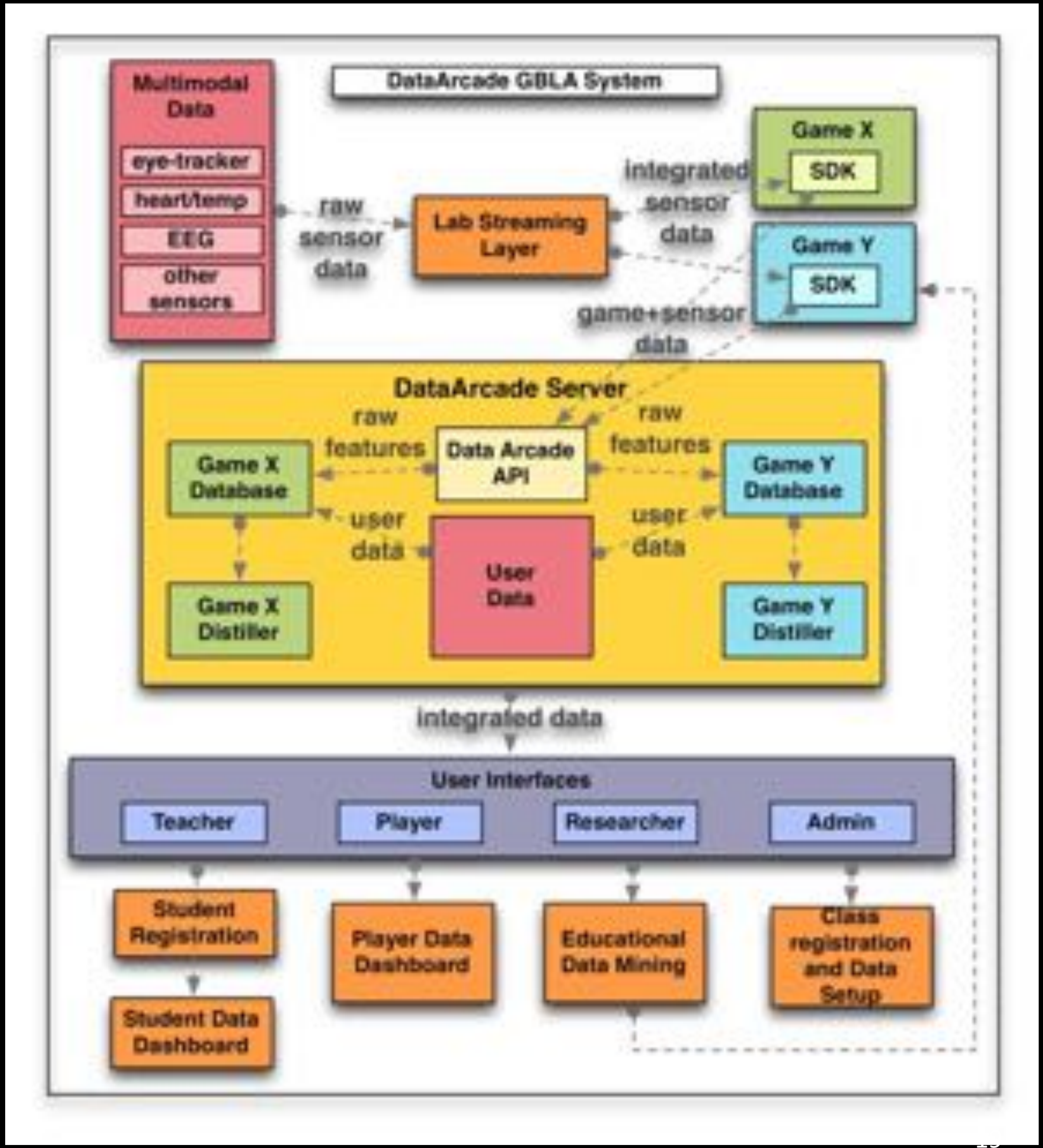
Game Behaviors

Data mining models identify when players demonstrate implicit understanding of salient phenomena

Implicit Game-Based Learning Assessments

DataArcade

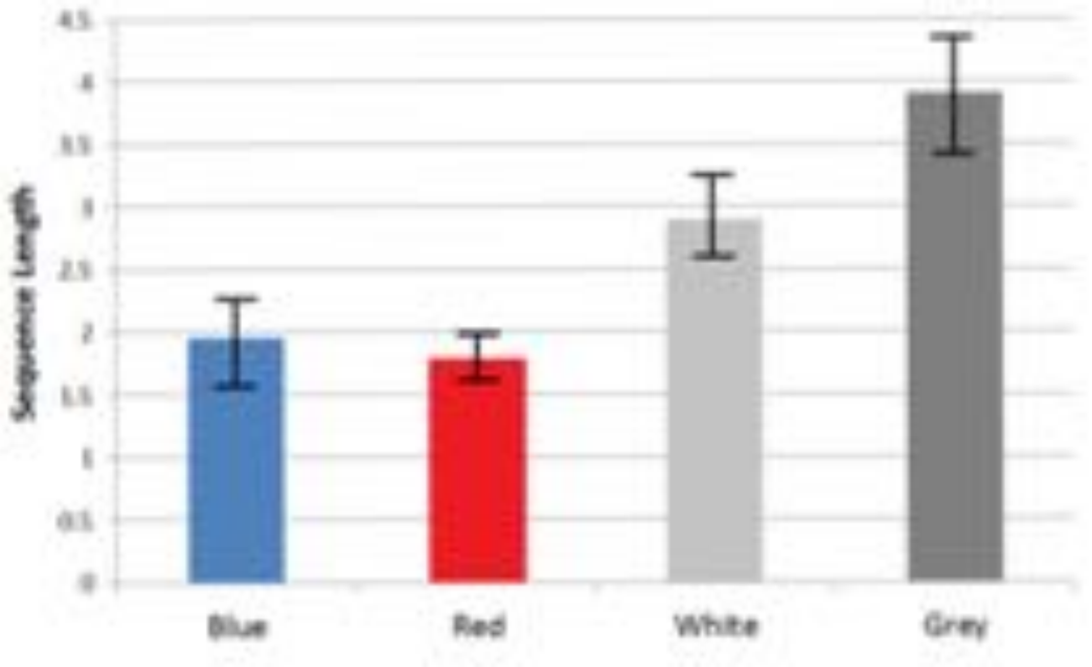
Multimodal Data Architecture for Game-Based Learning Analytics



EDM Findings for Game-Based Assessments of Physics Learning In Impulse

Intended Strategic Move	Kappa	AUC
Float	0.738	0.901
Move Toward Goal	0.757	0.907
Stop/Slow Down	0.512	0.779
Keep Player Path Clear	0.865	0.967
Keep Goal Clear	0.772	0.943
Buffer	0.759	0.928

...onsistent with Implicit understanding ...s 1st Law



Mass Differentiation consistent with implicit understanding of Newton's 2nd Law

Evidence of Attention

Awareness of All Objects

Inattentiveness to relevant game events can be used as a filter

Longer Fixations on Gameplay Relevant Objects

Implicit learning may be indicated by attending longer to more gameplay critical objects

Tracking Attention in Impulse

Event Related Potentials

Error Negativity (Ne)

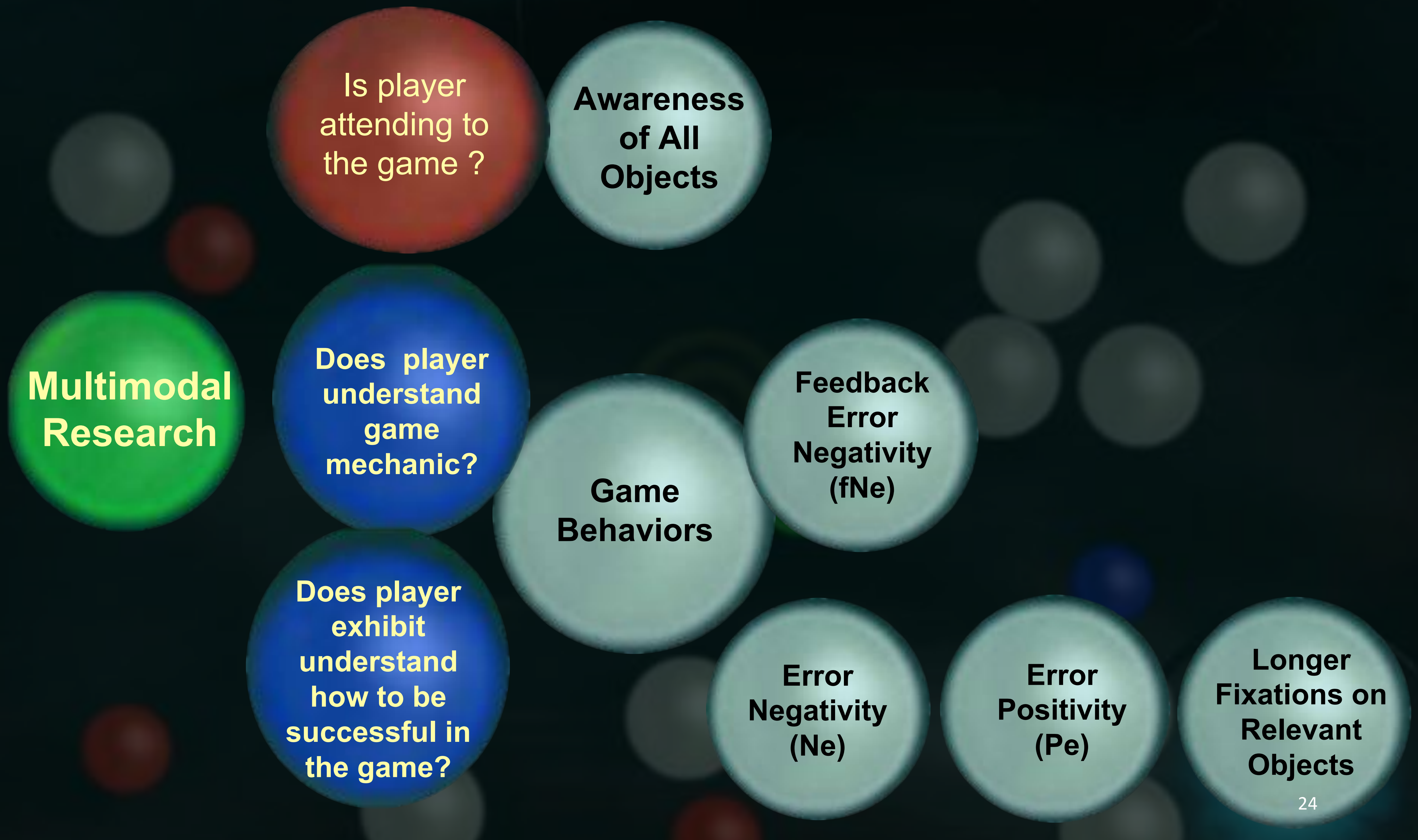
Negative ERP typically occurring 50-80 ms following an erroneous response

Error Positivity (Pe)

Positive ERP typically occurring 100-200 ms following an erroneous response

Feedback Error Negativity (fNe)

Negative ERP typically occurring 250-300 ms following the presentation of feedback that an error has occurred


Multimodal Research
Is player attending to the game ?
Awareness of All Objects
Does player understand game mechanic?
Game Behaviors
Feedback Error Negativity (fNe)
Does player exhibit understand how to be successful in the game?
Error Negativity (Ne)
Error Positivity (Pe)
Longer Fixations on Relevant Objects

Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it

Game Behaviors

Float

Stop/Slow

Clear Path

Attention

Fixate Path

Fixate Clear Path

Fixate Potential Colliders

ERP

fNe following a collision due to poorly placed impulse

Ne and Pe following an action leading to a collision (prior to colliding)

The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object

Game Behaviors

n-clicks by target type

Attention

Fixate high mass colliders at longer distances

Fixate path proportional to exerted force

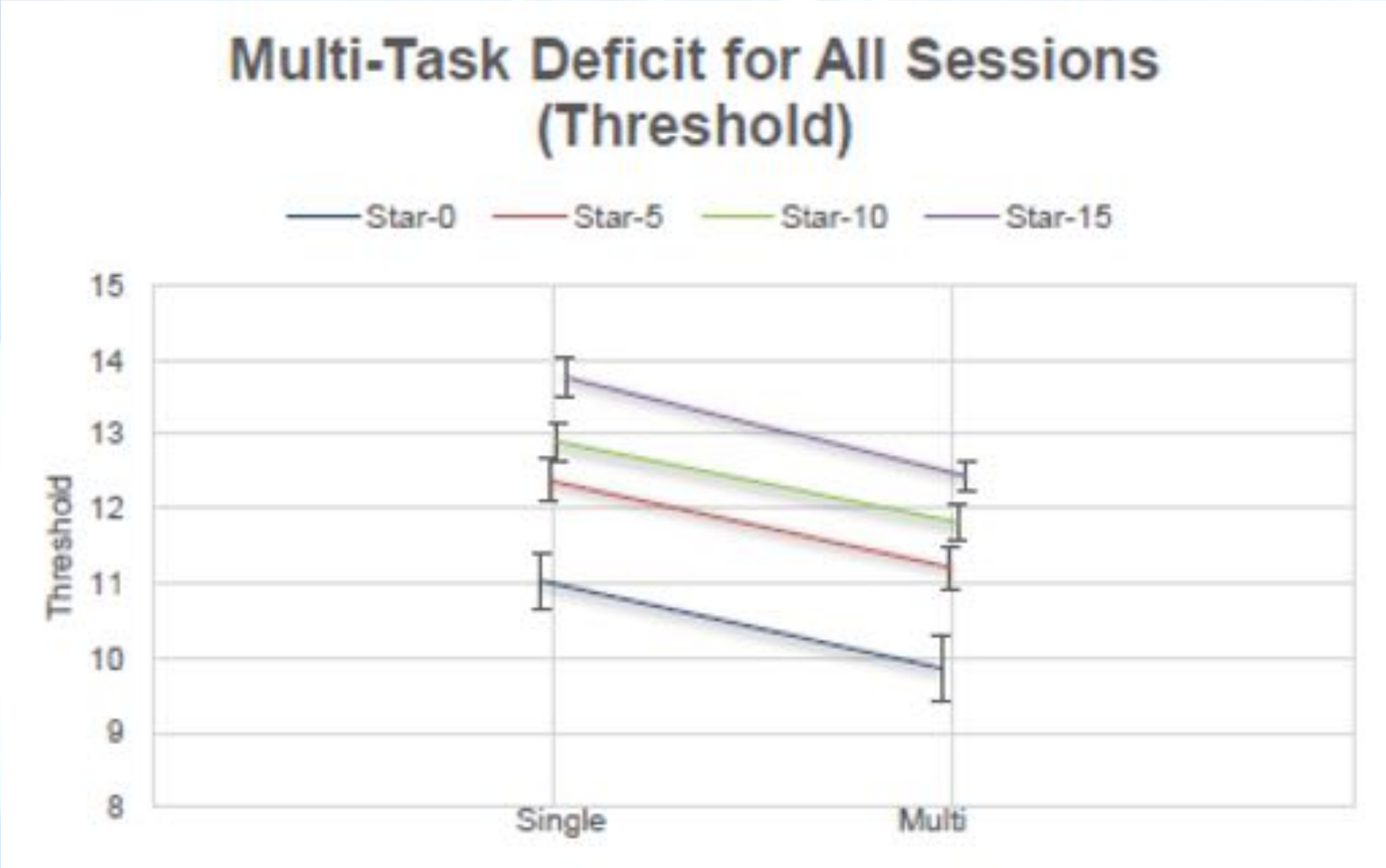
ERP

Ne and Pe following poor direction or insufficient force exertion

On the Horizon

Navigation and Go/No Go Task

Pilot


Multi-Task Deficit for All Sessions (Threshold)
Star-0
Star-5
Star-10
Star-15
15
14
13
12
11
10
9
8
Threshold
Single
Multi

Pilot

- Training leads to improvements on navigation and go/no go tasks
- Will training improve learning outcomes?
- Will improvements persist for students with EF disorders?

Far Transfer

- Full four week training protocol
- Pre/post eye tracking during reading and search tasks
- Looking for fewer regressions, fewer saccades to distractors and fixation durations guided by target processing
- Improvements signal the potential for downstream gains on real-world academic tasks

Whats on Horizon

- Curricular Materials
- Tools
- Sensors

Curriculum Resources

- High-quality interactive math-and science simulations for education

https://phet.colorado.edu/

- Games to promote scientific discovery, STEM learning, cognitive skill training , and games that explore collective over individual intelligence.

- Curriculum toolkit – lesson plans

http://centerforgamescience.org/games/

Curriculum Resources

MATTI MATH

- library of uniquely interactive virtual manipulatives for K-12 mathematics instruction

http://nlvm.usu.edu/en/nav/vlibrary.html

Edge

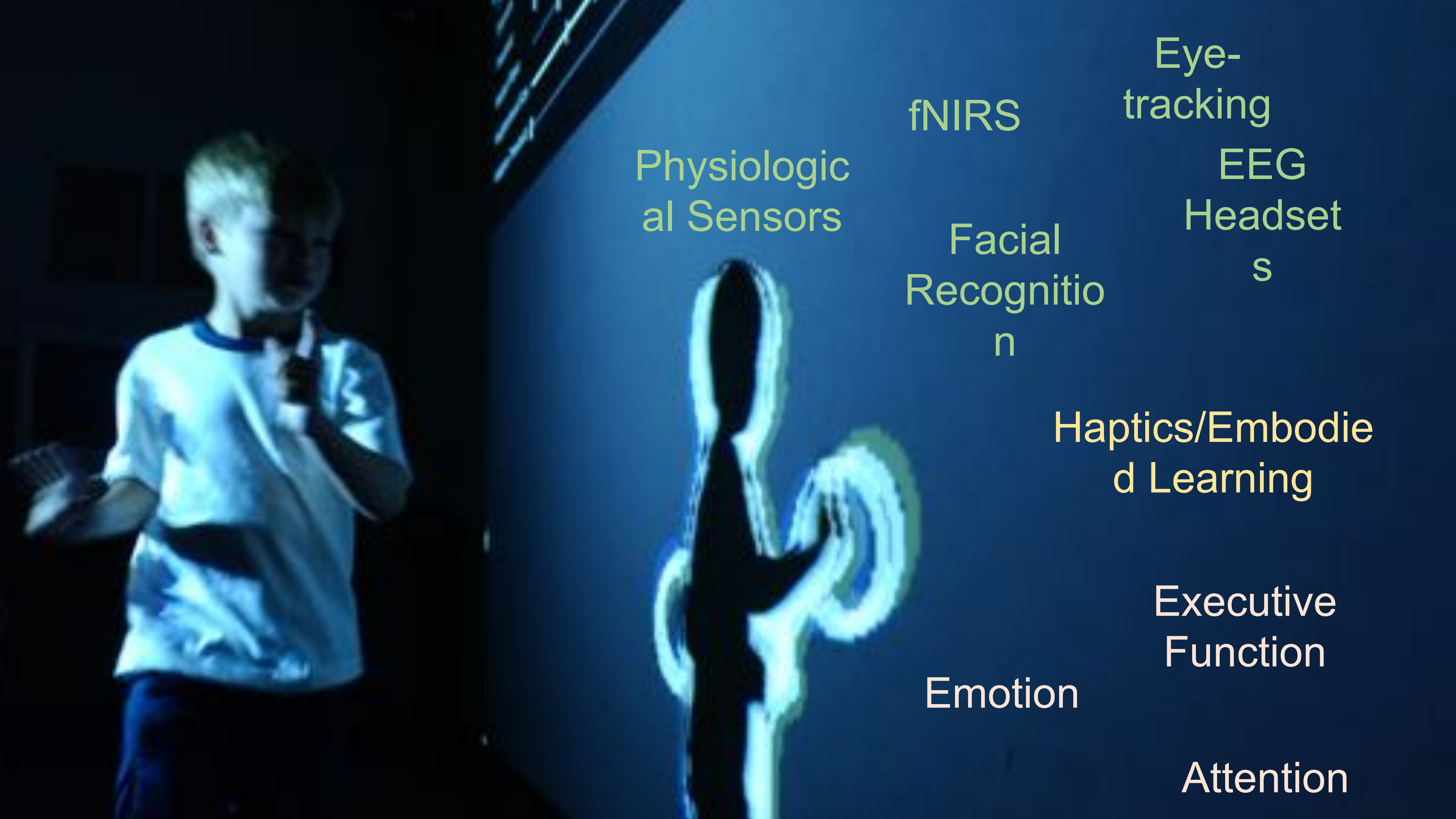
- The home of the beloved Zoominis
- Free-choice STEM learning games

Edge.terc.edu

CREATE

- STEM learning games
- Based on research from Create Labs (http://create.nyu.edu/)

http://create.nyu.edu/dream


Physiologic
al Sensors
fNIRS
Eye-
tracking
EEG
Headset
s
Facial
Recognitio
n
Haptics/Embodie
d Learning
Executive
Function
Emotion
Attention

Emerging Commodity Technologies

- Motion and heart-rate
- Virtual / augmented reality
- Face Tracking
- Eye tracking
- FNIR -- EEG

Now

5 Years

Commodity Technologies Available Now

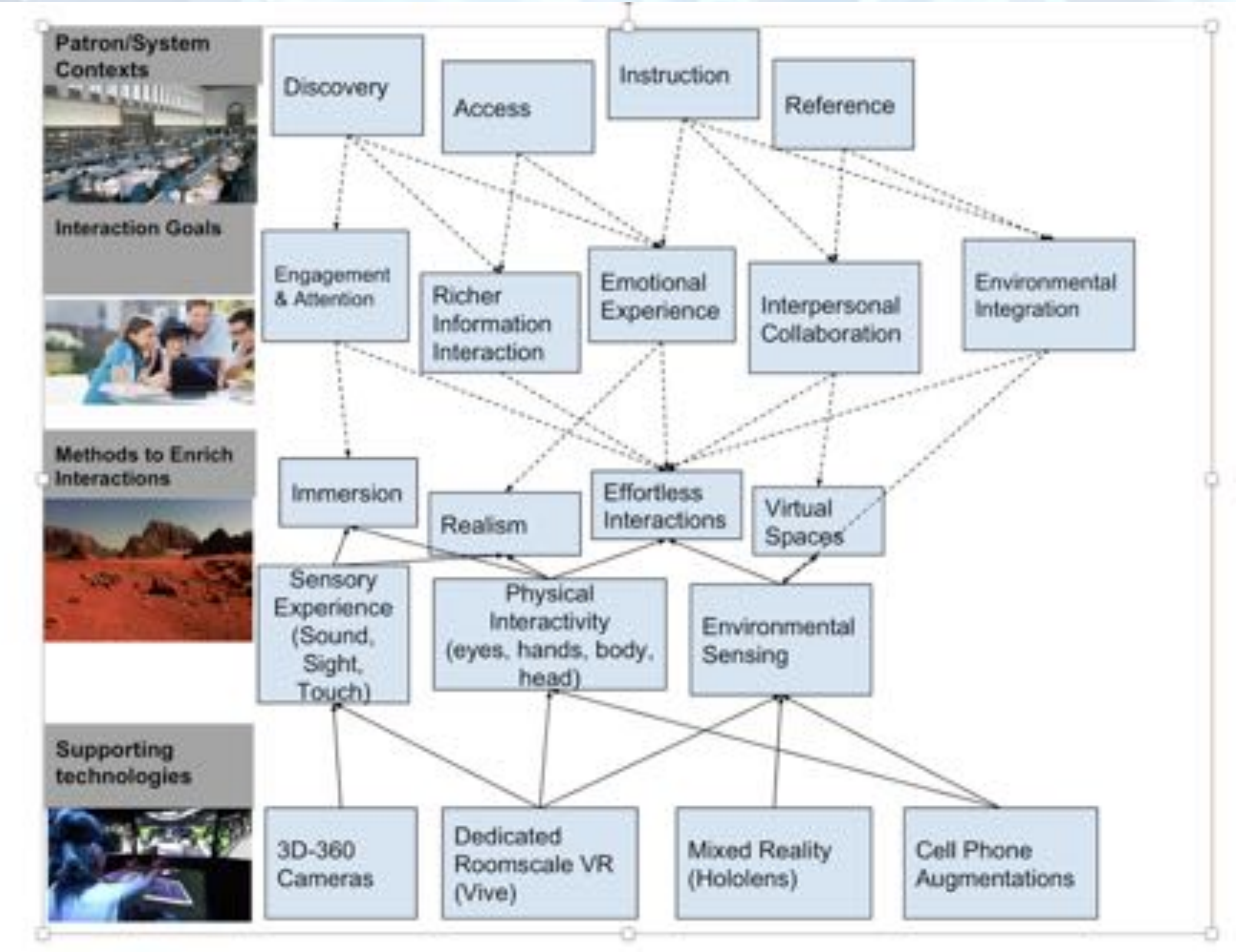
Motion and heart-rate

- Measures physical activity and arousal, relevant to immersion, emotion, attention
- Decreasing size & cost
- Increasing battery life, accuracy, connectivity
- Electrodermal monitoring sensors emerging

VR, MR, and AR

- Decreasing size & cost
- Increasing portability
- Can capture body position, head position
- Offers new interaction affordances
- Emerging eye-tracking integration

VR Potential for Instruction and Information Interaction



Commodity Technologies Coming Soon

Face Tracking

- Face recognition hardware & api’s increasingly common in mobile devices
- Face tracking not yet commonly available

Eye & Gaze Tracking

- Eye tracking hardware rapidly decreasing in price
- 60Hz consumer hardware readily available
- Robustness over individuals is a challenge – may go off track
- Not for real time adaptation

Technologies On the Horizon

EEG

- Needed for measurements of memory activity
- Consumer products are emerging, but not yet much above “toy” grade

FNIR

- Research grade pricing drop significantly
- Consumer products emerging in Japan
- Pre-frontal cortex – cognitive burden, processing load

References

- Alstad Z, Dahlstrom-Hakki I, Asbell-Clarke J, Rowe E, Altman M. The Use of Multidimensional Biopsychological Markers to Detect Learning in Educational Gaming Environments. Working Paper.
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For More Information

Project Website:
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edge.terc.edu

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