Baseball's Sight-Audition Farness Effect (Safe) When Umpiring Baserunners:

Competing Visual and Auditory Cues

by

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ABSTRACT

In baseball, the difference between a win and loss can come down to a single call, such as when an umpire judges force outs at first base by typically comparing competing auditory and visual inputs of the ball-mitt sound and the foot-on-base sight. Yet, because the speed of sound in air only travels about 1100 feet per second, fans observing from several hundred feet away will receive auditory cues that are delayed a significant portion of a second, and thus conceivably could systematically differ in judgments compared to the nearby umpire. The current research examines two questions. 1. How reliably and with what biases do observers judge the order of visual versus auditory events? 2. Do observers making such order judgments from far away systematically compensate for delays due to the slow speed of sound? It is hypothesized that if any temporal bias occurs it is in the direction consistent with observers not accounting for the sound delay, such that increasing viewing distance will increase the bias to assume the sound occurred later. It was found that nearby observers are relatively accurate at judging if a sound occurred before or after a simple visual event (a flash), but exhibit a systematic bias to favor visual stimuli occurring first (by about 30 msec). In contrast, distant observers did not compensate for the delay of the speed of sound such that they systematically favored the visual cue occurring earlier as a function of viewing distance. When observers judged simple visual stimuli in motion relative to the same sound burst, the distance effect occurred as a function of the visual clarity of the ball arriving. In the baseball setting, using a large screen projection of baserunner, a diminished distance effect occurred due to the additional visual cues. In summary, observers generally do not account for the delay of sound due to distance.

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Getting seats that are close to a sports game's action are often favored over seats farther away due to a better visual experience, but what about the auditory experience? This study investigates the potential bias exhibited by observers when perceiving the order of competing auditory and visual stimuli, and tests the impact of sound delays due to viewing distance. Many studies have looked at how observers pair stimuli together, but few have looked at how such stimuli are paired as a function of distance. In some situations like sports, the outcome of such multimodal judgments can be the difference between a win or a loss. A single call by a referee or umpire can change the overall score, based on her or his perception of when the sound of a ball arrived versus a visual event. Work has been done which shows how sound can alter the appearance of visual stimuli that is ambiguous (Lewis & Mcbeath, 2004; Sekuler, Sekuler, Lau, 1997) as well as unambiguous (Shams, Kamitani, Shimojo, 2000). Further, research has confirmed that when observers experience different sensory modalities that are interpreted to be from the same root source, observers are prone to experience them simultaneously (Shimojo & Shams, 2001).

Most research on how humans pair visual and auditory information together as a function of distance is conducted with the goal of identifying and localizing common real world events and objects (Bertelson & Aschersleben, 1998; Lewis & Mcbeath, 2004; McBeath & Kaiser, 1992). For a complete review of research on multisensory integration see (King, 2009). Some research has looked at how sound and visual stimuli combine to help one localize a face in a set of faces placed at a relatively small distance (Chan, Maguinness, Lisiecka, Setti, & Newell, 2012). More recently work by Calcagno has explored how perception of distance is influenced by auditory stimuli, but this study did not test how visual and auditory stimuli are paired as a function of distance (Calcagno, Abregu, Eguia, & Vergara, 2012). Further research suggests that one area of the brain believed responsible for synchronizing visual and auditory stimuli together is the superior colliculus (Meredith, Nemitz, Stein 1987; Wallace, Willkinson, Stein, 1996).

However, little work has examined how the temporal onset of an auditory stimulus may alter its paring with the visual stimulus in a way that can create a bias over a physical distance. By bias, we mean a systematic misperception as to when the sound burst originally occurred relative to the visual event, in particular a reversal of precedence

Such research is important since from a physics perspective, sound travels much slower than light and as such an observer's experience for perceiving the order of auditory and visual events may be misinformed in certain situations such fans or other observers viewing from a distance. One prominent example is this is lightning and the delay of thunder which are often observed several seconds apart, despite originating from the same source at the same time. In many such real-world situations, observers perceive multi-sensory stimuli at a considerable distance, which leads to the question of how accurately observers pair simultaneously originating auditory and visual stimuli together, and/or judge the order of such competing sensory modalities. We may have we evolved perceptual mechanisms that account for delays due to the slow speed of sound that allow observers to accurately judge which sound is paired with which visual stimulus based on the pattern of *when* the stimuli occurred (Figure 1). Alternatively, we may simply pair auditory and visual stimuli if they both simultaneously reach our eyes and ears, ignoring acoustic delays due to the slower speed of sound (Figure 2). Hereafter we refer to these two ideas as allocentric where an observer adjusts accurately to multimodal stimuli and egocentric when the observer does not adjust.

We hypothesize that observers will generally judge the order of simple auditory and visual events relatively accurately based on the order that the sensory information reaches the observer, and in so doing they will not account for the delay of sound due to observation distance. In short we hypothesize a Sight-Audition Farness Effect (SAFE). This hypothesis is consistent with pilot study data collected prior to the study. We also hypothesize that the pattern of multisensory precedence judgments will support a bias to not account for delays due to the slowness of sound, and thus lead observers to favor judging visual stimuli to occur earlier than auditory. In other words, the farther away from the stimuli, the larger the bias will be for observers to interpret visual stimuli as occurring earlier.

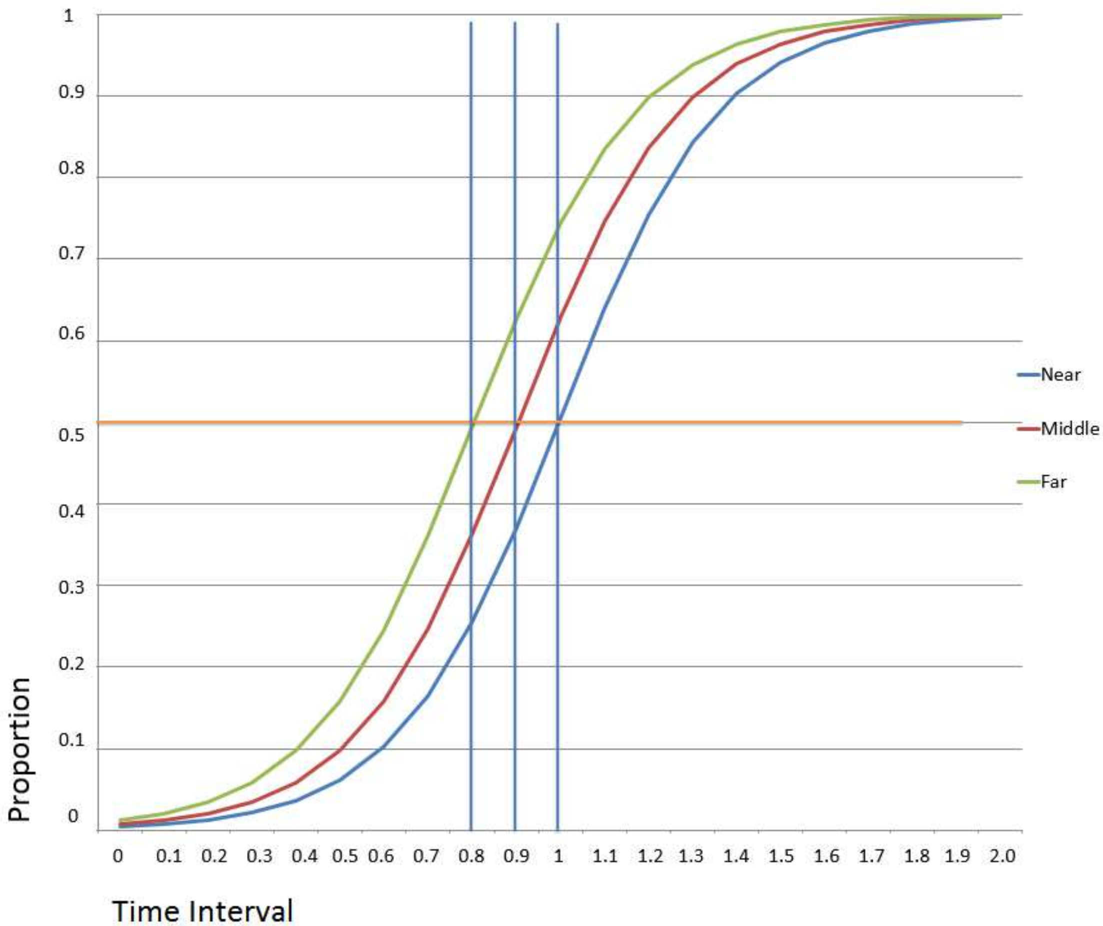

Figure 1. Anticipated results if SAFE bias exists. As distance from the source increases, so does an observer's perception to link up delayed sounds with visual stimuli. Middle condition is 100 feet back from source, far condition is 200 feet back from source.

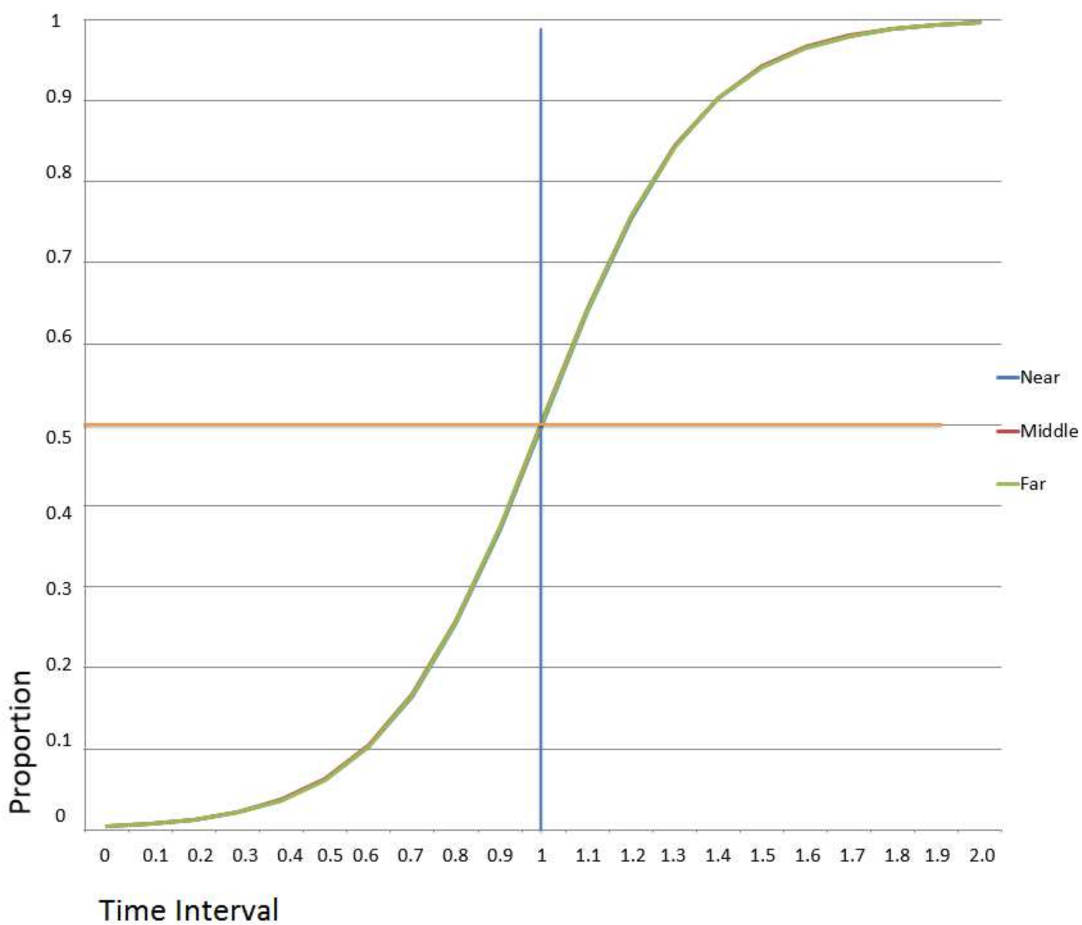

Figure 2. Anticipated results if SAFE bias does not exist. In this outcome, participants adjust for the delay of sound and consequently distance from source has no effect on perception of multimodal stimuli. The three distance curves are collapsed on top of each other.

Experiment 1

The first experiment's primary purpose was to use basic stimuli, a click of sound and a visual flash, to assess whether participants will adjust for the delay in sound relative to a visual stimulus as a function of distance.

Methods

Participants

Seventy Arizona State University undergraduate volunteers participated in this study. Students received research participation credit. There were 41 women and 26 men (mean age = 19.16 years old, *SD* = 3.43). Three participants were excluded due to having accuracy rates below a predetermined threshold of 25% for a final sample size of 67 participants (39 females, 25 males).

Stimuli

The stimuli consisted of a visual flash and an acoustic pulse, with two independent variables: distance, and timing of the sound pulse. Distance is defined by how far participants are located from the screen and speakers. The three observation distances included: 1) Directly in front of the screen/speaker. 2) 100 feet (30.4 m) away from screen/speaker. 3) 200 feet (60.8 m) away from screen/speaker.

Materials

We created a program in PsychoPy (Peirce, J., 2007), a freeware psychophysical program that controls timing of sound, display, and other perceptual factors for this type of research. Each participant observed displays of 10 randomized trials, each 2 seconds long. At the 1 second midpoint, a white flash of light displayed on the screen. A 10 msec. Brownian noise sound pulse occurred either prior to or following the light flash by either ±1 sec, or by one of the following ratios of a second: ±0.5, ±0.4, ±0.3, ±0.2, ±0.1, or 0 (i.e. simultaneously).

In order to have a sufficient space to test our observation distance variable, we used a campus gym with a length over 200 feet, which gave us the ability to implement the three viewing distances from the screen (Figure 3). We setup a laptop which ran the PsychoPy program, hooked up to a Pioneer SX-3500 external amplifier, Multimedia Labs SP510 monaural speaker, and NEC NP115 projector. The projector emits 2500 lumens which was sufficiently bright for participants to see from the other side of the gymnasium. The 40w external amplifier/speaker combination was also sufficiently loud for all participants to easily hear the noise pulse stimulus from the other side of the gymnasium.

Figure 3. Photos of how participants were placed in the gymnasium. Left panel shows a rear-facing forward view from the "far" condition and right panel shows a front-facing rearward view of participants as they observe stimuli.

Timing of sound

For an auditory stimulus, we used a 10ms Brownian noise sound pulse, since virtually any sound clip of such short duration does not contain enough information for the perception of meaningful timbre information. The short duration was selected to sound like a relatively instantaneous pulse or collision (like a ball hitting a mitt) and to not produce a confound of participants associating the sound with some other naturally occurring continuous source. We used the auditory vs visual stimulus time range of ±.5seconds with 100ms step sizes since any larger offset outside of this range was piloted to be easily discriminable regarding order of stimuli.

Procedure

We ran approximately 72 participants in four groups of 18 each. Each participant was randomly assigned to one of the three distance conditions, with 6 participants in each distance condition at any given time. Participants observed 10 randomized trials in this configuration, then rotated to a different distance from the screen. To further avoid order-effects, participants were split into groups of 3. One group rotated from front to back; the other group rotated from back to front during each distance condition.

The dependent variable, judgment of stimulus order, was collected as follows. Observers were told the stimuli would be presented at different times and each participant was given a response card on which they were to record one of four responses which indicated order of stimuli that they perceived. A “1” indicated the sound occurred before the flash, a “2” indicated the sound occurred after the flash. In the case that participants were uncertain as to when the sound occurred relative to the flash, they were instructed to write down a “1S” or “2S” both of which denoted it appeared that the sound synchronized with the flash but we still wanted them to say which response they would write down were they forced to choose. Hence, a “1S” indicated the two stimuli seemed to occur simultaneously but if forced to choose, the participant noted the sound played before the flash. A “2S” indicated simultaneous perception but when forced they noted the sound played after the flash. Finally, participants reported amount of hours spent playing video games, and sports. These data were collected to assess whether video game experience has any effect on multimodal perception given that video games have been shown to improve visuospatial ability (Green & Bavelier, 2003, 2006) and overall cognitive ability (Boot, Blakely, & Simons, 2011). Further, baseball players typically demonstrate improved visual ability over novice players (Uchida, Kudoh, Higuchi & Honda, 2013).

Results

Figures 4-6 show the mean percentage of estimates in which participants indicated the visual flash occurred before the auditory pulse, as a function of when the sound burst was emitted from the source. From these figures, one can see that participants were more likely to report a same response when the sound occurred before the flash and compared to after.

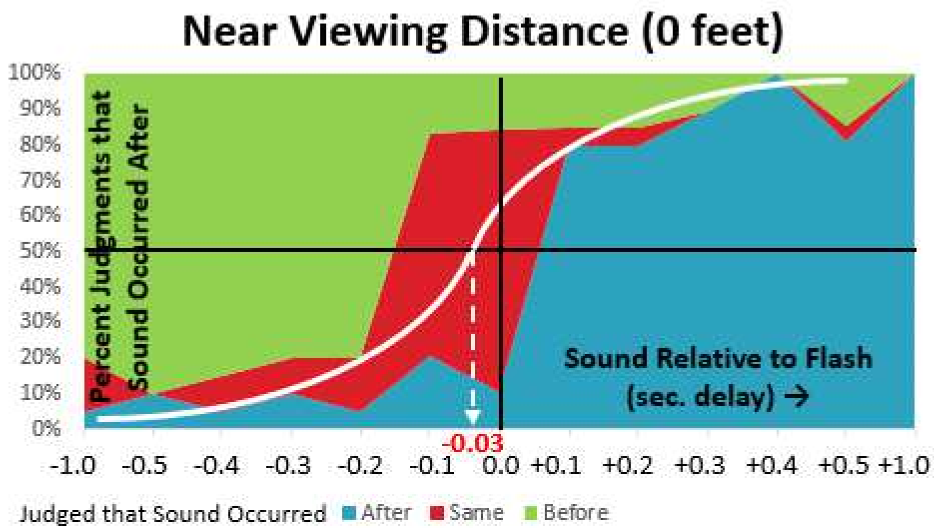

Figure 4. Percentage of responses for each auditory pulse delay interval in near the near viewing distance condition. The green "same" distribution is shifted to the left of the zero delay auditory pulse, indicating a bias to experience more simultaneity when the sound is presented earlier.

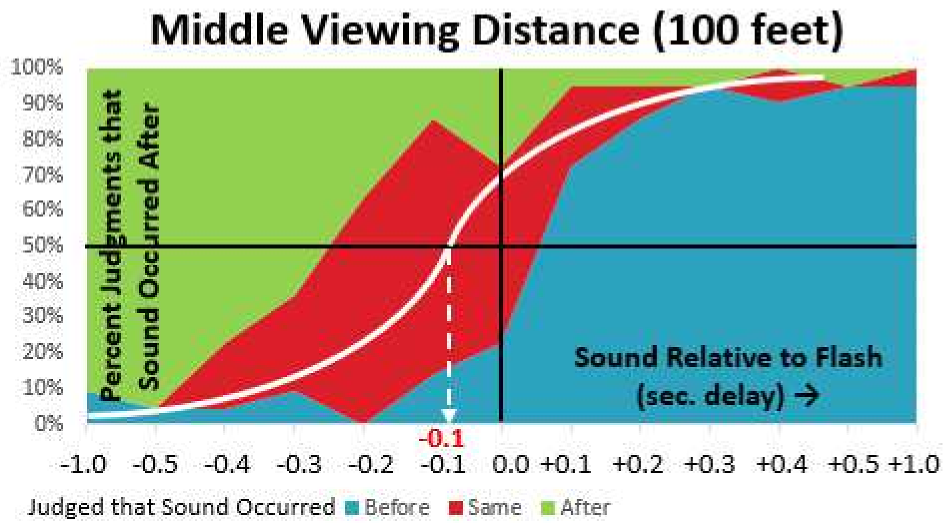

Figure 5. Percentage of responses for each auditory pulse delay interval in the middle distance viewing condition. The green "same" distribution is shifted even more to the left of the zero delay auditory pulse than in the near viewing condition, indicating a bias to experience simultaneity when the sound is presented even earlier. The middle of the distribution of "same" simultaneous perception is close to corresponding with the 100 msec delay (-0.1 sec) that occurs due to the speed of sound traveling the 100 feet to the middle observers.

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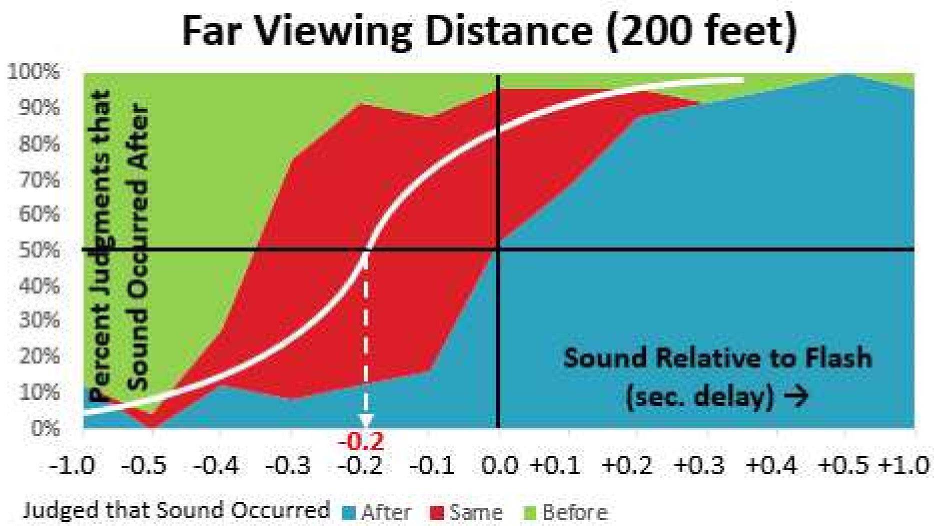
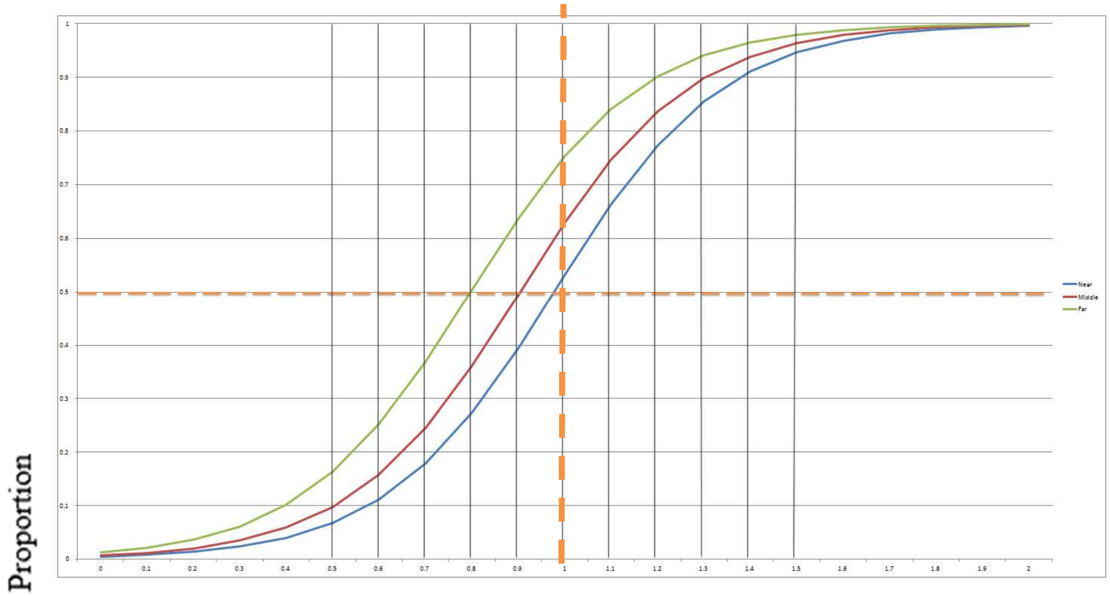


Figure 6. Percentage of responses for each auditory pulse delay interval in the far distance viewing condition. Once again, the green "same" distribution is shifted even more to the left of the zero delay auditory pulse than in the middle viewing condition, indicating a similar bias to experience simultaneity when the sound originates even earlier. The middle of the distribution of "same" simultaneous perception is close to corresponding with the 200 msec delay (-0.2 sec) that occurs due to the speed of sound traveling the 200 feet to the middle observers.



Time Interval

Figure 7. Graph of predicted probabilities from experiment 1 using best fit logistic regression. Note that chance probability corresponds in each condition with delay of sound, 111.64ms (the delay due to speed of sound) per 100 feet (61 meters) away from source.

Using a logistic regression, we assessed participant's responses to the various manipulated auditory stimuli. Responses of "1S" were collapsed into a response of "1" and responses of "2S" were collapsed into a response of "2." Using the near condition as our base group, we then compared the middle and far distance groups resulting in the far group being significantly different, [$t = 3.33$, $p = .001$] .]. We did analyze the data with a linear regression model, which allowed us to test the linear order of the three distributions; this revealed that the distance predictor was statistically significant. However the logistic regression model was ultimately chosen due to accounting for the most variance when compared to the linear regression model (Figure 7, Table 1).

Correlations between accuracy and video game experience as well as between accuracy and sports experience were non-significant.

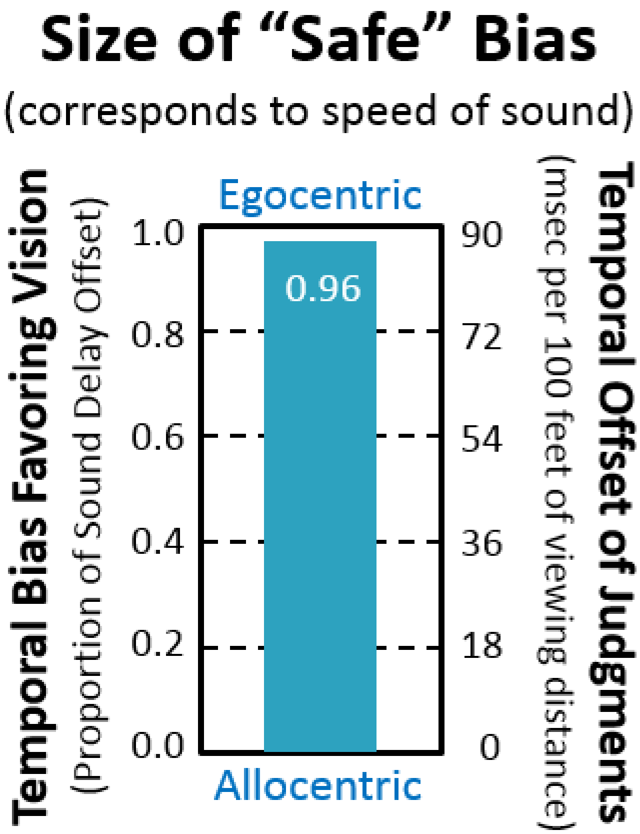


Figure 8. Amount of egocentric vs. allocentric judgment in experiment 1.

Experiment 1 demonstrated that observers made highly egocentric judgments.

Table 1. *Odds Ratio for Sound Before or After.*		95% CI for Odds Ratio		
Measure	*B*(SE)	Lower	Odds Ratio	Upper
Sound Before or After				
Intercept	5.37 (.44)***			
Sound	5.50 (.39)***	0.002	0.004	0.009
Distance (middle)	0.41 (.29)	0.378	0.667	1.177
Distance (far)	0.99 (.30)***	0.207	0.371	0.666

Discussion

Our first experiment shows that when judging precedence of timing of simple visual and auditory stimuli, participants do not account for distance in the delay of sound. As such, a systematic bias surfaces in which the further away observers are from the source, the more likely they are to judge earlier produced sounds as being synchronous with visual stimuli. We thus have found support for a SAFE bias. This is congruent with a physics perspective in which observers experience simultaneity when the earlier emitted sound arrives at the observer's ear at the precise time he or she sees the visual event (Figure 8). In this case the observer does not adjust for the reality that the delayed sound was generated prior to the visual event and judges the two stimuli to be synchronous. This is consistent with a bias to favor visual stimuli as typically perceptually preceding simultaneously occurring sound events. Finally, hours spent playing video games and sports had no bearing on an observer's accuracy in her or his multimodal judgment.

Experiment 2

Observing a bias in experiment 1 for simple auditory and visual stimuli, we then set out to test what factors would affect perception of the competing stimuli, namely, visual salience of the baseball.

Participants

For experiment two, 81 Arizona State University undergraduate volunteers were recruited. Participants received extra credit for their participation. Participants included 44 women and 37 men (mean age = 20, *SD* = 2.15). Two participants were excluded for analysis due to having accuracy below 25%. This resulted in a final sample size of 79 participants (44 females, 35 males).

Materials

Using Psychopy, participants observed motion of a sphere and rectangle relative to a static square on a display projected on the wall. The sphere was meant to represent a baseball while the rectangle represented a runner attempting to reach the base before the ball did. In all conditions the bar always crossed the plate at the same time but the ball's auditory and visual timing was varied (the auditory and visual timing were paired with each other) relative to when the bar crossed. We determined the speed of the bar to be approximately how fast the average baseball player runs: from home plate to first, 4.5 seconds divided by 90 feet for distance between the two plates to get 20 feet/second or ~14mph). Further, we scaled the projector display to be as large as possible and determined speed of bar to be 100inches/second (100" projector display with 1024x768 pixel resolution display=164ppi). We then calculated the speed of the ball to be roughly five times the speed of the player (this is certainly a conservative estimate) and programmed the ball to be 5 times faster as such. Four conditions ranging from perfect vision of the ball and no sound to no ball and sound were used (Figure 9). The final condition of sound with no ball was used to test the findings of experiment 1 where participants simply saw a flash of light and compared it to a sound.

The goal with each of the conditions was to degrade the visual salience of the ball systematically and observe the effect it would play on participant's timing judgments. Three different levels of brightness were used for the "ball:" 100% brightness, 25% brightness, 0% brightness (ball not visible). Each level of brightness replicated different levels of viewing accuracy of the ball by observers based on seating position, various lightning conditions and color contrast conditions commonly seen in a typical baseball game.

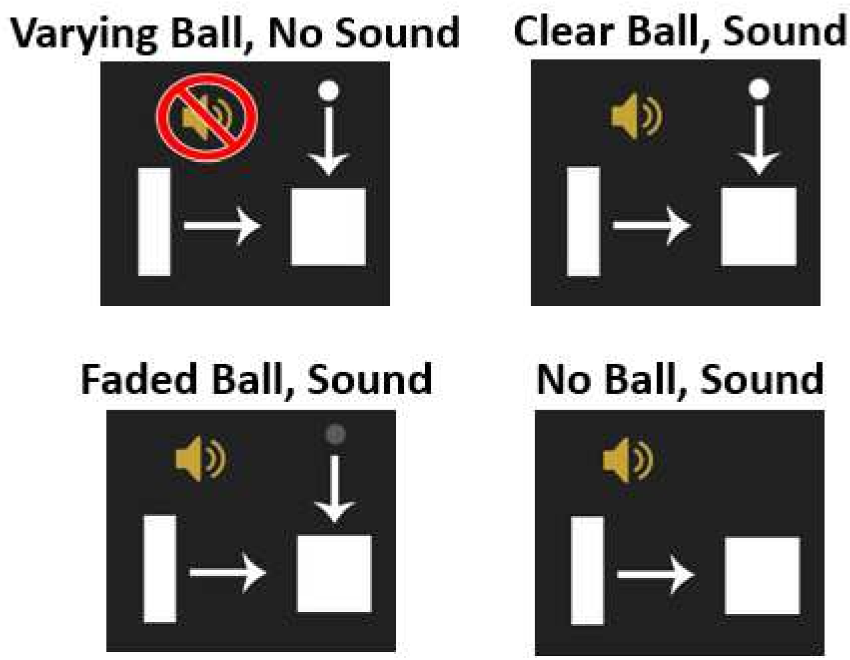


Figure 9. Four varying conditions used in experiment 2. The visual salience of the ball became increasingly diminished across conditions.

Procedure

The procedure for experiment 3 was identical to experiment 2 although the sound burst was presented at 100ms. intervals which were +/- 300ms. from the time of the ball intercepting the base including a synchronous trial of ball and player arriving at the same time. We used a narrower range for this experiment since in experiment 1 near perfect accuracy was observed at +/- 400ms intervals and larger. Again, the aim was to simulate different times of the ball arriving relative to the player. Using these conditions we created a 7 x 4 x 3 (Sound Timing x Ball Brightness x Distance) condition experiment.

Participants were instructed to write down “S” or “O” this time, a “O” response indicating that the ball arrived first (out) and the latter that the runner arrived first (safe).

Results

The no ball condition provided the strongest SAFE bias with an average delay of 68ms per 100 feet / 61 meters (Table 4). In increasing amount of visual salience of the ball, the remaining three conditions also showed smaller perceived sound delays per 100 feet / 61 meters. Judgments became increasingly allocentric as observers received more visual information in the display (Figure 10, 11).

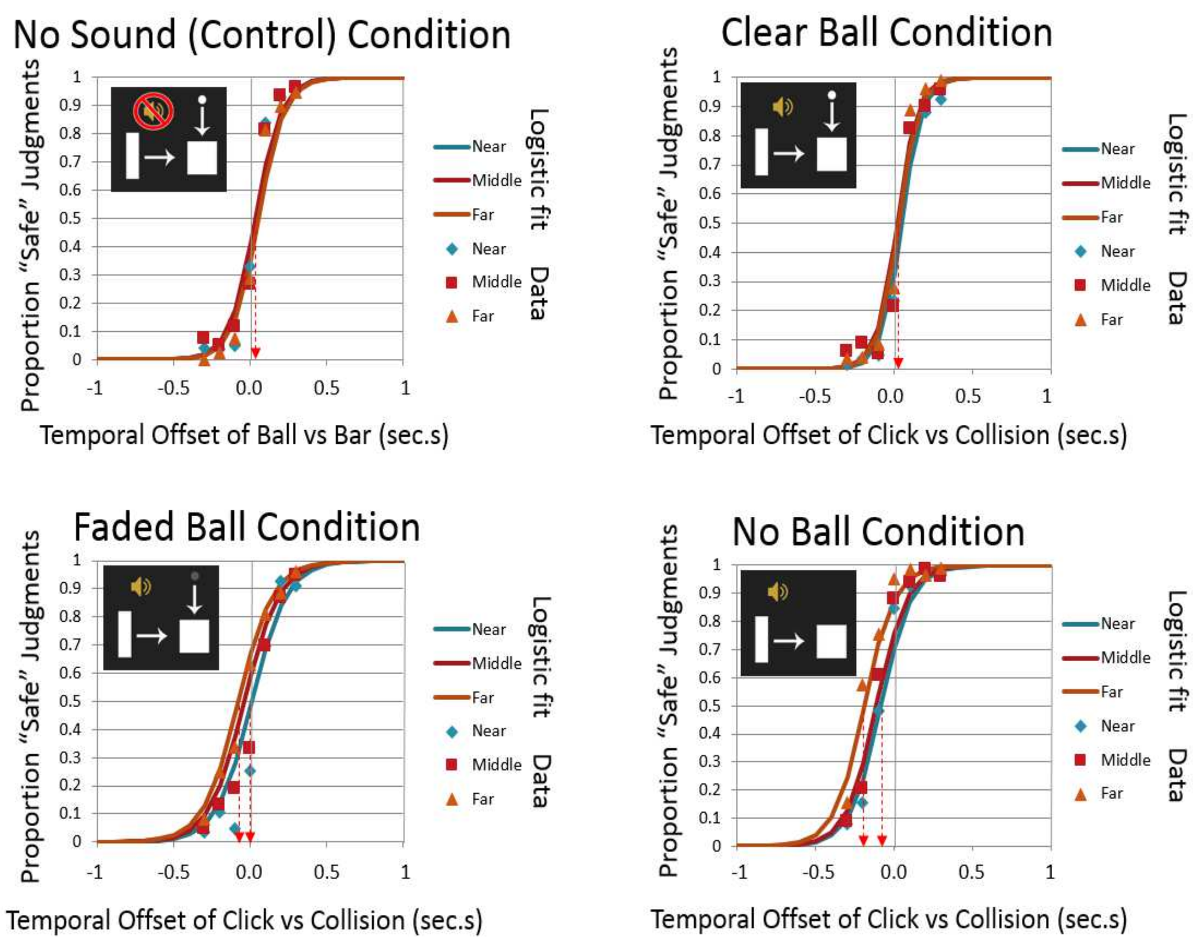


Figure 10. Results from each of the four visual salience conditions. A trend for the judgements to become more allocentric appears as the ball is made more visually salient. Dashed arrows represent the middle-point (50% probability) of the near line relative to the far line with the lines overlapping in the first two conditions. The points represent observed data and the sigmoid curves are predicted probabilities of calling “safe.”

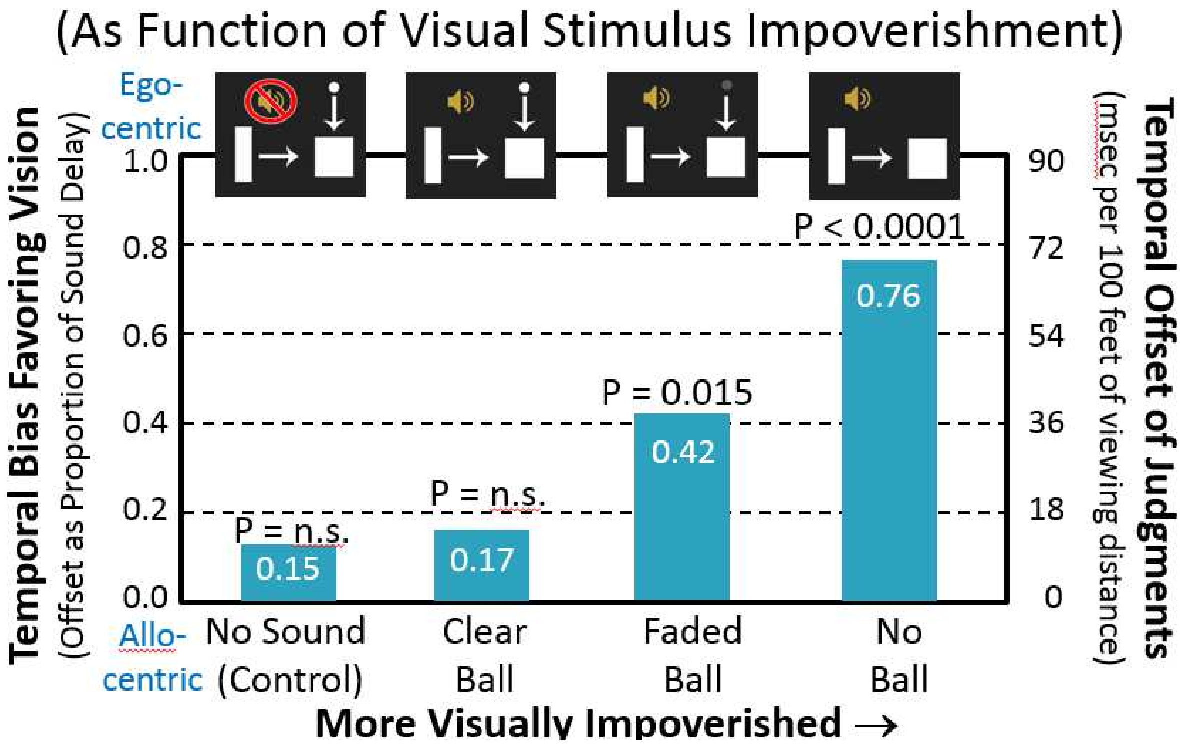


Figure 11. Temporal bias favoring vision and temporal offset of judgments. The "no ball" condition showed the highest amount of egocentric judgment.

We calculated the amount of bias/judgment offset of each condition (Figure 11) by dividing perceived distance per 100 ft (61m) by the amount of actual sound delay per 100 ft (61m).

Clear Ball Condition: $R^2 = 0.73$

Variable	Coefficient	Wald χ^2 (dF)	P value
Constant	-0.73	9.56 (1)	P = 0.002
Timing	Δ0.015/trial	152.7 (1)	P< 0.0001
Distance	15ms/100ft	1.85 (2)	P=0.4(n.s.)

Faded Ball Condition: $R^2 = 0.49$

Variable	Coefficient	Wald χ^2 (dF)	P value
Constant	-0.064	0.127 (1)	P=0.7(n.s.)
Timing	Δ0.009/trial	155.0 (1)	P< 0.0001
Distance	38ms/100ft	8.35 (2)	P = 0.015

No Ball Condition: $R^2 = 0.54$

Variable	Coefficient	Wald χ^2 (dF)	P value
Constant	0.87	18.9 (1)	P< 0.0001
Timing	Δ0.010/trial	138.4 (1)	P< 0.0001
Distance	68ms/100ft	21.2 (2)	P< 0.0001

Discussion

Experiment 2 demonstrated that as visual salience of the ball decreased, so did reliance upon the delayed auditory stimulus. Consequently, the conditions with impoverished visual stimuli showed the largest amount of bias for participants to perceive the visual stimulus (the runner) arriving at the base before the auditory stimulus (the ball) and calling the runner as being safe. These results were consistent with our hypotheses in that distance away from the stimuli and degraded visual salience resulted in the largest SAFE bias.

Experiment 3

Because the previous experiments showed promising results for a bias in how participants judge auditory and visual stimuli as a function of physical distance, for Experiment 3 we extended our study to using more ecologically-valid stimuli in a baseball setting. Experiment 1 demonstrated that observers did not account for distance in their judgment of auditory and visual stimuli, while experiment 2 demonstrated the same effect but as a function of visual salience of the baseball. Our next step was then to create video stimuli to see if the same systematic bias would appear.

Participants

The same set of participants from experiment 2 were used for experiment 3.

Materials

We used two video cameras simultaneously to record each video clip so we could simulate different angles from which a viewer may be positioned while watching the players. The two viewing conditions observing the runner pass the base were as follows: -45 degrees (optimal viewing condition) and 45 degrees (occluded viewing condition), see Figure 5. The research assistants also volunteered to help create the videos.

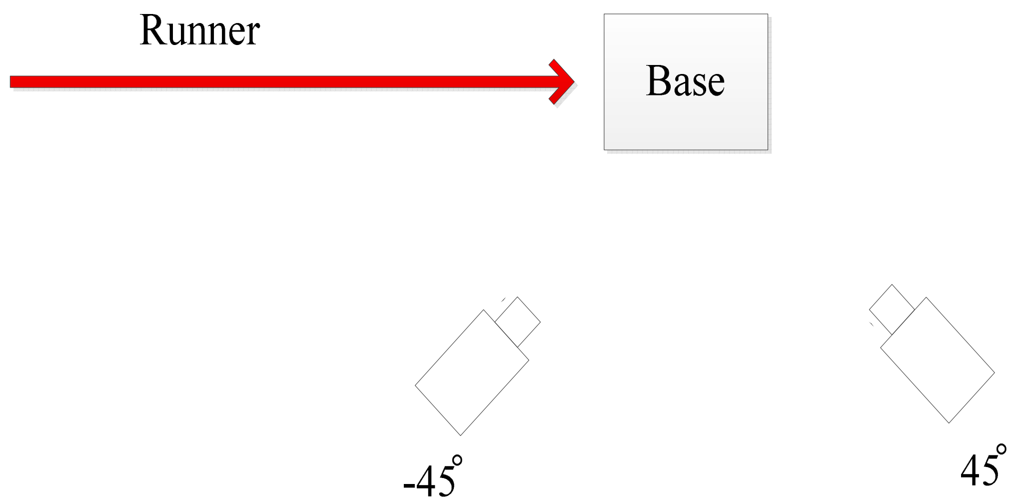


Figure 12. Top-down view of orientation of camera set up. Cameras recorded from different angles simultaneously.

Using Adobe Premiere Pro, we removed all sound and inserted just the sound of a simulated baseball hitting the mitt (the "click" sound which intentionally remained identical across all experiments). In the final condition, the top half of the screen was occluded so as to remove the visual information of the player's mitt and upper body as he caught the ball. This resulted in three conditions: Optimal viewing condition, an occluded condition, and an occluded bottom-half view (Figure 13).

Procedure

Using the same gymnasium as the previous two experiments, we again placed participants either near the screen, 100ft (61m) away at a middle condition or 200ft (122m) away at a far condition. While the prior experiments used a simple visual stimuli, the new experiment used video clips of baseball players running to the base while a fielder caught a ball close to the same arrival time. This resulted in a 7 x 3 x 3 (Sound Timing x Viewing Angle x Distance) condition experiment.

We recorded three research assistants as one threw the ball (the thrower), a second caught the ball at first base (the catcher), and the third ran to the base (the runner), see Figure 6. The runner was told to run to first base as quickly as possible while the thrower was instructed to throw the ball at approximately the same time that the runner would touch base. The sum total of these actions was meant to look like "close calls," where a runner arrives at base around the same time the ball does. Participants did not see the thrower as she was cropped out of each video. As in experiment 2, participants indicated if the player was safe (S) or out (O).

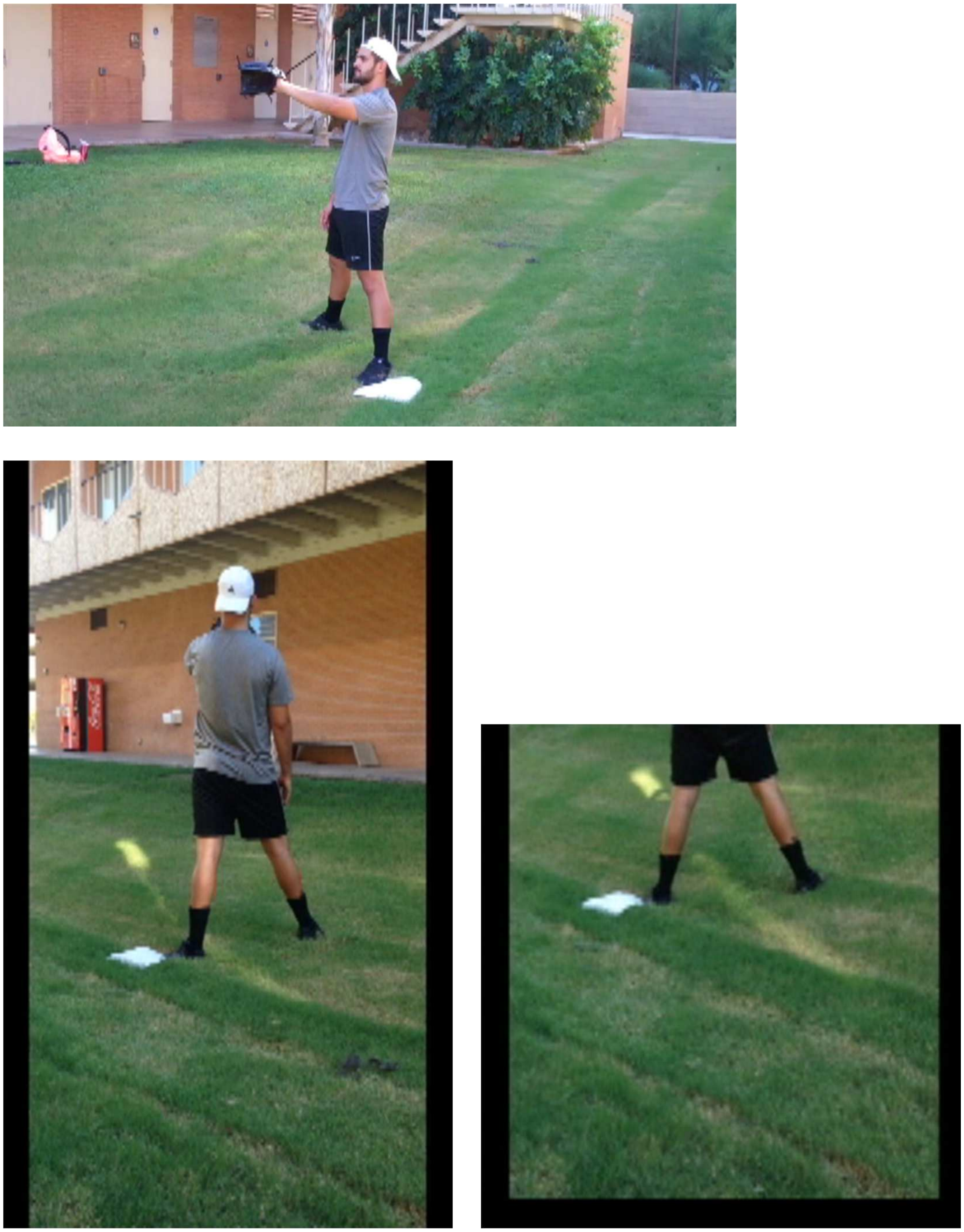
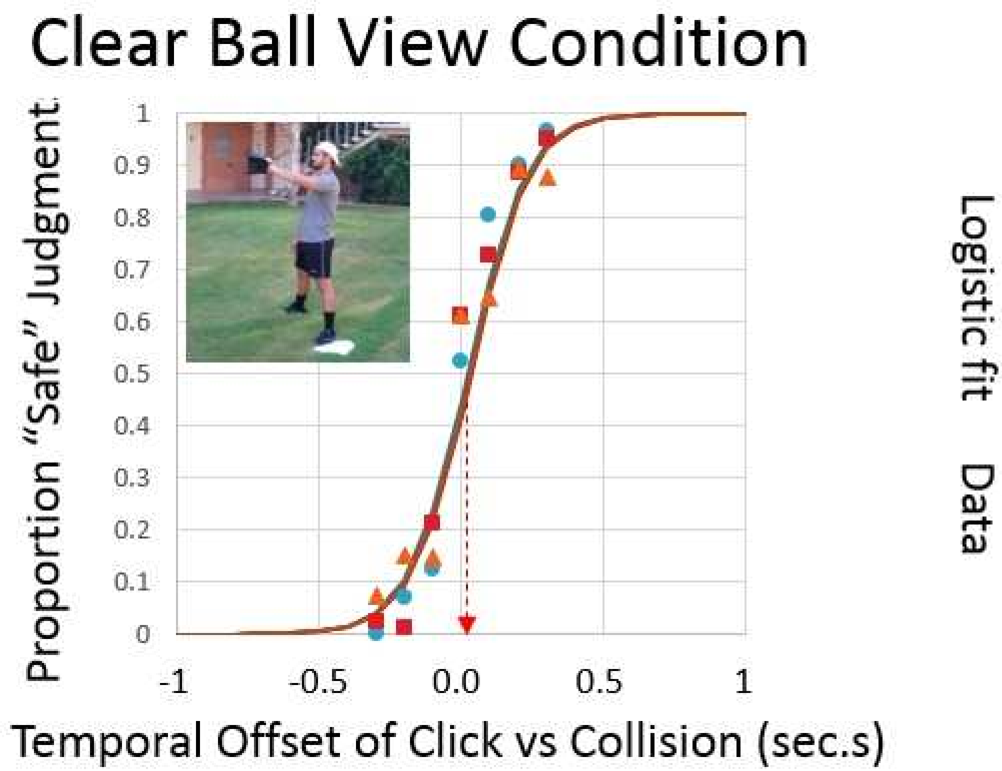


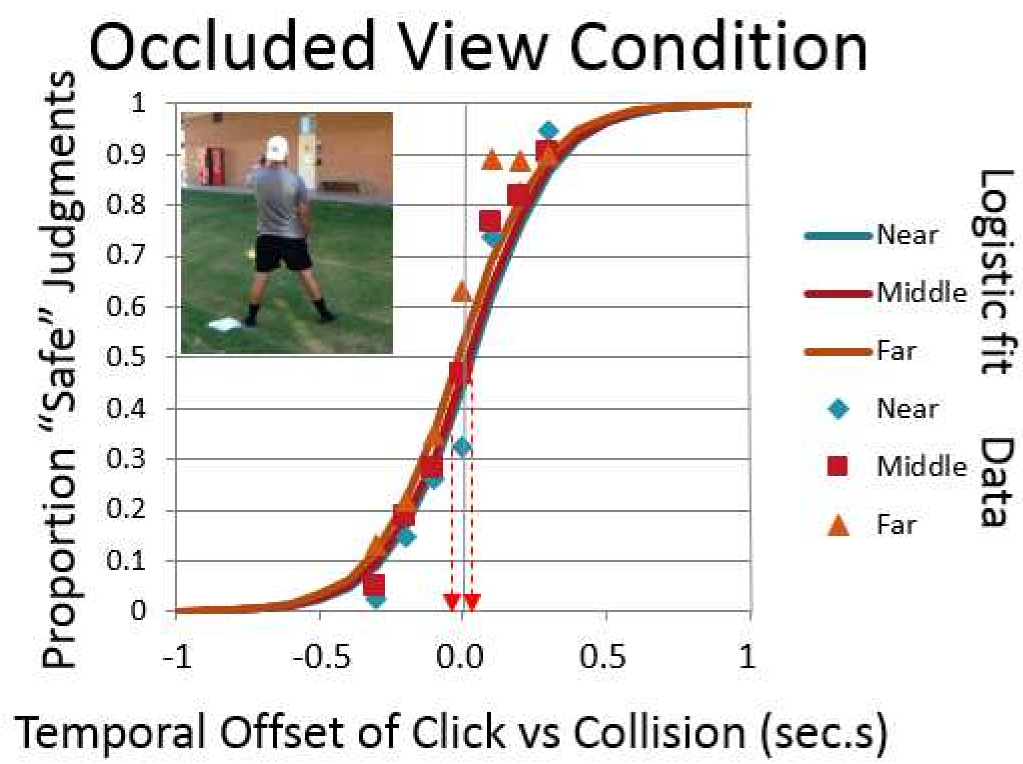
Figure 13. Different visibility conditions that observers viewed in experiment 3. Top panel depicts an optimal view with full view of mitt and ball, bottom left shows occluded view and bottom right shows occluded bottom-half view.

Figure 14. Screenshot of what participants observed. This is a 45 degree frame where the ball and runner arrive at the same time.

Results

Concordant with experiment 2 the condition in which the ball was not visible, the occluded bottom-half view condition, showed the strongest effect of the SAFE bias (Table 7). The other two conditions, optimal and occluded, showed a trend for the ball's visual salience to affect the judgment of observers, however distance was not a significant predictor.


Clear Ball View Condition
Proportion "Safe" Judgment
Temporal Offset of Click vs Collision (sec.s)
Logistic fit
Data
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-1
-0.5
0.0
0.5
1


Occluded View Condition
Proportion "Safe" Judgments
Temporal Offset of Click vs Collision (sec.s)
Logistic fit
Data
Near
Middle
Far
Near
Middle
Far
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-1
-0.5
0.0
0.5
1

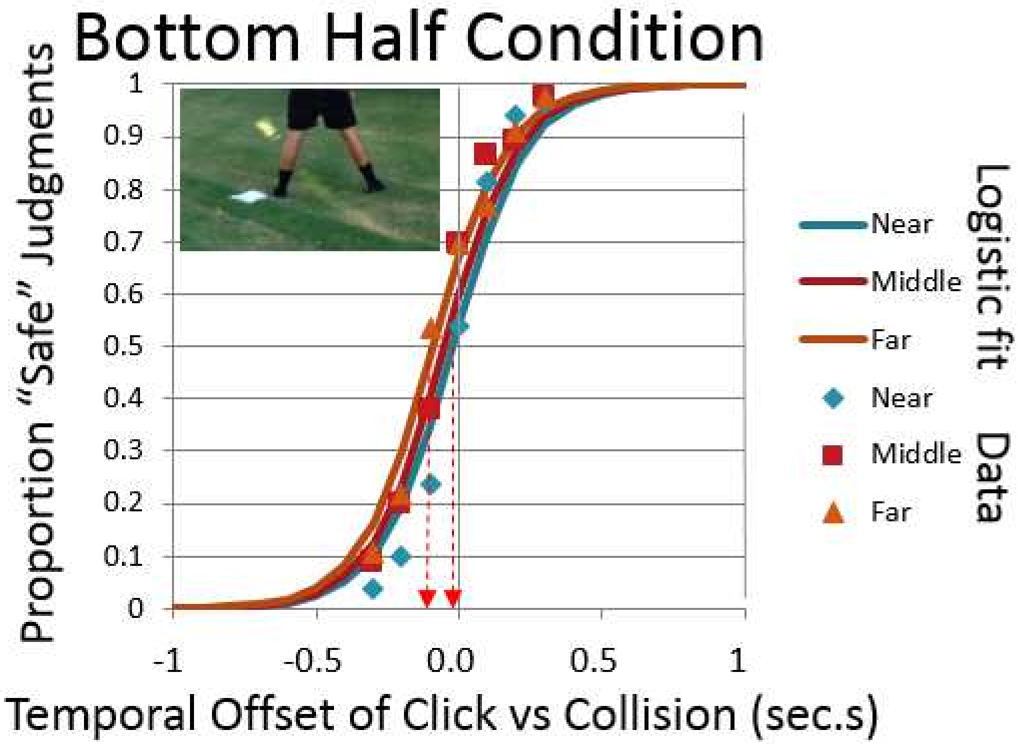


Figure 15. Logistic regression curves for each condition. Dashed arrows represent the middle-point (50% probability) of the near condition line relative to the far condition line.

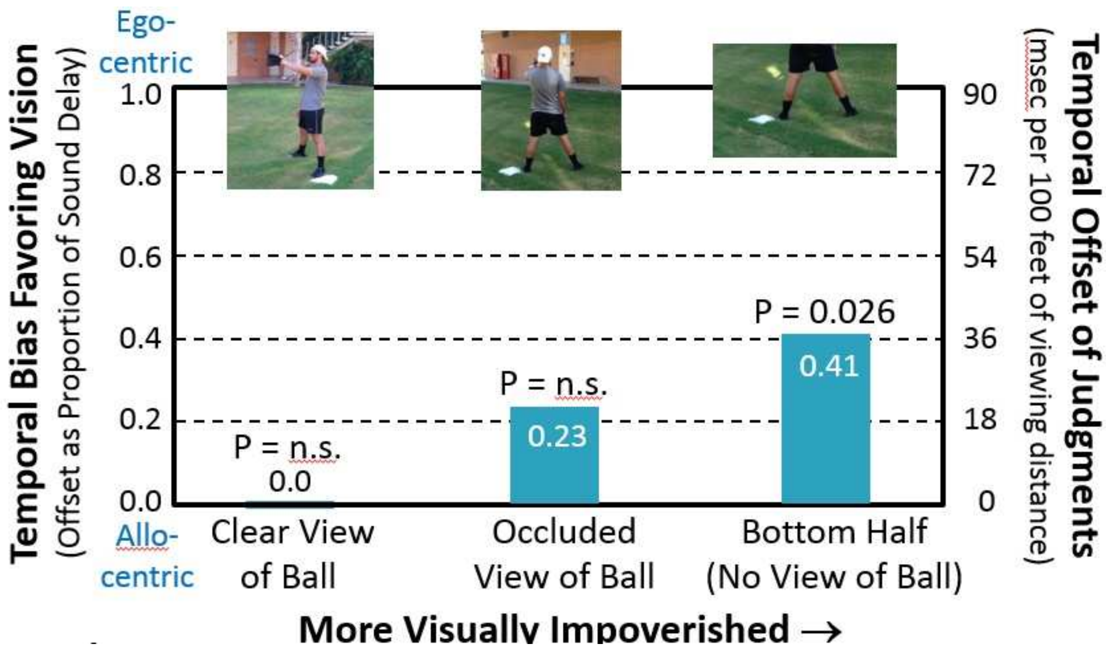


Figure 16. Temporal bias favoring vision and temporal offset of judgments for experiment 3. The bottom half occluded condition showed the highest proportion of egocentric judgment relative to the other two conditions in which distance was not a significant predictor in observer judgments.

Clear Ball Condition: $R^2 = 0.62$

Variable	Coefficient	Wald χ^2 (dF)	P value
Constant	-0.42	3.94 (1)	P = 0.047
Timing	Δ0.012ms/trial	165.0 (1)	P< 0.0001
Distance	0.0ms/100ft	0.0 (2)	P=1.0(n.s.)

Occluded Ball Condition: $R^2 = 0.54$

Variable	Coefficient	Wald χ^2 (dF)	P value
Constant	-0.40	4.12 (1)	P < 0.042
Timing	Δ0.010ms/trial	162.8 (1)	P< 0.0001
Distance	21ms/100ft	2.44 (2)	P=0.3(n.s.)

Bottom Half Only Condition: $R^2 = 0.52$

Variable	Coefficient	Wald χ^2 (dF)	P value
Constant	0.092	0.23 (1)	P=0.6(n.s.)
Timing	Δ0.009ms/trial	157.7 (1)	P< 0.0001
Distance	37ms/100ft	7.34 (2)	P = 0.026

Discussion

Using ecologically valid stimuli resulted in better accuracy for participants in judging timing of sound bursts relative to a visual event as more visual information was displayed. The amount of visual information in this scenario then enhanced participant's observations. This supports a Gibsonian theoretical perspective that in the full-viewing real world condition, one would have fewer biases or distortions, especially given that observers had a great deal of redundant confirmatory information such as the visual stimulus of the ball arriving.

The SAFE effect was slightly diminished in the occluded bottom-half view due to other visual cues not present in experiment 2. For example, the player's legs would still oscillate as he caught the ball and hence give participants added visual information as to when the ball was received. Further, we believe the SAFE bias was attenuated across all three video conditions due to using stimuli that were relatively slower than what one would observe in a professional baseball setting thereby making visual judgments easier.

General Discussion

Our hypothesis that distance from the source would affect synchrony of sound was supported: the further from the source, the more the delay affected participant's perception of when a simple discrete sound synchronized with the simple discrete visual stimuli as in Experiment 1, this only held true when the sound occurred before the flash. Participants showed much less of a tendency to err in the direction of the experiencing sound to be leading when the sound occurred after the flash. Experiment 2 also showed the SAFE bias, but further disambiguated the mechanism behind the bias, namely that the amount of visual salience of the ball affects how strong the bias manifests. Finally, in Experiment 3 we confirmed the bias continues to exist using real world stimuli, again, with the bias altered by amount of visual salience.

These results suggest that other real-world multimodal perceptions are affected by distance such as when viewing car accidents, other sports phenomena and even scenarios where one might be asked to judge who first fired a weapon.

Multisensory integration experiments are typically done in close proximity to the stimuli (such as sitting in front of a computer screen). Yet, we found that there is a systematic observational distance bias consistent with delays due to the speed of sound. Most past work on multisensory comparisons has explored the manner in which observers integrate sensory information of nearby common source events. The present work examined cases of competing sensory events and judgments of which occurred first at various observational distances. We found that observers exhibit a systematic bias to not consider the delay due to the speed of sound when the different sense information is a simple acoustic pulse and visual flash, but that when additional visual information augments the sound stimuli (such as seeing ball hit a mitt), the bias to experience auditory delay is greatly diminished. It appears that participants were judging two visual events, visual and sound versus visual, instead of just sound versus visual stimuli. In short, the slow speed of sound can systematically bias distant observers to misjudge multisensory events like baseball runners being safe vs out, leading to a “safe” bias.

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