From Psychology Experiment to Physics Lab: Feeling Angular Momentum

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AAPT Winter Meeting
New Orleans
12 January 2016

Work supported by the National Science Foundation through FIRE DRL-1042955

Our group explores embodied activities, in which students directly feel the physics concept.

The vector nature of angular momentum

Torque = (change in Angular Momentum) / (change in time)

$$\tau = \frac{\Delta L}{\Delta t}$$

Torque & Angular Momentum are vectors

Tilting the axle means:

- Direction of L vector changes
- ΔL is ***not*** zero
- Person tilting the axle ***feels*** a resistive force

The Embodied Experience:

First study: a Psychology/Cognitive Science Experiment*

- We used an algebra-based introductory physics class
- Traditional lecture / lab format
- In the lab, students were assigned to one of two groups:
  - Actors – handled the wheels
  - Observers – did NOT handle the wheels
- 56 students included in the study

Guide students to vary

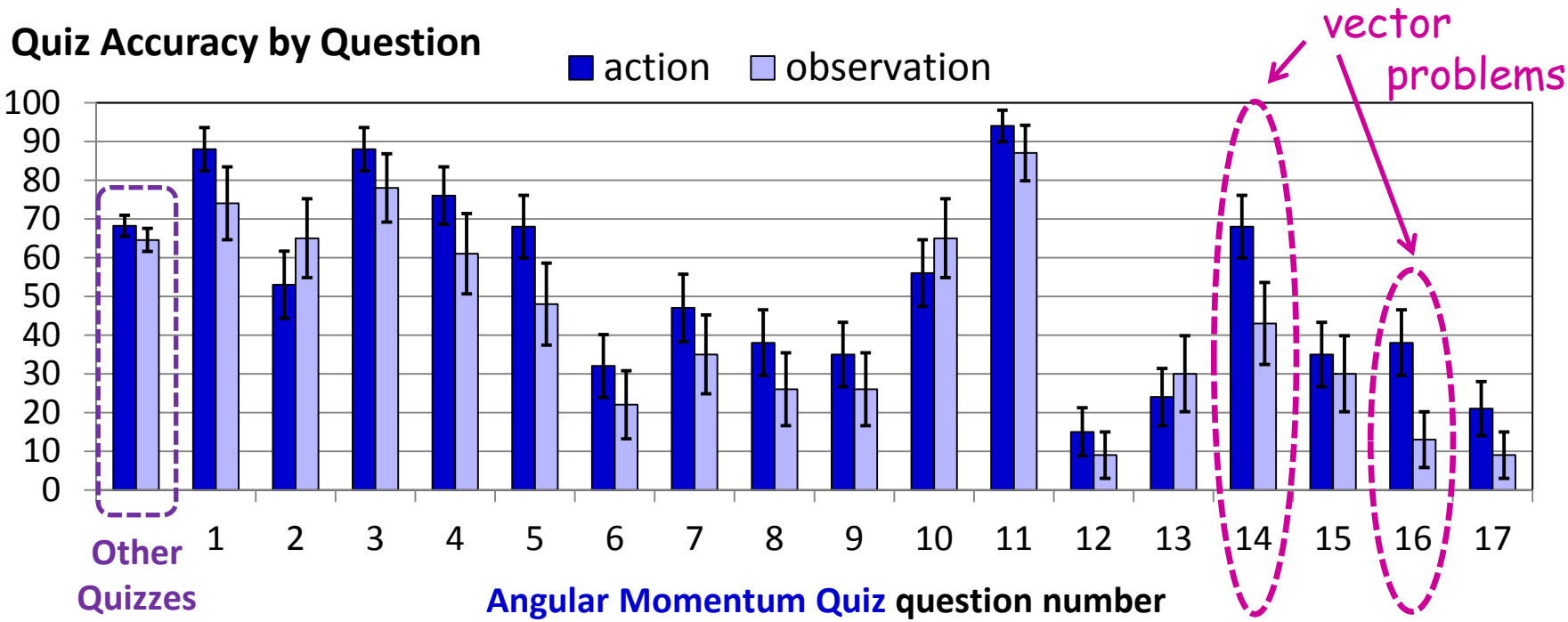
- wheel size
- spin speed
- spin direction
- tilt speed

* Carly Kontra, *et al.*, "Physical Experience Enhances Science Learning," Psych. Sci., 26, 737 (2015).

Does the embodied experience enhance student learning?

Students took a quiz the same week as their lab
and BEFORE doing homework.

Actors have better performance on problems that rely on
the vector nature of angular momentum.



Second Study:

Can we Transform the Psychology Experiment into a Physics Lab?

Necessary Ingredients

Cognitive Science

- Order the embodied experiences so there is a high degree of contrast between actions
- Actions must be repeated multiple times
- Don't analyze the experience while you're doing it

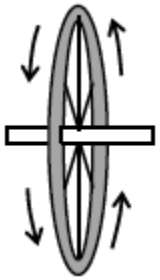
Physics Education

- Active engagement
- Predictions precede the experience and analysis
- Include exploratory or discovery aspects

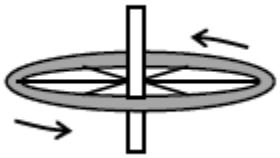
N = 98 in the physics lab study

The 2-hour Physics Lab

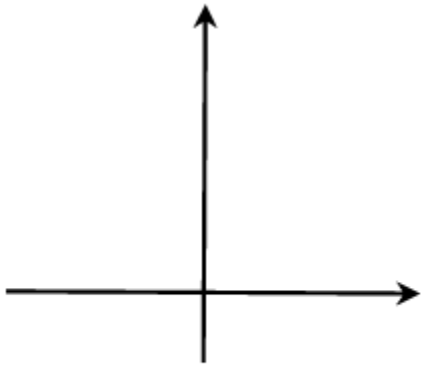
- Online pre-lab assignment with short reading and several questions
- Initial interaction with the wheels – tilt the axle by 90 degrees 6 times:
  - Contrast not spinning vs. 1 wheel spinning very quickly
- Introduce the right hand rule, and create a graphical representation of the vector relationship: $\vec{L}_{final} - \vec{L}_{initial} = \Delta \vec{L}$



draw $\mathbf{L}_{initial}$



draw $\mathbf{L}_{final}$

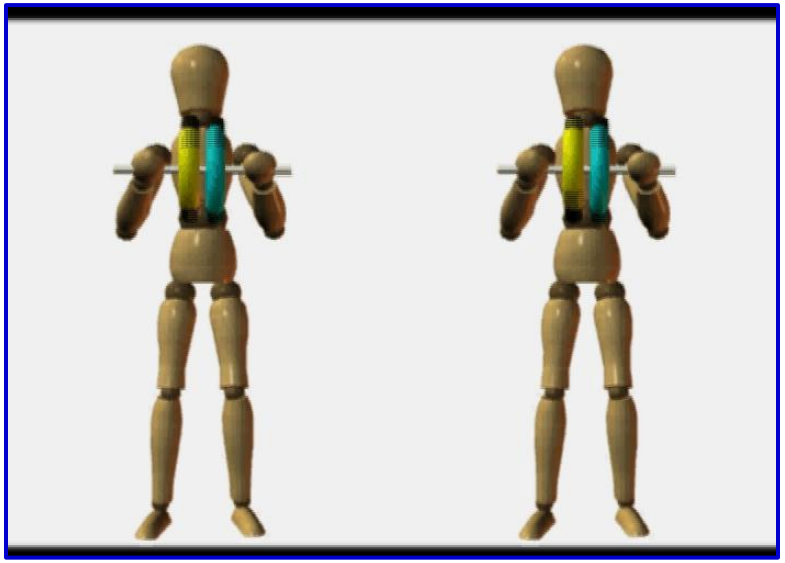


draw a graphical representation for $\mathbf{L}_{final} - \mathbf{L}_{init} = \Delta\mathbf{L}$.

- Introduce the relationship between torque and angular momentum.

The 2-hour Physics Lab (more)

A: Woody B: Woody's friend



- View simulations and make predictions:

  Who feels more resistance?

- Second embodied activity – tilt the axle by 90 degrees 6 times
  - Not spinning (control)
  - 1 wheel spinning quickly
  - 2 wheels spinning quickly in the same direction
  - 2 wheels spinning quickly in the opposite direction
  - Not spinning (control)
- Analyze – How do these experiences prove that angular momentum is a vector?

The 2-hour Physics Lab (last)

- Predictions and explorations (without guidance) considering:
  - Size of wheels
  - Spin speed of wheels
  - Tilt speed of the axle

- Closing "Group Summary" questions based on simulations

Woody Woody's friend

Does Woody experience more, less or the same torque as his friend?
How do you know this? Base your answers on physics equations and/or concepts and on your vector drawings from the previous question.

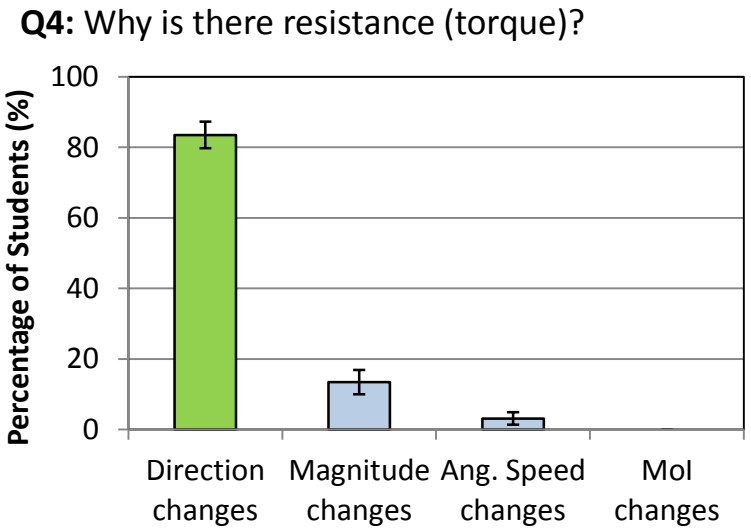
Comparing Student performance on Quizzes – the Casey Question

Casey is wondering **why** he **experienced a significant resistance, or torque**, when he tilted the axle of a spinning double bicycle wheel in his physics lab. His **TA correctly explains** that

A. The **direction of the angular momentum vector** of the system **changes** as the axle is tilted.
B. The **magnitude of the angular momentum** of the system **changes** as the axle is tilted.
C. The **angular speed** of the wheels **changes** as the axle is tilted.
D. The **moment of inertia** of the system **changes** as the axle is tilted.

Percentage correct in original study
Actors: 56 (9)
Observers: 65 (10)

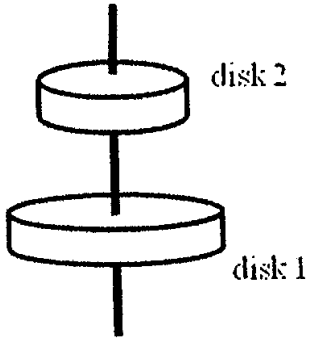
Embodied physics lab (new study)
Percentage correct: 84 (4)



Comparing Student performance on Quizzes – Double wheel flip (A)

7. Two disks are free to rotate about the same axle. The moment of inertia of disk 1 is 5.1 kg·m^2, and the moment of inertia of the disk 2 is 1.6 kg·m^2. Disk 1 spins counterclockwise with an angular speed of 2.7 rad/s, and disk 2 spins clockwise with an angular speed of 4.2 rad/s.

   A. What is the magnitude of the angular momentum of the two-disk system?



Percentage correct in original study

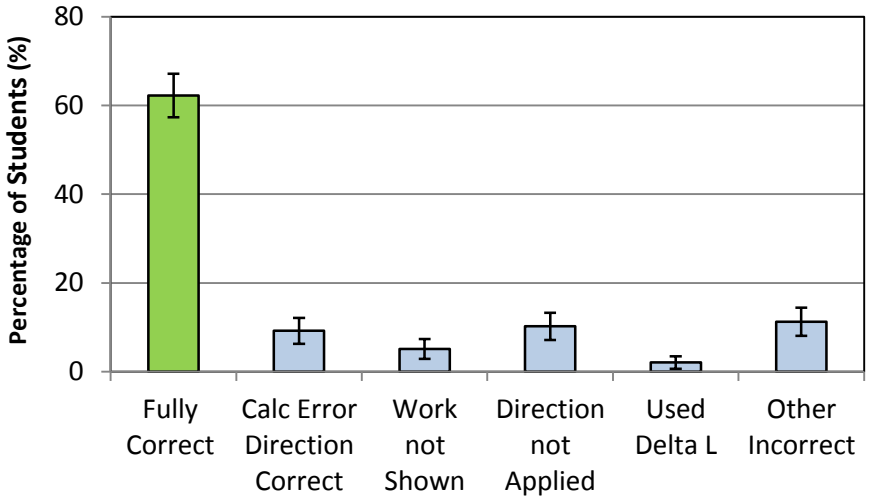
Actors: 68 (8)

Observers: 43 (11)

Embodied physics lab (new study)

Percentage correct: 62 (5)

Q7A: Magnitude of L of system



Results:

- We have transformed the heavily scripted original lab activity to a much more reasonable physics lab that maintains what we feel are the key features of the embodied experience.
- Student performance on the quiz is similar or improved when we compare the physics lab study with the original study.

Open Questions related to Embodied Learning:

- How much repetition of an embodied action is necessary to ground the experience?
- Is it critical to isolate the embodied experience from analysis of the experience?

Thank you - sfischer@depaul.edu