Learning From Where Students Look While Observing Simulated Physical Phenomena

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Introduction

- The Ohio State University's (OSU) Physics Education Research Group has been developing and testing Virtual Reality (VR) simulations
- Winter quarter, 2005, we worked in conjunction with OSU's Center for Cognitive Science Eye Tracking Lab for an exploratory study of how students use the simulations
- This poster discusses:
  - An introduction to the VR simulations
  - Our recent research using the eye-tracking lab, and
  - Implications for future research questions which could be studied using this technology

The Virtual Reality Simulations

- Two VR simulations were used in this experiment –Linear Motion VR and Collisions VR
  - These were chosen because frames of reference are possible where the objects remain at fixed positions on the screen, allowing for simple eye-tracking analysis
- These simulations (plus a 3rd on circular motion) have been tested as lecture demonstrations and have been used as labs in conjunction with physical equipment
  - Student have responded positively to these simulations, and evidence of improved student understanding has been observed *

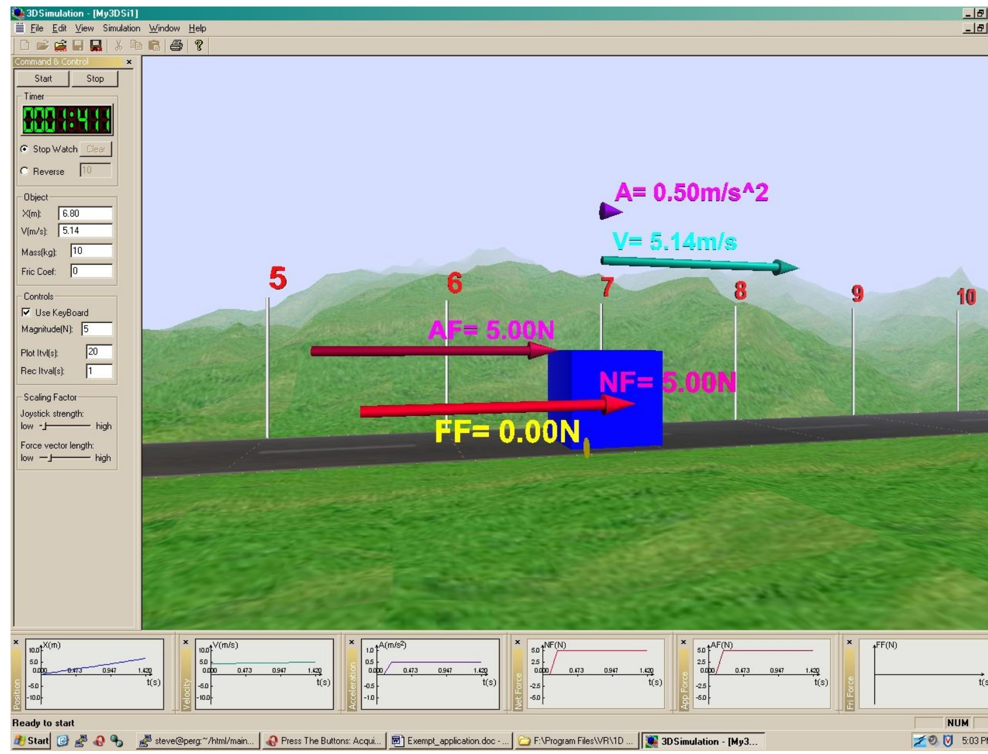
* "Virtual Reality Experiments in Introductory Physics Laboratories", Demaree, D., Stonebraker, S., Zhao, W., and Bao, Lei. In Review for PERC Proceedings (2004)

General Features of the Virtual Reality Programs

- VR allows for the study of things not easily possible with traditional equipment - for example: fast or microscopic processes
- The VR environment can be fully controlled – all parameters are adjustable
- The VR program is manipulated using a touch-sensitive joystick which allows for immediate sensory feedback and direct manipulation of the VR environment
- Using a joystick mimics playing a video game, which prompts students to use the VR
- VR is fun and engaging while providing a learning experience for the students – this may improve student attitudes and motivation

The Linear Motion VR Simulation:

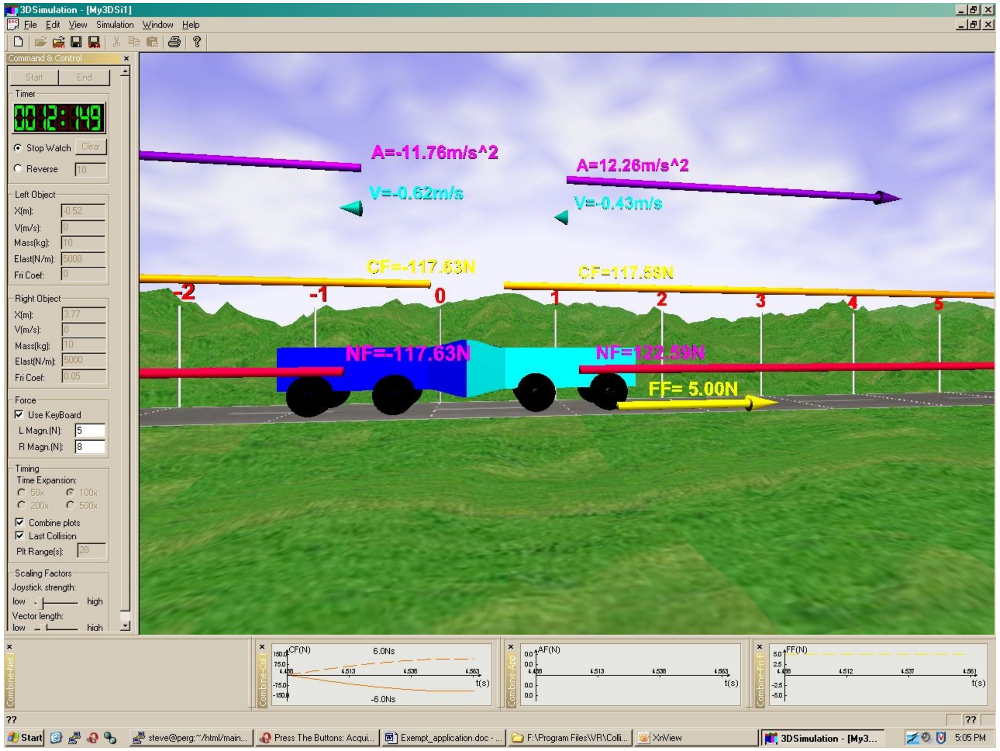
- Students probe Newton’s 2nd law using a joystick to exert an external force on the block
- The initial conditions, mass of the block and coefficient of friction can all be easily adjusted by the user
- The force diagram, velocity and acceleration vectors, and motion graphs for the block can all be displayed in real time



Screen shot of the Linear Motion VR interface

The Collisions VR Simulation:

- Students study impulse and momentum using the collisions VR software
- The initial conditions, the coefficient of friction and the elasticity of the bumpers can be set by the user
- The force diagram, velocity and acceleration vectors, and motion graphs for both carts can be displayed in real time



Screen shot of the Collisions VR interface

OSU's Center for Cognitive Science Eye Tracking Lab *

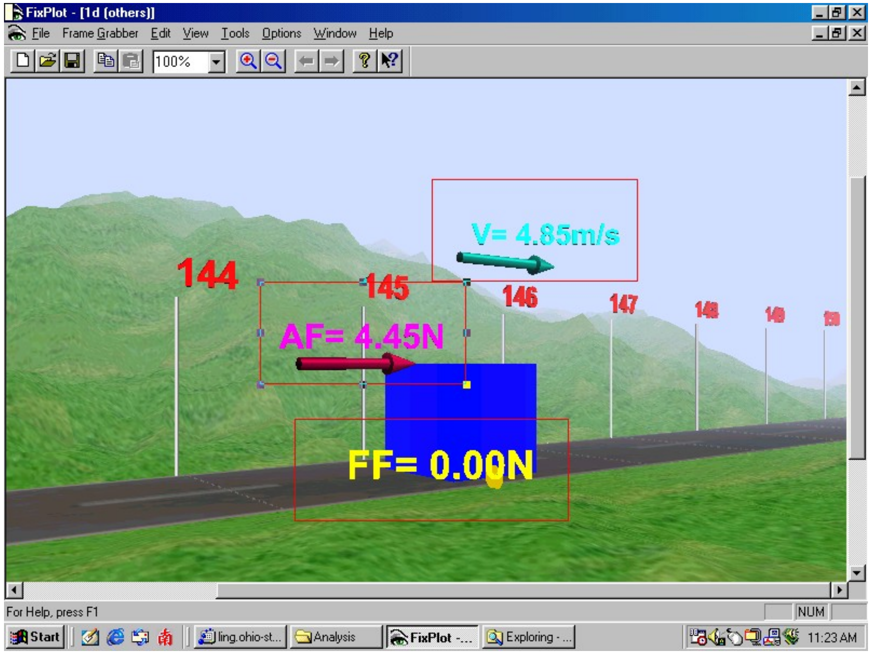
- The lab uses an Applied Science Laboratories Model 501 High Speed Eye Tracker with head-mounted optics and Eyehead Integration
  - A head-mounted camera provides an image of the user's pupil and corneal reflection
  - The relative position is calculated to determine the direction in which the eye is gazing
  - The Eyehead Integration uses the relative position of a head-mounted magnet with a wall-mounted magnet to correct for the user's head movement

Researcher demonstrating Eye Tracking Equipment

* More information can be found at www.cog.ohio-state.edu/etlab

Data Available from Eye Tracking

- The system samples at a rate of 60 Hz (approximately every 17 milliseconds) and reports eye position to within 1 degree (with precision of ½ a degree)
- The VR simulations are divided into regions of interest as shown in the figure
- A software program (Eyenal) runs analysis routines to determine lengths of fixations occurring in defined regions
  - A fixation is a stable point of gaze lasting at least 100 ms
  - The software corrects for blinking



Defined regions of interest – the height extent of each region is approximately 4 Degrees

Experimental Procedures

- We solicited 8 volunteers, half from a Physics By Inquiry (PBI) class which does not cover mechanics and half from the introductory calculus-based mechanics course (131)
  - The 131 students had completed course instruction on Newton’s laws and momentum conservation
  - Some PBI students had taken physics in the past (for example a high school course)
  - Volunteers were compensated for their time with $10 gift certificates to Barnes and Noble
- Two sets of experimental groups were established: PBI vs. 131 and Predictions vs. No-Predictions
  - Two students from each class first gave predictions on the Linear Motion questions and no predictions on the Collisions questions, while the other two students did the converse

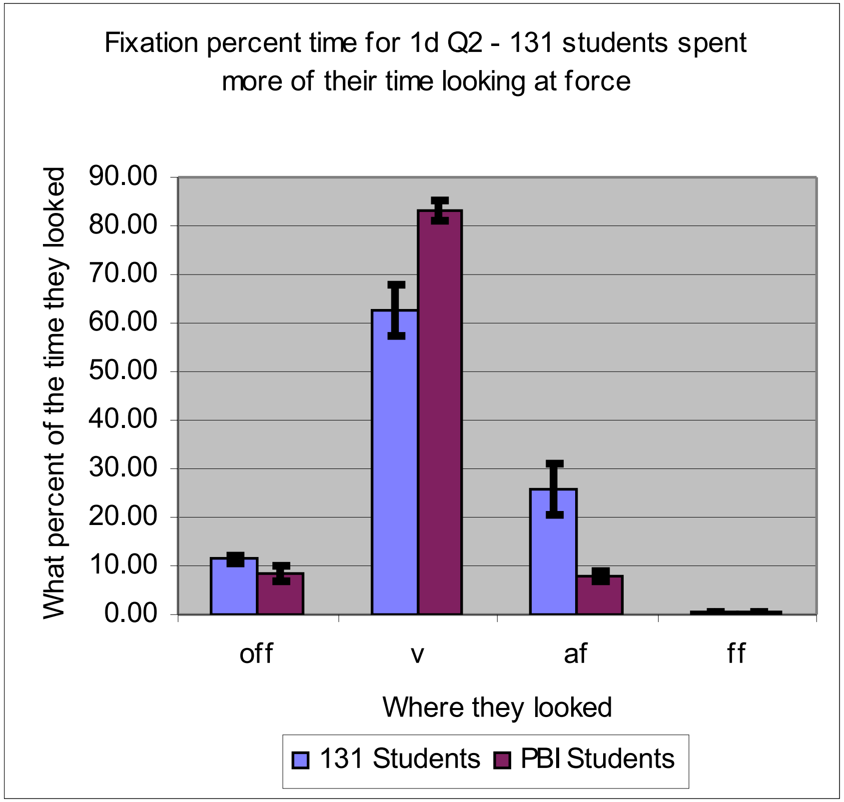
General Observations

- The 131 students completed the tasks significantly faster than the PBI students
  - A video recording was made of each session starting from after the eye tracker calibration and including all question explanations, predictions, and tests with the VR simulations
  - 131 students averaged 12.25 minutes to complete all the questions, while PBI students averaged 27 minutes
  - Due to this, the graphs presented here will focus on the percent of time a student fixated in a given area of interest and not on the total number of fixations or the total time spent fixated
- 131 students needed less repetitions of the collisions to answer the questions than PBI students
  - An average of 1.33 repetitions were needed by 131 students while 2.17 were needed by PBI students

Linear Motion Question #2

"With friction 'turned on', use the joystick to get the block moving at 2 m/s then maintain that speed."

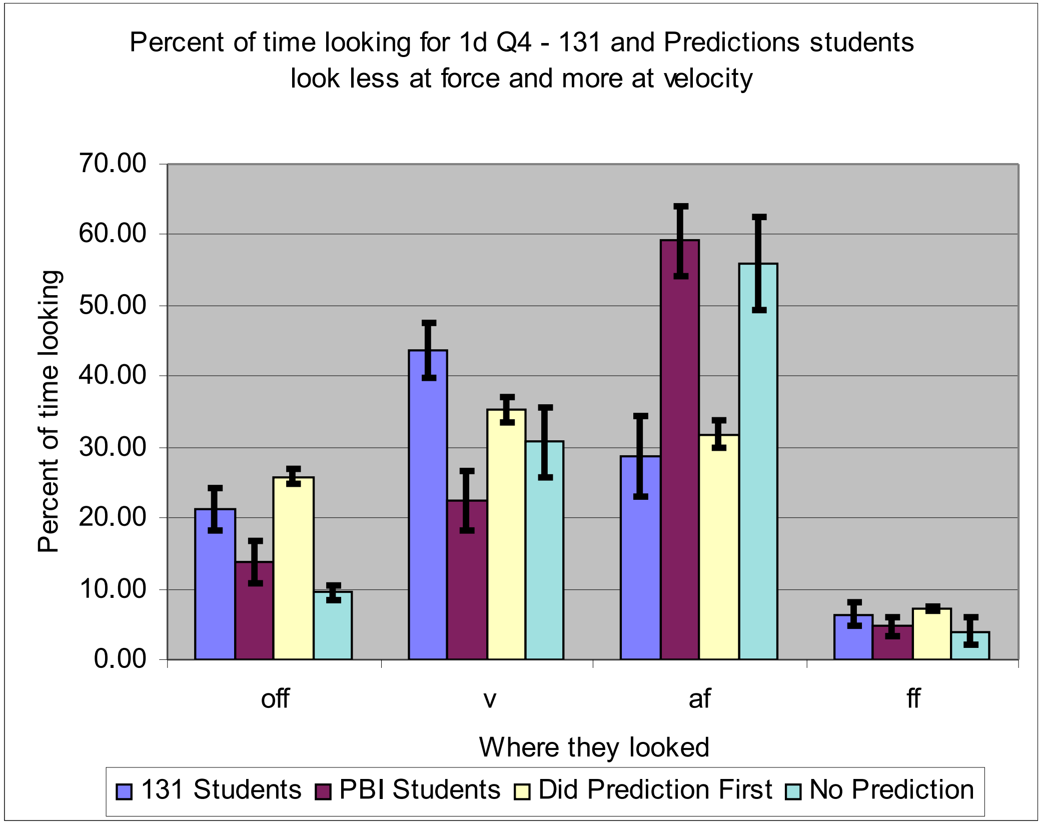
- For this question, students may realize they need applied force = friction force, or they may simply watch the speed while they adjust the joystick – we asked them to do this until they could explain how to keep a constant speed
- 131 students spend more time looking at the applied force and less time looking at the velocity
  - Note they spend very little time looking at friction - it is a fixed value so it is not necessary to refer to it multiple times
  - All error bars given are standard error (StandardDeviation/N)



Linear Motion Question #4

"With friction 'turned on', use the joystick to apply a constant strength push and describe the block's motion."

- For this question, students need to express that a constant force will cause an increasing speed (which changes more slowly than it did in a previous question without friction)
- 131 students and students who first made predictions look far less at their applied force, and more at the velocity than the corresponding groups
    - Note that "off" means they were not looking in a defined region of interest

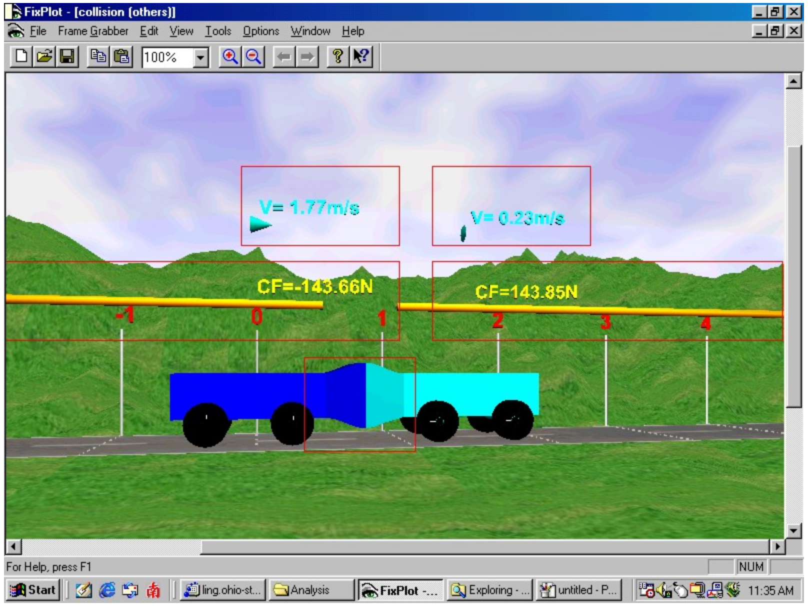


Collisions Questions

Each of the Collisions questions given are known to be tricky for many students, however, simple consideration of Newton's 3rd law yields the answer each time, and the forces are clearly shown in the simulation.

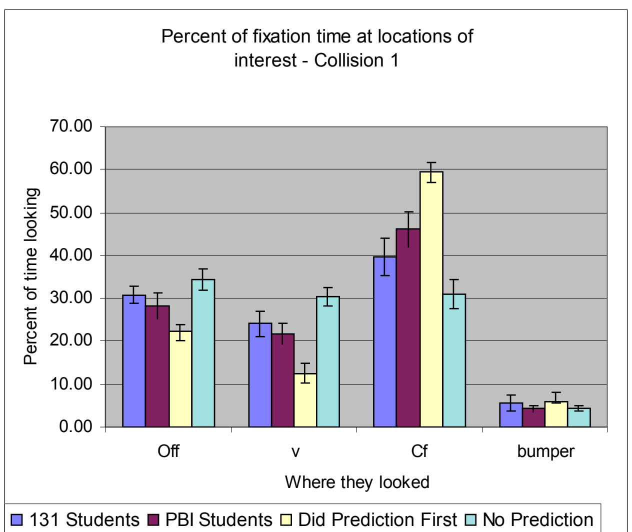
For each question we keep all but one variable equal between the two carts:

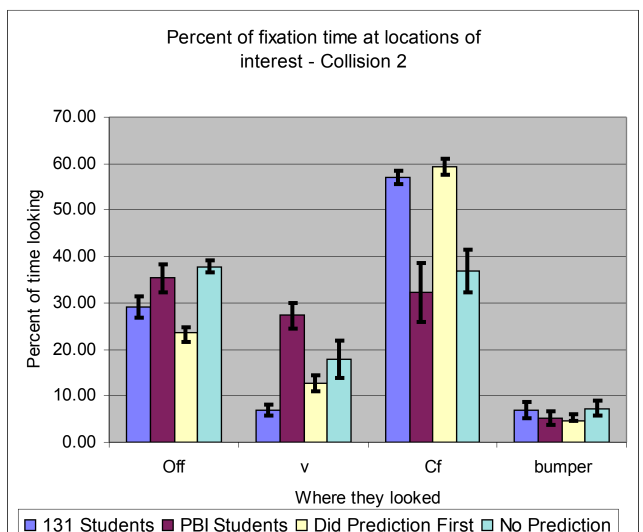
- Q1: Observe the collision, then tell me if the heavier object pushed harder than, less hard than, or the same as the light object pushes.
- Q2: Observe the collision, then tell me if the moving object pushed harder than, less hard than, or the same as the stationary object pushes.
- Q3: Observe the collision, then tell me if the left squishy object pushed harder than, less hard than, or the same as the right hard object pushes.

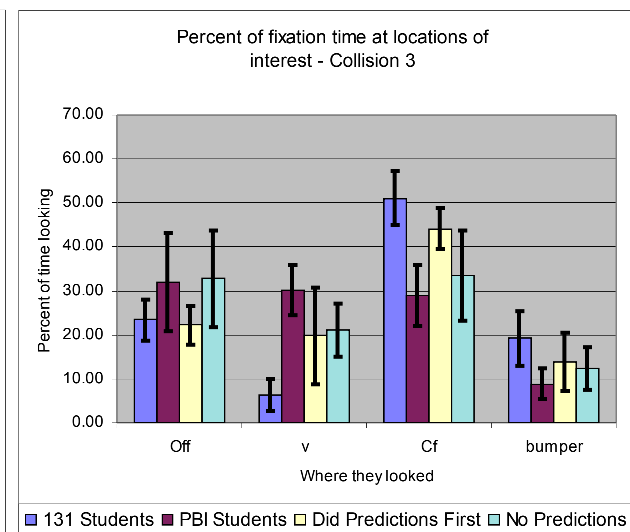


Collisions Questions Cont…

- For Q1, Prediction students looked more at the collision force and less at the velocity
- For Q2 and Q3, both 131 and Prediction students looked more at the collision force and less at the velocity
  - Perhaps 131 students realized after Q1 that Newton's 3rd law applies - they only needed to see one collision before applying the correct physics (this seems likely considering typical student comments during the experiment)
  - It seems Prediction students realized the importance of the collision force immediately – but is this because they thought of the correct physics, or did the prediction inadvertently prompt them?
  - Notice students look more at the bumpers in Q3 – one bumper is made more "squishy" and the difference in the compression of the two bumpers can be observed (this helps students understand that there is an observable difference between what happens to objects in a collision, while realizing that the force is equal and opposite between them)

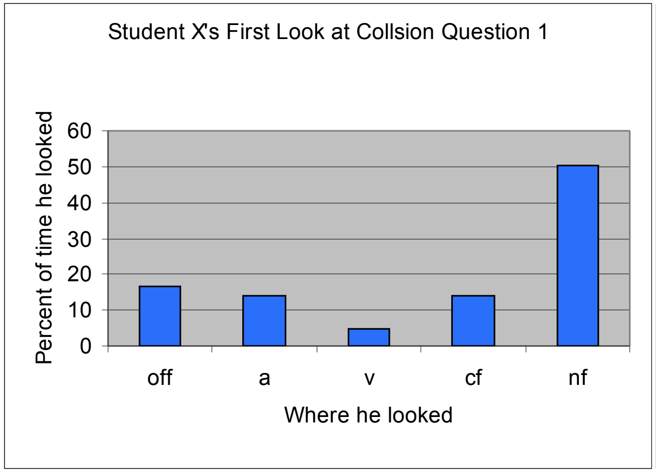


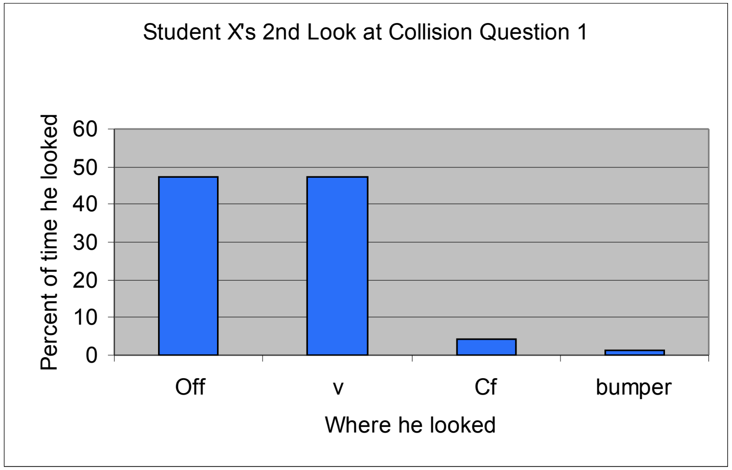




Persistent Misconceptions or Too Much Information?

- One student saw the first collisions question with more vectors turned on than we intended - a, v, collision force (cf) and net force (nf). After observing the collision, this student told us *the left object had pushed harder on the right object*
- After observing the collision a second time with only v and cf shown, he gave the correct response that the two forces were equal in strength
- HOWEVER: in the first observation, he fixated over 50% of the time on the net force, this is far more than he spent fixated on anything else!
  - Is this evidence for persisting with a misconception even after a direct observation?
  - Could the 5% of time spent looking at velocity have lead him to the wrong conclusion?
  - Note in the second observation he looks very little at the forces and quite a bit at the velocity - we can only speculate on what he is thinking – unfortunately his statements to us were vague when we inquired





Conclusions and Future Prospects

- We observed that students fixate on potential helpful aspects of the VR simulations (as in the bumpers in Collisions Q3)
- We found differences in the fixations between "novices" (PBI students) and "experts" (131 students), as well as between students who make predictions and those who do not
  - This could help with further studies on learning differences between students as well as developing curriculum aimed at maximizing the effectiveness of the simulations
- We observed evidence for a student holding onto a misconception after fixating on the "correct" information
  - Understanding more about this could be extremely beneficial – this effect has been frequently observed and is very difficult to counteract!

Abstract

- The Physics Education Research (PER) Group at the Ohio State University (OSU) has developed Virtual Reality (VR) programs for teaching introductory physics concepts. Winter 2005, the PER group worked with OSU's cognitive science eye-tracking lab to probe what features students look at while using our VR programs. We see distinct differences in the features students fixate on depending upon whether or not they have formally studied the related physics. Students who first make predictions seem to fixate more on the relevant features of the simulation than those who do not, regardless of their level of education. It is known that students sometimes perform an experiment and report results consistent with their misconceptions but inconsistent with the experimental outcome. We see direct evidence of one student holding onto misconceptions despite fixating frequently on the information needed to understand the correct answer. Future studies using these technologies may prove valuable for tackling difficult questions regarding student learning.