Tie Goes to the Runner:

The Physics and Psychology of a Close Play

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NSF: Everyday Examples in the Science/Engineering Classroom

- E^3s are relevant and relatable [1]
- E^3s help students retain information [2]
- E^3s improve retention in the major [3]
- E^3s improve engagement [4]
- E^3s student satisfaction [5]

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Outline

When there is a close play at first base, how does an umpire determine if the runner is safe or out?

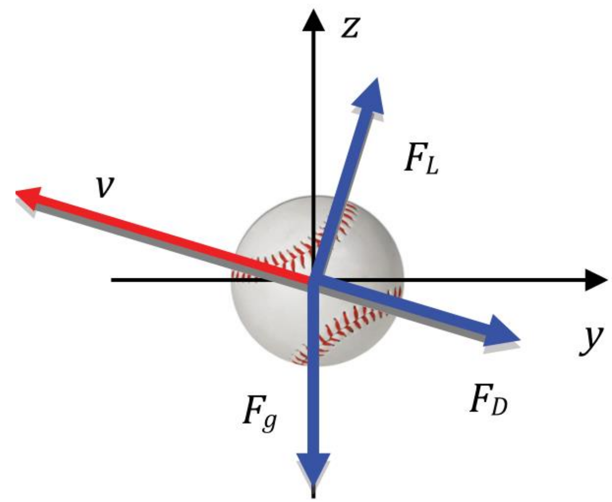
- Baseball + Physics *and* Baseball + Psychology

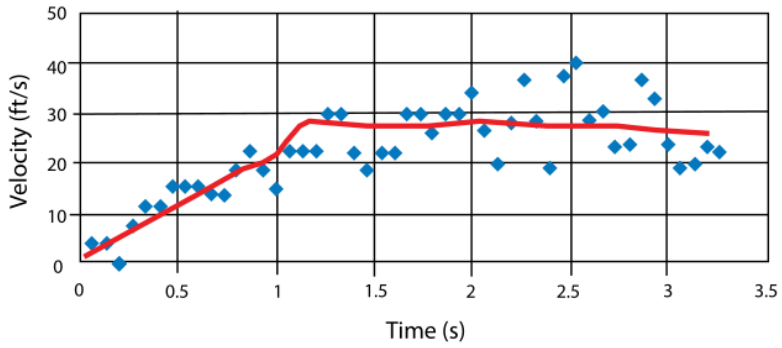
- The "Problem"
- Physics Approach
- Psychology Approach
- Results

(Fox Sports Detroit)

Physics and Baseball

- Best Launch Angle for a Home Run [6]
  - Spoiler: it's much less than 45 degrees
- Modeling the Drag on a Baseball [7]
  - Uses real world data from PITCHf/x
- Kinematics of a Stolen Base [8]
  - We'll use these results later





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Psychology and Baseball

- Vision Training Helps Batters [9]
- Perceptions of a Fly Ball Apex inconsistent with reality [10]
- Strikes are called less often if the umpire and pitcher do not match race [11]

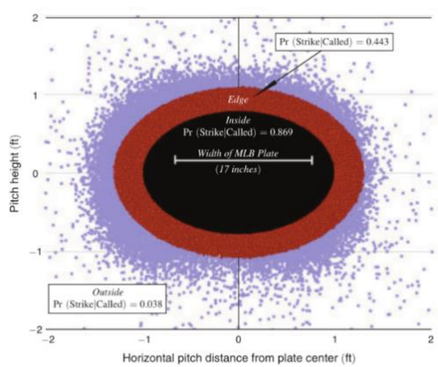
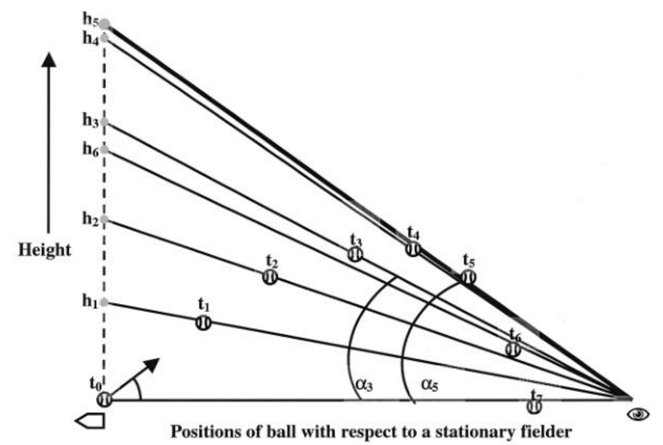


FIGURE 4. CALLED STRIKES BY DISTANCE FROM HOME-PLATE CENTER, 2007–2008 ($N = 144,990$)



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The Problem

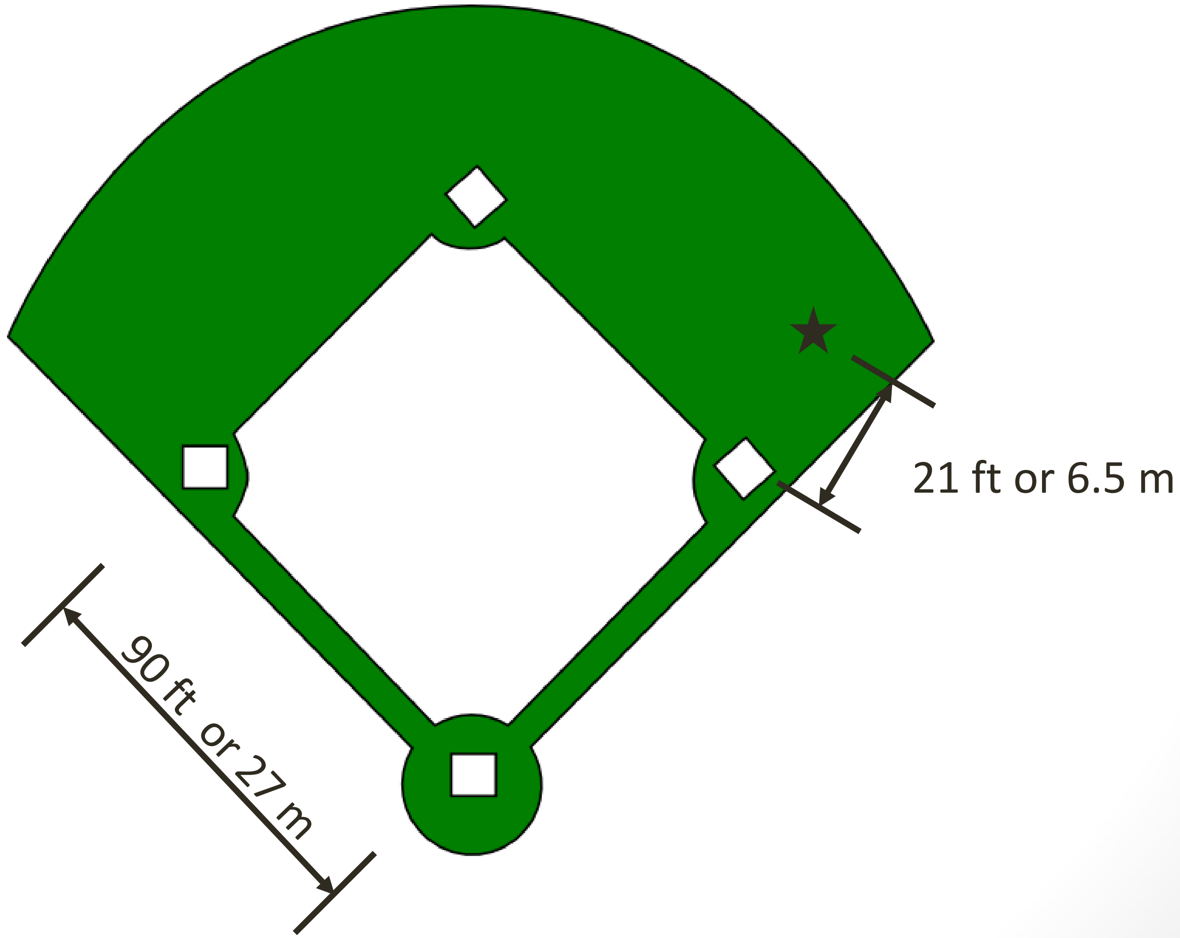
- The runner is moving quickly toward first base
- The ball is moving quickly toward the glove
- The umpire cannot observe both the base and the glove simultaneously

(MLB.com)

- Attempted Solution:
  - Listen for the sound of the ball and watch the base
  - Distinguish the order based on stimuli

Physics Approach

- The Baseball diamond



Physics Approach

- Assumed Umpire Distance from Base: 21 ft or *d* = 6.5 m
- Speed of sound at SATP: v_s = 346.4 m/s
- Speed of light in air: *c* = 299,704,644 m/s

- Travel time for Sound:

$$t_s = \frac{d}{v_s} = 19 \text{ ms}$$

- Travel time for Light:

$$t_L = \frac{d}{c} = 22 \text{ ns}$$

- Time delay for *simultaneous* events: 19 ms

Physics Approach

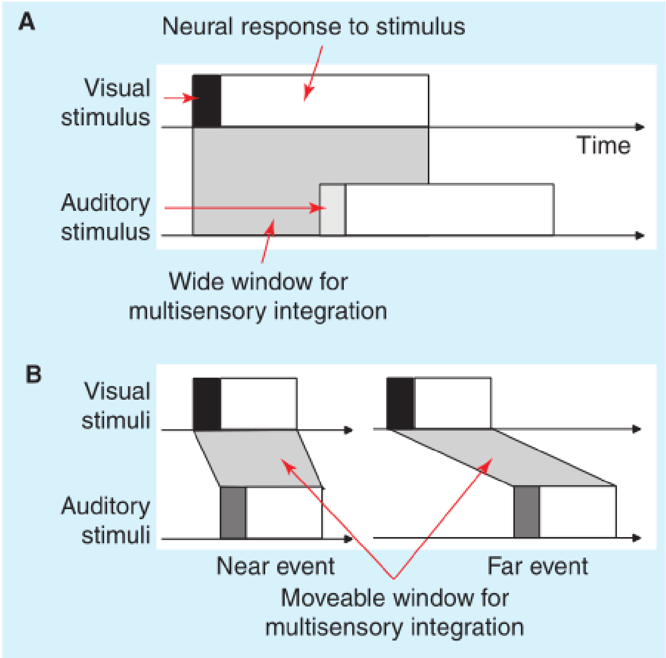
- Detector response:
  - Optical detectors: less than 1 ns
  - Audio detectors: ≈1 μs.
  - Consider the detectors to be *ideal*
  - *19 ms is huge!*

- How far does the runner move in 19 ms?
  - Runner moving at 8.6 m/s (19 mph) [8]
  - d = 8.6 x 0.019 = 0.16 m = 6.4”

If we do not correct for the time delay, the runner can be out by 6” and still be called safe!

Psychology Approach

- The human body is not a perfect detector
  - Moveable window for multisensory integration [12]
  - Cross-modal simultaneity: for two senses, how far apart in time must two events be to be perceived as sequential? [13]



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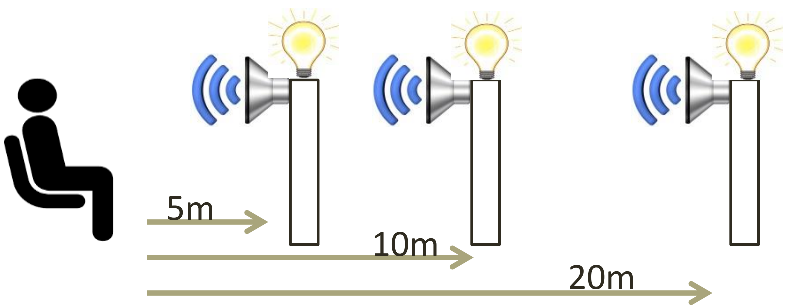
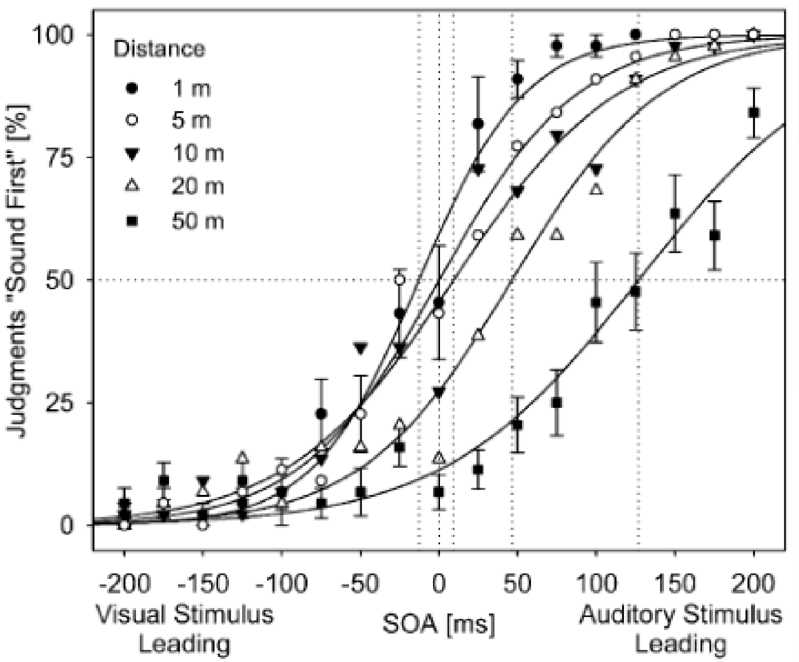
Psychology Approach

At what SOA do we perceive sound and light as simultaneous? [14]

**Distance Dependent*





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Psychology Approach

- Sound processed faster than sight (10 ms vs 50 ms) [15]
- Horizon of Simultaneity
  - Simultaneous event appears simultaneous
  - *Located 10-15 m from event*

- Asynchrony Detected [13]:
  - -25 ms to +42 ms if an *Actor* (Runner, First Baseman)
  - -41 ms to +45 ms if an *Observer* 2 m away (Umpire)

- Inside this range, no asynchrony detected

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Results

- For synchronous events, an umpire:
  - 6 m away, experiences a 19 ms discrepancy
  - 6 m away, will preferentially call a runner safe
  - should be at least 10 m away to perceive the events correctly (as synchronous)
- For asynchronous events:
  - an umpire will experience them as synchronous in an 80 ms window [15]
    - (80 ms corresponds to 27” of runner motion)
  - an actor (baseman, runner) may have better resolution

- Umpires have a really hard job, but seem to exceed the resolution of experimental results in most cases.

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