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Abstract

Previous research shows links between body language and perceptions of deception. Traditionally, this is considered to stem from a form of speaker-modelling: lying takes cognitive effort, and effort is associated with certain visible gestures (e.g. scratching head, shifting position). Recently, work has highlighted how listeners' associations between the manner of spoken delivery (speech disfluency) and dishonesty happen at the earliest stages of reference comprehension. The studies presented here ask whether listeners also rapidly integrate the visual channel in making these pragmatic judgments. Eye- and mouse-tracking experiments investigate the time-course of any associations listeners' might have between gestures and lying.

Participants saw and heard a potentially dishonest speaker describe treasure being hidden behind a named object, while also viewing both the named object and a distractor object. Their task was to click on the object behind which they suspected the treasure to actually be hidden.

Experiment 1 is an exploratory attempt to assess which, if any, types of gestures listeners might associate with deception, and investigates the potential obstacles to incorporating a video element into a visual world paradigm.

Experiment 2 establishes that listeners do associate gestures with deception, and that this happens at an early stage in reference comprehension. Additionally, it examines whether listeners' judgments correlate with how nervous they think the speaker was in each video.

Title

That people deceive one another is an inescapable aspect of everyday communication. After studying participants' social interactions over a one week period, DePaulo, Kashy, Kirkendol, Wyer, and Epstein (1996) concluded that people lie on average twice a day. The idea that it possible to detect deceit — that there are systematic differences in people's behaviour depending on whether they are telling a truth or a lie — has long captivated human interest in a variety of areas, from criminal interrogations to the business world.¹ Research suggests, however, that the behaviours which we associate with lying are often at odds with those behaviours which actually signal dishonesty; a better understanding of why and how listeners interpret certain non-verbal behaviours as 'cues to deception' can help to explain this inconsistency. While associations between deception and speech disfluency have been shown to occur at the early stages of comprehension, the link between gestures and perceived deceit has been studied only in terms of after-the-fact judgments, or explicit beliefs about cue validity. The present experiments investigate listeners' associations between a speakers honesty and their visual behaviour, and study the time-course of how multi-modal information (speech and gesture) is integrated influence such pragmatic judgments.

Much research has investigated the behaviours which listeners associate with a speaker's metacognitive states. In speech, disfluency has been found to influence perceptions of both a speaker's certainty (Swerts & Krahmer, 2005) and their honesty in an utterance (Loy, Rohde, & Corley, 2017; Zuckerman, DePaulo, & Rosenthal, 1981). Interestingly, listeners appear to hold the association between disfluency and lying despite its accuracy as a deception-detection strategy being inconclusive. A 2003 meta-analysis of 116 studies by DePaulo et al. found little evidence for speech disturbances as cues to deceit, with Arciuli, Villar, and Mallard (2009) even suggesting that the opposite association may be more accurate, with lies being more fluent than truths.

In most natural communication, however, there are multiple channels of

¹Where, in some cases, "how to lie" is equally as important. See <https://www.marketplace.org/2008/02/18/business/lying-essential-doing-business>

information on which to base pragmatic judgments such as that of (dis)honesty: Lies may be discernable from truths in body-language and gestures as well as in spoken delivery. The influence that being deceitful has on a speaker's movements may pattern with the influence it has on their speech: A reduction in illustrative gesturing has been associated with deceit (Cohen, Beattie, & Shovelton, 2010; DePaulo et al., 2003), as has both shorter talking time and a reduction in detail (DePaulo et al., 2003), suggesting that speakers are less informative — in both speech and gesture — when lying. Just as speech contains disfluencies, the visual modality contains a collateral channel in the form of potentially unconscious movements and postures. Furthermore, just as research has found conflicting results in the actual relationship between speech disfluency and deception (DePaulo et al. 2003; Zuckerman, DePaulo, and Rosenthal 1981), the same is true for these visual cues. Several studies have suggested that deception is associated with a decrease in hand, arm, and leg movements (DePaulo, 1992; Ekman, 1989; Vrij, 1995), perhaps as a result of liars making efforts to control their behaviour. The two main meta-analyses in the area (DePaulo et al. 2003; Zuckerman, DePaulo, and Rosenthal 1981) have mixed conclusions: Zuckerman, DePaulo, and Rosenthal (1981) found more movement (specifically shrugs and fidgeting) be indicative of deceit, whereas ? found little evidence of a relationship between lying and any form of movement, with the exception of fidgeting (although this was unclear, depending upon the target of the fidgeting).

The disparity between listeners beliefs about what a liar sounds like and how a liar actually speaks is matched by a disparity in their beliefs about what a liar looks like. For ten visual cues across 33 studies, Zuckerman, DePaulo, and Rosenthal (1981), found that nine were *believed* to be associated with deceit, but only three reliably signalled actual deception. Furthermore, in a subset of 13 studies which reported relationships between potential cues and subsequent deception judgments (rather than beliefs about cues), three of the four available visual cues were associated with judgments of deception, and none of these patterned with their accuracy as actual cues. Even post-hoc perceptions of speakers' own gestures when producing a lie have been found to be at odds with how they actually behaved: Vrij, Semin, and Bull (1996) found that after partaking in two

interviews — one in which they were truthful, the other dishonest — participants believed that their movements increased when lying, even though a decrease actually occurred. Furthermore, whether or not participants were informed before-hand that deception is usually associated with a decrease in movements had no affect on subsequent beliefs about their own behaviour.

The divergence between actual and perceived cues to deception patterns with the consistent finding that we are bad at detecting lies from truths. In reviewing 39 studies in detection of deception, Vrij, Kneller, and Mann (2000) found an average accuracy rate of 56.6% — only just above chance. One suggested reason for this was that listeners often look for the wrong cues in attempting to detect deceit (as evidenced in DePaulo, Rosenthal, Rosenkrantz, and Green 1982), perhaps resulting from being unaware of their own behaviour during lying (as in Vrij et al. 1996), combined with an inaccurate model of what deceitful behaviour looks and sounds like. This inaccurate model may be predicated on introspection as a speaker rather than experience as a listener: Speakers believe themselves to both be more disfluent (Zuckerman, Koestner, & Driver, 1981) and produce more movement (Vrij et al., 1996) when lying.

In order to better understand how listeners make judgments of deception, recent research by Loy et al. (2017) investigated the time-course of the disfluency-lying bias. Loy et al. (2017) used a visual world paradigm in which participants were presented with two objects along with utterances describing the location of some treasure which was hidden behind one of the objects. These utterances were presented as having been elicited in a previous experiment, and could be either truthful or dishonest. Crucially, Loy et al. (2017) manipulated the manner of spoken delivery, with half of the experimental items containing a speech disfluency (with experiments investigating both utterance-initial and utterance-medial disfluencies). Participants were tasked with choosing where they *believed* the treasure to really be hidden — the object named in the utterance (indicating a judgment of honesty), or a distractor (indicating dishonesty). Participants judged disfluent descriptions of the treasure’s location as more dishonest than fluent ones (as indicated by their choice of object). Importantly, this corresponded to an early bias in

both eye and mouse movements towards the not-referred-to object, providing evidence that listeners are capable of accessing and integrating contextual information (manner of spoken delivery) to alter the interpretation of an utterance’s global meaning.

Little is known, however, about whether this might extend to the visual channel. Research into how speech and gesture interact in language comprehension has focused largely on how illustrative gesture can influence the literal interpretation of the message. Gestures which mismatch accompanying speech have been found to interfere with comprehension in an on-line fashion, suggesting that speech and gesture are integrated in the real-time to form a unified system in comprehension (see Habets, Kita, Shao, Özyurek, and Hagoort 2011; Kelly, Creigh, and Bartolotti 2010). The interplay between gesture and pragmatics, however, remains largely under-studied. In the field of deception research, measuring listeners associations between movements and lying has been limited to post-hoc judgments, or assessing their explicit beliefs about the associations (see Vrij and Semin 1996; Zuckerman, Koestner, and Driver 1981). The same is true of the few studies there have been outside of the deception literature, focusing on illustrative and pointing gestures and their effect on the comprehension of, for example, indirect requests (see Kelly and Barr 1999).

The present studies develop the ‘treasure-game’ paradigm from Loy et al. (2017) to include a visual display of the speaker, manipulating the presence of gestures. Experiment 1 attempts to assess which, if any, types of gestures listeners might associate with deception, and investigates the potential obstacles to incorporating a video element into a visual world paradigm. In Experiment 2 we focus on if, how, and when, adaptor gestures (fidgeting movements) influence listeners’ judgments of deception. Additionally, we ask whether listeners’ judgments are predicted by their perceptions of how nervous they think the speaker to be in each video.

Experiment 1

Eye- and mouse-tracking methods are used to investigate the time course of listeners’ judgments about the honesty of an utterance, and how these judgments are

influenced by the occurrence of various types of gestures. Specifically, we look at 3 types of gesturing, all of which have different (dis)advantages to consider when trying to integrate video in to a visual-world paradigm. Visual-world studies typically present participants with a disembodied voice which produces expressions referring to a number of objects in a display which is visible to the participant. Tracking participants eye-movements during this procedure allows researchers to study the time course of referential comprehension, and thus see how listeners' processing is influenced by a speaker's use of language. However, the link between eye-movements and language processing is indirect: information in the presented speech affects participants' allocation of attention, which in turn regulates gaze position. The inclusion of a video component will likely draw more attention than the other, static, objects, potentially delaying or diminishing the detection of any on-line effects of gesture.

Materials

Visual stimuli consisted of the same 120 line drawings from Snodgrass and Vanderwart (1980) which were used in Loy et al. (2017), presented in pairs across sixty trials. In each trial, the speaker named one object (referent) as that which concealed the treasure; the other object is hereafter named the distractor. Each referent was associated with a recording specifying the image as the object that the treasure was hidden behind ("The treasure is behind the <referent>"). Along with these images, each trial contained a video of a person who was purported to be the speaker of the utterances. So that videos could be counterbalanced across referents, and thus across utterances, the face of the person in the video was blurred. This meant that, when presented with a given utterance, it was believable that both audio and visual stimuli had been produced concurrently.

Sixty videos (30 Gesture, 30 No-gesture) were created. The thirty no-gesture videos were comprised of ten recordings (each presented thrice) of a speaker sitting motionless with her hands either side of a tablet on a table, upon which the location of treasure was purported to be displayed. Ten videos presented the speaker making one of five trunk movements, ten presented various adaptor gestures (e.g. finger tapping, head tilts), and

ten presented the speaker sitting motionless but in a different position to that of the no-gesture videos (e.g. hand on chin, arms crossed, etc).

A selection of trunk movements, adaptors (e.g. finger tapping, head tilts), and different postures, were used as gestural cues to deception. Stimuli for this experiment had to strike a balance between being salient enough to register as a potential cue, but not being so distracting as to delay participants' fixating upon the images under discussion, thus losing any detection of possible on-line effects. The chosen selection balanced these two requirements in different ways. Adaptor gestures, allowed for the most variation, but were required to overlap with speech in order to make the audio and video look believable. This increased the potential for interference of the video at the point of the onset of the referent. Trunk movements were not susceptible to this, as they were believable when the gesture was presented in its entirety prior to speech onset. Different postures were presented in videos of the speaker sitting motionless but in a different position to that used in the no-gesture condition. This meant that these videos were no more salient across the presentation of the utterance than the no-gesture videos. However, because these different postures presented the speaker having implicitly shifted position at some earlier point, this ran the risk of weakening the association between the change of posture with the current utterance.

For each video of a trunk movement, the frame at which the movement ended was identified, and was the point at which the utterance began. However, this meant that video onset to speech onset varied (Mean = 1430ms, sd=440ms), the duration of which could be interpretable as speech initiation time, which in turn could be associated with preparing a dishonest utterance. To control for any effect of gesture being explained as simply a sensitivity to the duration of pre-utterance video, these durations were matched in the no-gesture videos. For each of the adaptor gesture videos, the amount of overlap between speech and gesture was adjusted to make it as believable as possible that the two modalities were simultaneously produced (Mean = 1370ms, sd=410ms). These durations were matched by the different posture videos.

Twenty referents were counterbalanced across two lists, each containing 10 trunk

movement videos, and 10 no-gesture videos. The remaining referents (40) were randomly paired with the remaining videos (10 adaptors, 10 differeng postures, 20 no gesture) for each participant. This was done only to match the structure of the previous treasure-game paradigm (Loy et al., 2017), with trunk movements initially considered to be our best bet of eliciting gesture-dishonesty associations without interfering with the time-course of the judgment.

Procedure

Stimuli were displayed on a 21 in. CRT monitor, placed 850 mm from an Eyelink 1000 Tower-mounted eye-tracker which tracked eye movements at 500 Hz (right eye only). Audio was presented in stereo from speakers on either side of the monitor. Mouse coordinates were sampled at the frame rate of the videos (25 fps). The experiment was presented using OpenSesame version 3.1 (Mathôt, Schreij, & Theeuwes, 2012).

Participants were told that they were going to watch videos which were recorded from a previous experiment, in which one participant had to deceive another as to the location of some hidden treasure. Figure 1 presents a sample trial from the experiment. Between trials, participants underwent a manual drift correct, after which the fixation dot turned red for 500ms. The two objects (referent and distractor) were displayed on the screen for 2000ms. After this, the video appeared and the cursor was centred and made visible. After a given time ($M=1410\text{ms}$, $sd=410\text{ms}$), the utterance began.

Bonus Rounds

To maintain motivation throughout the study, participants were told that there were a number of “hidden bonus rounds” which offered more treasure. Following 25% of the filler trials, a “bonus round” message appeared before progressing to the next trial. This informed participants that they had successfully located bonus treasure (regardless of the object chosen). Half of these appeared on randomly chosen trials in the gesture condition, and the other half in the no-gesture condition.

Participants were also told that the top scorers would be able to enter their names on a high-score table, which was shown at the beginning of the experiment.

Participants completed five practice trials (one of which was presented as a bonus round) prior to the main experiment. Two of these were static, two displayed the speaker in different postures, and one displayed the speaker making a trunk movement.

Eye movements, mouse coordinates and object clicked (referent or distractor) were recorded for each trial.

Post-test Questionnaire

Participants were asked to complete a short post-test questionnaire. The questionnaires contained three questions, the most important of which asked if participants noticed anything odd about the visual or audio stimuli. Any participant who indicated that they noticed anything unusual was then verbally questioned, to decide whether they believed that the speech and gesture had been produced naturally and simultaneously. All participants were subsequently debriefed (told that the audio and video were created separately and stitched together), and asked again verbally if they noticed anything unusual in that respect.

Results

Twenty-four native English speaking participants took part in the experiment for a desired sample size of twenty. Participants were recruited from the University of Edinburgh community, and participated in return for a payment of £4. Four participants who indicated suspicion of the proposed origins of the audiovisual stimuli, and their data was removed from all analysis.

Analysis

Analysis was carried out in R version 3.4.4 (R Core Team, 2017), using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015). Trials in which participants did not click on either the referent or distractor (0.003% of trials) were excluded from all analyses.

Object clicked (referent or distractor) was modeled using mixed effects logistic regression, with fixed effects of gesture type (No Gesture, Different Postures, Trunk Movements, Adaptor Gestures) and video-to-speech duration (Z-scored), thus controlling

for any possible effect of perceived speech latency on judgments of dishonesty. Random intercepts and slopes for gesture type and video-to-speech were included by-participant, along with random intercepts by-referent. Reaction times (measured from referent onset) were modelled with the same fixed and random effect structure. Following Lo and Andrews (2015), we compared mixed effects logistic regression models which specified an identity link function, assuming gaussian, gamma and inverse gaussian distributions.

In previous studies using the treasure game paradigm, eye- and mouse- movements have been analysed over the time window starting at the onset of the referent name and extending for 800 ms; just beyond the duration of the longest referent (800 ms). Because the current study includes in the analysis all available referents (rather than the subset used in previous experiments) the longest referent is 1062 ms, and so this window is extended to 1100 ms. Visual inspection of the time-course of proportions of fixations towards either object suggested that there may be a later effect of gestures in the decision of which object to click. Growth curve analysis (See Mirman, Dixon, and Magnuson 2008) was used to investigate this further, over the time window from referent onset to 1815 ms post-onset (mean click time).

Eye fixation data was averaged into 20 ms bins (of 10 samples) prior to analysis. For each bin, we calculated the proportions of time spent fixating referent or the distractor, resulting in a measure of the proportions of fixations on either object over time.

The position of the mouse was sampled every 40 ms. Using the X coordinates only, we calculated the number of screen pixels moved and the direction of movement (towards either referent or distractor). We then calculated the cumulative distance travelled towards each object over time as a proportion of the cumulative distance travelled in either direction. Movements beyond the outer edge of either object were considered to be ‘overshooting’ and were not included in calculations (0.8% of samples). Eye- and mouse- biases were calculated from the proportions of referent to distractor fixations, and were subsequently empirical logit transformed (Barr, 2008). In these measures, a value of zero indicates no bias towards either object, and positive and negative values indicate a bias towards the referent and distractor respectively.

Eye and mouse data was modelled over the time window from 0 to 1100 ms post-referent onset using linear mixed effects models, with fixed effects of time, gesture type, and their interaction. Random intercepts and slopes for time were included both by-referent and by-participant, along with by-participant random effects of gesture type. Following Baayen (2008), we considered effects in these models to be significant where $|t| > 2$.

Growth curve analysis over the time window from 0 to 1815 ms post-referent onset included 3 degrees of orthogonal polynomials for time, based on the pattern of the eloit referent-distractor bias having 2 turning points. These time polynomials, along with their interaction with gesture type, were included as fixed effects in a linear mixed effects model, with random intercepts and slopes for all time polynomials both by-participant and by-referent.

Mouse clicks

Across the experiment, participants clicked on the referent in 55% of trials and the distractor in only 45%. Table 1 shows the proportions of clicks to either object following different types of gesture. When presented with an utterance accompanied by no-gesturing, participants showed a bias toward a final interpretation of the utterance as truthful, with more clicks to the referent than the distractor $\beta = 0.62$, $SE = 0.16$, $p < 0.001$. All types of gestures saw a reduction in this bias, with adaptor gestures ($\beta = -1.03$, $SE = 0.34$, $p < 0.005$) showing a greater change than different postures and trunk movements ($\beta = -0.72$, $SE = 0.31$, $p < 0.05$ and $\beta = -0.62$, $SE = 0.26$, $p < 0.05$ respectively). The duration of video shown prior to the beginning of speech was not found to be associated with which object was eventually clicked.

Comparisons — via both AIC and BIC — of reaction time models suggested that an inverse gaussian distribution provided the best fit to the observed data. Neither gesture type nor duration of video prior to speech was associated with a significant change in reaction times.

Eye movements

Figure 2 shows the time-course of fixations to referents and distractors over 2000 ms from referent onset, split by each type of video.

Analyses conducted over the period from referent onset to 1100 ms post-onset (duration of the longest referent) showed that, when presented with no gesture, participants displayed a fixation bias towards the referent which increased over time ($\beta = 1.15$, $SE = 0.29$, $t > 2$). For videos which presented the speaker either in a different posture, or producing an adaptor gesture, this increasing bias to the referent was significantly reduced ($\beta = -0.97$, $SE = 0.13$, $t > 2$, $\beta = -0.59$, $SE = 0.13$, $t > 2$), but this was not the case for videos of trunk movements ($\beta = -0.25$, $SE = 0.15$, $t = 1.67$).

Growth curve analysis over the period from referent onset to 1815 ms post-onset (mean click time) showed that when presented with no gesture, participants showed an tendency to fixate on the referent over the course of this time period ($\beta = 0.67$, $SE = 0.11$, $t > 2$). Significant effects of gesture type on the intercept term indicated lower overall referent fixations during this period after viewing a different posture ($\beta = -0.36$, $SE = 0.04$, $t > 2$), a trunk movement ($\beta = -0.29$, $SE = 0.4$, $t > 2$), or an adaptor gesture ($\beta = -0.67$, $SE = 0.4$, $t > 2$), in comparison to the no gesture videos. Significant interactions of gesture type and the linear time coefficient indicate that this reduction in referent-bias due to gesture type increases over the course of the window, with adaptor gestures showing a larger reduction relative to no gesture videos ($\beta = -116.89$, $SE = 11.62$, $t > 2$) than different postures ($\beta = -75.41$, $SE = 11.65$, $t > 2$) and trunk movements ($\beta = -58.78$, $SE = 12.97$, $t > 2$). Figure 3 shows the time-course of the elogit referent-distractor bias, alongside the fitted values from the growth curve model.

Mouse movements

Figure 7 shows the time-course of the proportions of cumulative distance the mouse moved towards the referent and distractor for 2000 ms from referent onset, split by each type of video. Analysis on the time window from 0 to 1100 ms post-referent onset patterned with the eye-tracking data: When the speaker made no gesture, participants

showed a tendency to move increasingly towards referent over this period ($\beta = 1.08$, $SE = 0.22$, $t > 2$). As with eye-movements, different postures and adaptor gestures resulted in a weakening of this referent-bias ($\beta = -0.81$, $SE = 0.13$, $t > 2$ and $\beta = -0.77$, $SE = 0.13$, $t > 2$ respectively), but trunk movements did not ($\beta = -0.10$, $SE = 0.14$, $t = 0.69$).

Discussion

Experiment 1 investigated how the pragmatic inferences listeners make about a speaker's honesty might be influenced by the presence of different types of gestures and postures, and which of these provide the best means of studying the time-course of such inferences. Comparable to Loy et al. (2017), participants showed a tendency to interpret an utterance as truthful when it had been presented without any potential cue to deceit. Utterances presented alongside different postures and movements weakened this tendency, but only the presence of adaptor gestures resulted in significantly more judgments of deception than truthfulness (indicated by clicks to the distractor over the referent). The influence of the visual channel was also evident in the early stages of utterance processing, with videos of different postures and adaptor gestures resulting in a reduction of the tendency to fixate on — and move the cursor toward — the referent. Interestingly, this early effect was not found for videos of trunk movements, perhaps a result of these gestures having been fully presented prior to the onset of speech, meaning that at the point of referent onset the audiovisual information immediately available to the listener was indiscernable from the no gesture videos. Similarities may be drawn here to the subtle differences when presented with either utterance-initial or utterance-medial speech disfluencies in Loy et al. (2017): The temporal proximity of a cue potentially influencing how much it reduces the initial referent-bias.

Unlike Loy et al. (2017), when presented with a possible cue to deception, the point at which listeners preference toward the referent tended to be matched (or overtaken, in the case of adaptor gestures) by the distractor was later, approximately 1000 ms post-referent onset. Contrastingly, participants in Loy et al. showed little to no initial

referent-bias following a disfluent utterance, with a distractor-bias appearing approximately 600 ms post-referent onset following both utterance-initial and utterance-medial disfluencies.

There are several possible explanations for the later effect found in the current study. Firstly, the inclusion of longer referents, along with the fact that not all referent-distractor pairs were controlled for phoneme onset, may result in establishing reference being delayed. Secondly, the visual component of the paradigm may be detracting from fixations to the two objects. This could also explain the differences in the early window (0 to 800 ms) between the types of gestures: The reduction in the referent-bias may be due to the video being more salient in both the different posture and the adaptor gesture conditions. That said, however, the initial referent-bias appears at approximately 300 ms post-referent onset in all conditions — a point comparable to previous studies using this paradigm (King, Loy, and Corley 2018; Loy et al. 2017).

Lastly, it might be that the integration of gestural cues into judgments of deception is simply slower than it is for speech cues, perhaps because the link from gestures to deception follows a different path than that from disfluency to deception. Where a listener might link associate lying with speech disfluency via the effort involved in planning a dishonest utterance, this might not be the case for gestures. Speech disfluency can be mapped directly to the processes of speech production: It is a straightforward inferential link from the way a given utterance is delivered to the content of that utterance, be it pragmatic (e.g. lying Loy et al. 2017) or literal (e.g. naming difficulty Arnold, Kam, and Tanenhaus 2007). Co-speech movements, however, can map to many things, some only indirectly related to the production of speech, and some completely unrelated (e.g. scratching an itch). Whilst there is evidence to suggest that cognitive effort increases gesturing (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001), an alternative intuitive line of reasoning would, for instance, link gestures to nervousness/anxiety, and link nervousness to deception. The post-test questions revealed that 4 participants felt that they had been responding to whether the speaker looked tense or relaxed (with 1 even mentioning that the movements looked more relaxed, and so signalled honesty). In fact,

only 2 participants explicitly linked an *increase* in movement with lying; 9 mentioned using body language and gestures to make their judgments but specified neither rationale nor direction; and, oddly, 15 described perceiving differences in spoken delivery which they believed signalled lying (intonation, hesitancy). It might be that participants were not responding directly to the presence of a gesture, but to something which took longer to establish, such as how nervous the speaker looked over the course of the video.

To clarify whether gestural information can be integrated on a similar time-course to spoken delivery, and investigate whether a gesture-deception bias may be via perceived anxiety patterning with perceived dishonesty, we conducted a simplified version of Experiment 1 which focused only on adaptor gestures associated with anxiety.

Experiment 2

Experiment 2 focused on the influence of adaptor gestures on judgments of dishonesty, and looked at whether these judgments paralleled with perceptions of nervousness in the speaker. If gesture is linked to deception via perceived anxiety, then gestures which are rated as more nervous should result in more judgements of dishonesty. Using the same paradigm as Experiment 1, participants in Experiment 2 saw utterances accompanied by either an adaptor gesture or no gesture. After the eye-tracking task, participants then rated each video on how nervous the speaker looked.

Materials

A subset of 40 images from those in Experiment 1 were used across twenty trials. As in Experiment 1, these images were presented in referent-distractor pairs, combined with 20 utterances naming the referent as the location of the treasure. The referents and distractors used were those which, in Loy et al. (2017), had been matched for both ease of naming and familiarity.

In Experiment 2, participants saw these pairs of images alongside a selection of 10 Adaptor Gestures and 10 Static/No Gesture videos. Based on participant feedback from Experiment 1, care was taken to ensure that the No Gesture videos presented the speaker in a relaxed posture. Adaptor gestures were based on descriptions of anxious non-verbal

behaviour from Gregersen (2005). Prior to running the study, 28 videos (18 different adaptor gestures, 10 static) were rated on how nervous the speaker looked. 10 native english speakers were told that they were going to watch videos (without audio) of someone being questioned in a stressful situation, and were asked to rate how nervous the speaker looked in each video (1: very relaxed, 7: very nervous). The 10 adaptor gestures with the highest ratings (Mean = 4.1, SD = 1.5) were included in the experiment, along with the 10 static recordings (M = 1.9, SD = 1.1).

The 20 referents were counterbalanced across two lists such that each referent that occurred with a gesture in the first list occurred without a gesture in the second. The pairings of referents with specific videos/gestures within each condition was randomised on each run of the experiment.

Figure 5 presents a sample trial from Experiment 2. One key difference from Experiment 1 was that speech initiation time (the duration from video onset to speech onset) in Experiment 2 was a fixed constant: In all trials, speech began 1170 ms after the beginning of the video. There were no other procedural differences in trials between experiments 1 and 2, and no trials in Experiment 2 displayed a bonus round message.

After the main task, participants were asked to watch the videos again, without audio, rating how nervous they thought the speaker looked (using the same 1-7 scale as described above). Participants then completed the same post-test questionnaire as in Experiment 1, with data being excluded from analysis based on the same criteria.

Results

Twenty-three native English speaking participants took part, with three participants excluded due to suspicion of the audiovisual stimuli being scripted. Participants were paid £3.

Analysis

We followed the same analysis strategy as was used for Experiment 1, with the experimental manipulation of gesture being a dichotomous Gesture vs. No Gesture.

Trials which did not result in a click to either object (0.8%) were excluded, along with mouse movements beyond the outer edge of the objects (1% of samples).

Analyses of object clicks and reaction times did not control for video-to-speech duration, since this was controlled in the experimental design. To investigate whether listeners' deception judgments were predicted by their subsequent ratings of perceived nervousness, analysis of object clicks included participants' post-test ratings (Z scored) of each video as a fixed effect, along with the interaction with gesture.

The time window of analysis for eye- and mouse- movements was reduced to the 800 ms following referent onset, based on the fact that the subset of referents included in this experiment had a maximum duration of 776 ms. Because Experiment 2 fully counterbalanced gesture across all referents, random effects of gesture and time and their interaction were included both by-referent and by-participant.

Mouse clicks

Across the experiment, participants clicked on the referent in 53% of trials and the distractor in 47%. Table 2 shows the proportions of clicks to either object following videos displaying either an adaptor gesture or no gesture. As in experiment 1, participants showed a bias toward a final interpretation of the utterances without gestures as truthful, with more clicks to the referent than the distractor ($\beta = 1.15$, $SE = 0.37$, $p < 0.005$). Patterning with the adaptor gestures in experiment 1, utterances presented with an adaptor gesture resulted in bias towards clicking the distractor ($\beta = -2.45$, $SE = 0.51$, $p < 0.001$). Inclusion of participants' post-test ratings of how nervous they perceived the speaker to be in each video did not improve model fit ($\chi^2=0.46$). There was no effect of gesture on time to click.

Eye movements

Figure 6 shows the time-course of fixations to referents and distractors over 2000 ms from referent onset, split by presence of gesture. Analyses conducted over the period from referent onset to 800 ms post-onset patterned with results from Experiment 1: When presented with an utterance unaccompanied by gesture, participants displayed a fixation

bias towards the referent which increased over time ($\beta = 3.03$, $SE = 0.77$, $t > 2$). When presented with an utterance accompanied by an adaptor gesture, this bias was greatly reduced ($\beta = -3.00$, $SE = 1.02$, $t > 2$).

Mouse movements

Figure ?? shows the time-course of the proportions of cumulative distance the mouse moved towards the referent and distractor for 2000 ms from referent onset, split by presence of gesture. Analysis on the period from 0 to 800 ms post-referent onset patterned with the eye-tracking data: Following no gesture videos, participants showed a tendency to move increasingly towards referent over this period ($\beta = 1.90$, $SE = 0.39$, $t > 2$). As with eye-movements, this referent-bias was greatly reduced following a gesture ($\beta = -2.46$, $SE = 0.77$, $t > 2$)

Discussion

Across both experiments, participants showed a slight overall tendency to take an utterance as honest rather than dishonest, although this only differed from chance in Experiment 1. Our results show that the body language and gestures which accompany a spoken utterance affects the judgments which listeners make about the utterance's veracity. Utterances presented with a comparatively neutral posture and no gesturing bias listeners towards believing the speaker to be truthful, as shown by increased tendency to fixate on, and move towards, the object which was named by the speaker. Comparable to fluent (as opposed to disfluent) utterances in Loy et al. (2017), this implicit honesty-bias when faced with no obvious potential cue is consistent with previous research in detecting actual lies from truths, which suggest a general tendency to judge a speaker as truthful (Vrij et al. 2000).

Consistent with previous research in deception judgments and beliefs about deceptive cues, participants linked dishonesty with an increase in movement. As in Loy et al. (2017), the pragmatic judgments which listeners made began during the on-line processing of speech, becoming apparent alongside the unfolding of the critical linguistic input. The speed with which these judgments were made — especially in Experiment 2 —

suggest that visual information can modulate listeners' judgments about a speaker's intentions concurrently with the integration of lexical information.

Different types of gestures and postures influence deception judgments to different degrees, affecting the time-course of these judgments accordingly. A reduction in the tendency to believe the speaker was apparent when the speaker was either in a different posture or made a trunk movement prior to speaking, although these resulted in no final tendency towards interpretations of either honesty or dishonesty. Only utterances presented with adaptor gesturing were associated with more judgements of dishonesty than of truthfulness, and this patterned with the greatest reduction in the early eye- and mouse- movement biases towards the referent. Experiment 2 provided a clearer account of the influence of adaptor gestures on deception judgments at the early moments of referent comprehension, with the tendency to look — and move — towards the referent being completely attenuated when the utterance was presented with a gesture. However, following adaptor gestures in both experiments, the bias towards the distractor — signifying perceived dishonesty — over the referent appeared approximately 1000 ms after the referent began, at a later point than previous versions of this paradigm have found speech disfluency to modulate deception judgments. To better understand how cues to deception in different modalities differ, further research would require investigating the effect of disfluency when the visual channel is also available — for example, studying the time course of deception judgments when faced with one or both of a disfluency and an adaptor gesture.

Interestingly, participant's subsequent ratings of how nervous the speaker looked in each video did not pattern with their final judgments beyond whether or not the video presented a gesture, suggesting that listeners' associations between gesture and lying is not a consequence of perceived anxiety in the speaker.

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Table 1

Object clicks

	No Gesture	Different Posture	Trunk Movement	Adaptor Gesture
Clicks to Referent	63.8%	48.0%	49.7%	41.5%
Clicks to Distractor	36.2%	52.0%	50.3%	58.5%

Table 2

Object clicks

	No Gesture	Gesture
Clicks to Referent	80.9%	24.2%
Clicks to Distractor	19.1%	75.8%

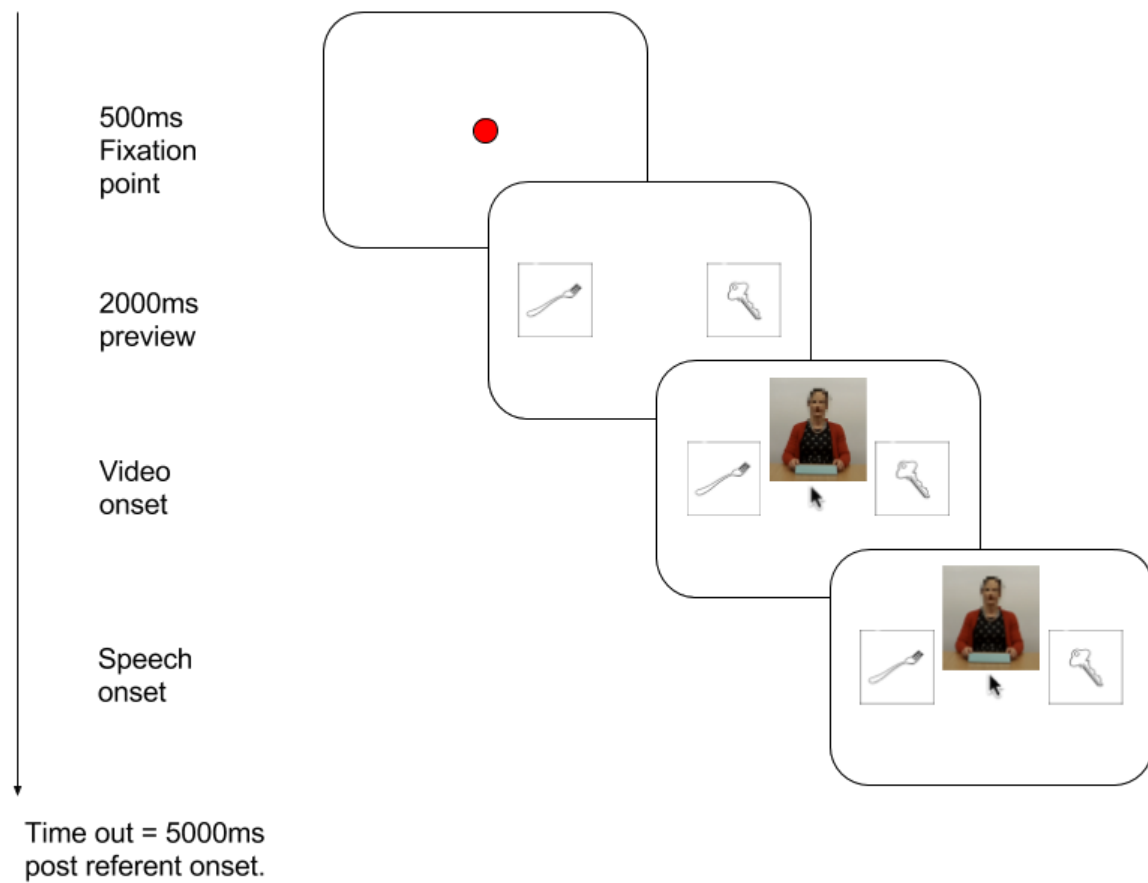


Figure 1. Procedure of a given trial, Experiment 1

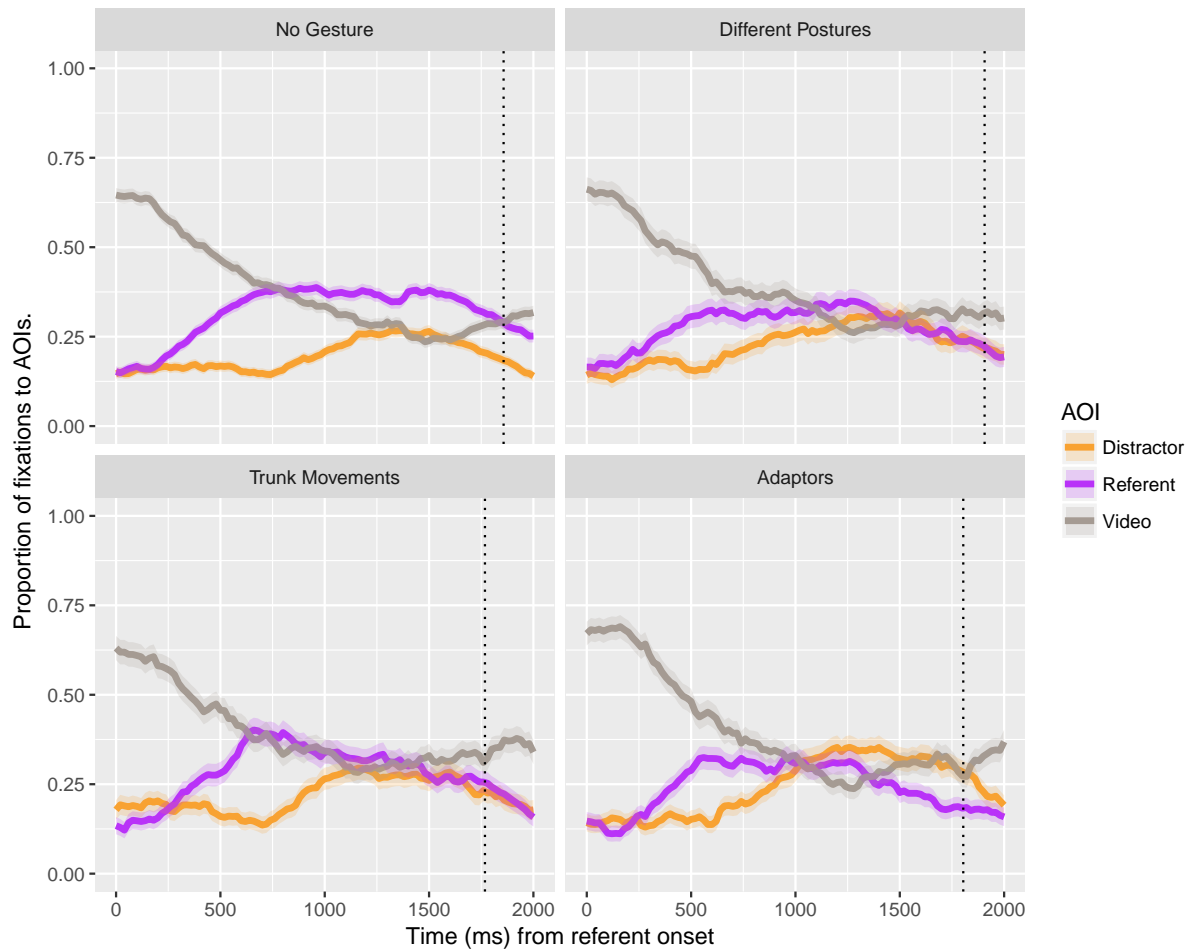


Figure 2. Eye-tracking results for Experiment 1: Proportion of fixations to each object (referent, distractor, video), from 0 to 2000 ms post-referent onset, calculated out of the total sum of fixations for each 20 ms time bin. Shaded areas represent ± 1 standard error of the mean.

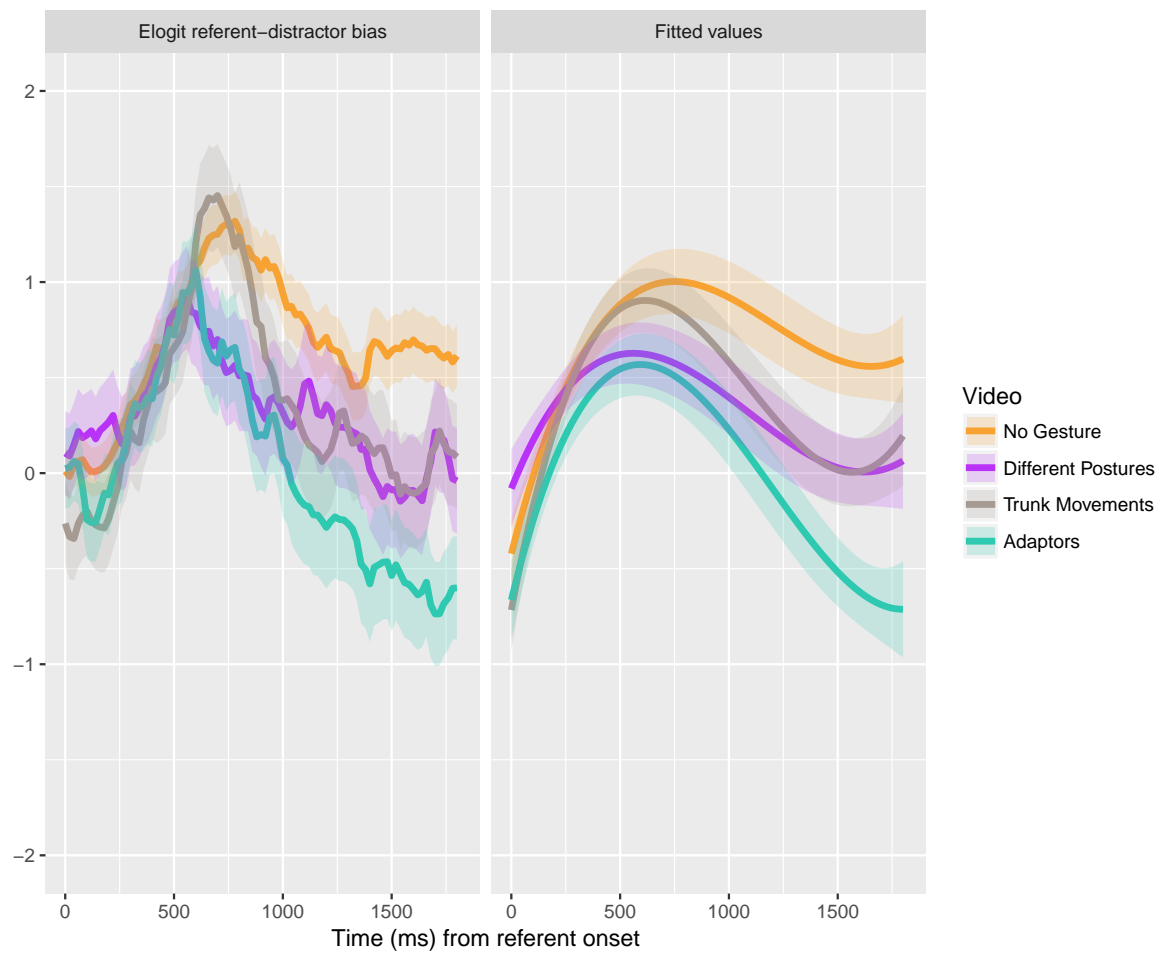


Figure 3. Elogit referent-distractor bias, and fitted values from growth curve analysis

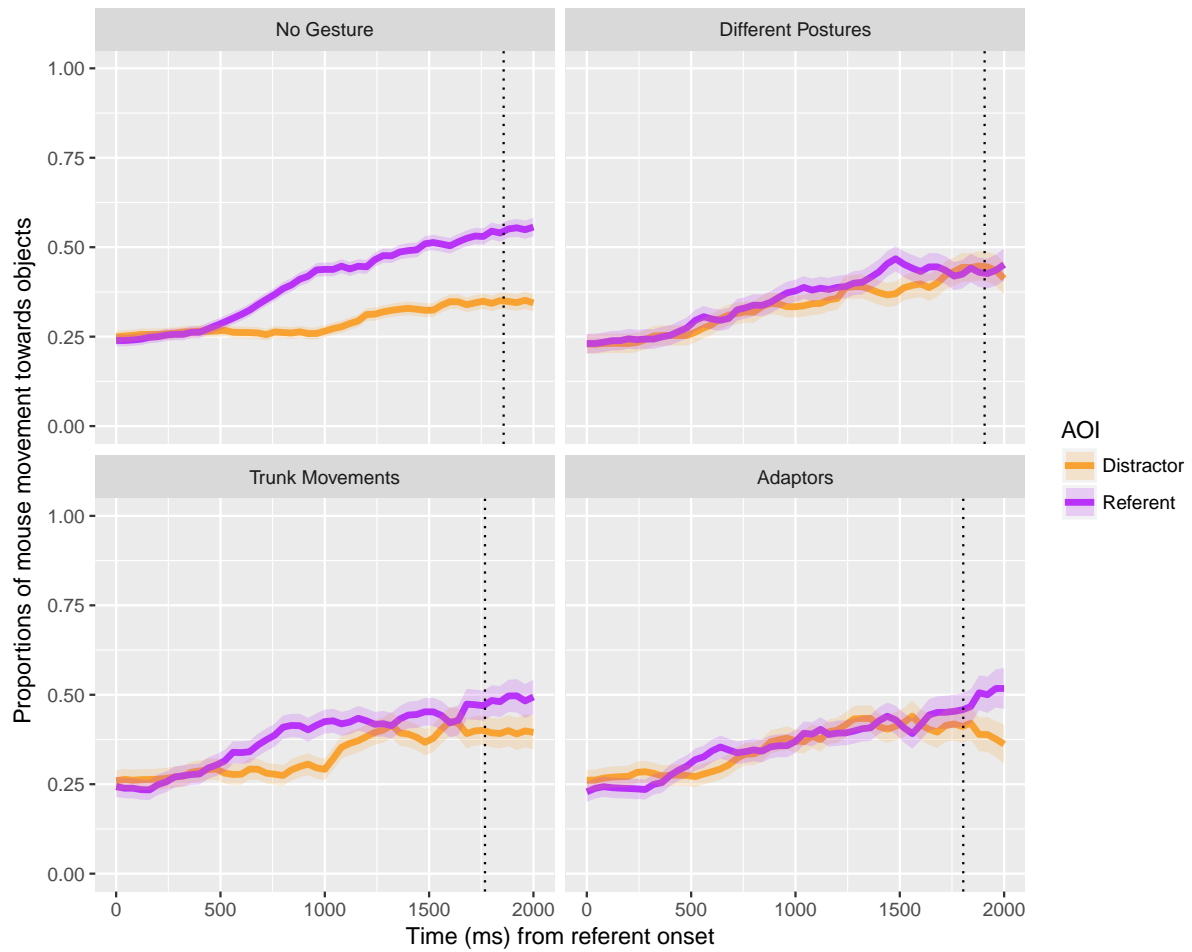


Figure 4. Mouse-tracking results for Experiment 2: Proportion of cumulative distance traveled toward each object from 0 to 2000 ms post-referent onset. Proportions were calculated from the total cumulative distance participants moved the mouse until that time bin (from video onset, when cursor was made visible). Shaded areas represent ± 1 standard error of the mean.

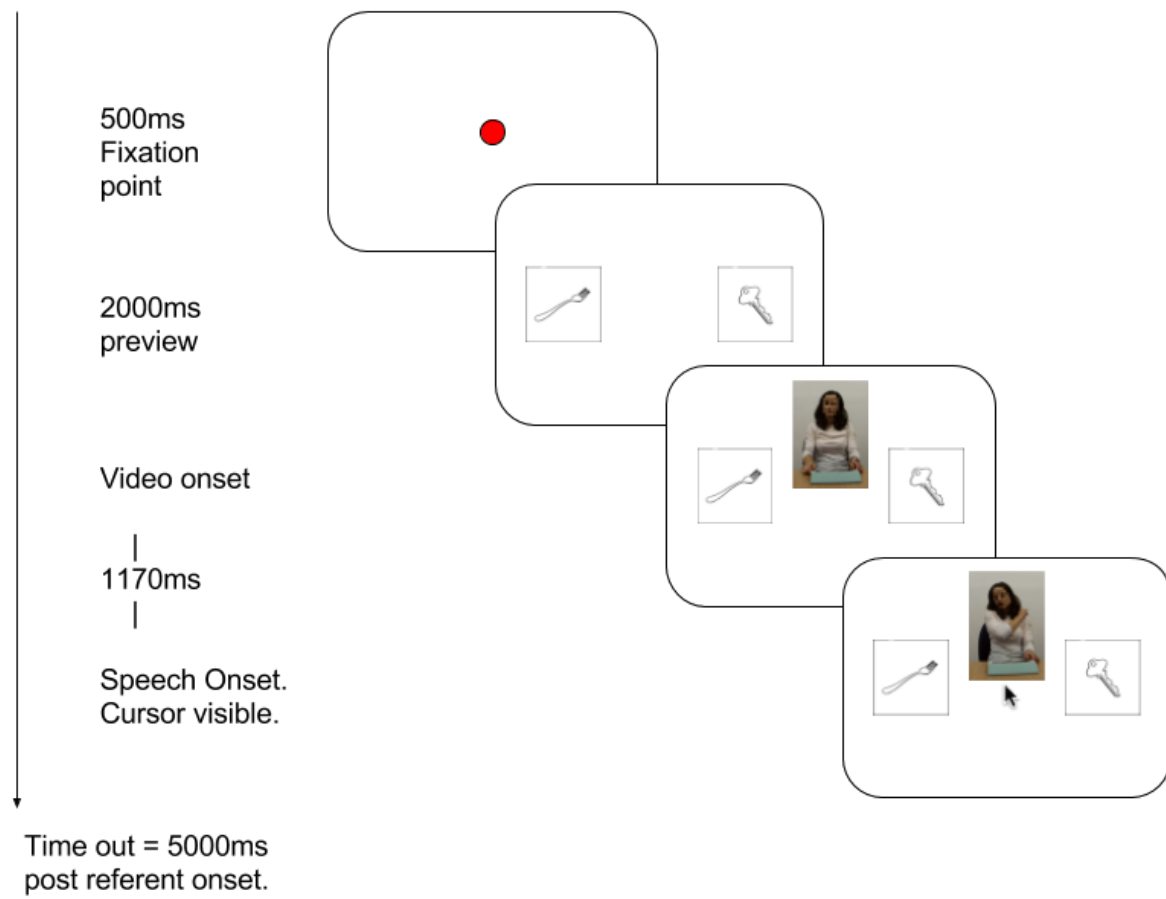


Figure 5. Procedure of a given trial, Experiment 2

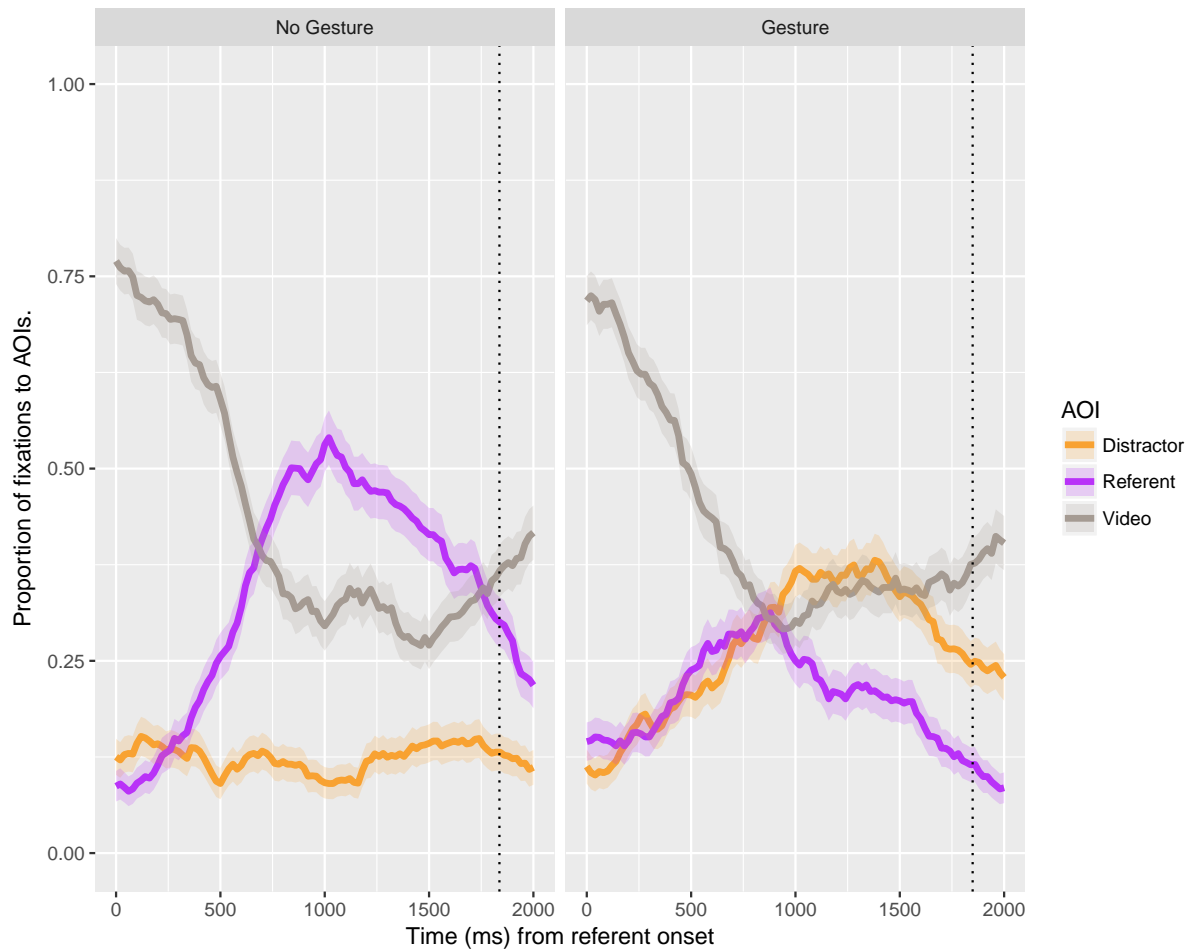


Figure 6. Eye-tracking results for Experiment 2: Proportion of fixations to each object (referent, distractor, video), from 0 to 2000 ms post-referent onset, calculated out of the total sum of fixations for each 20 ms time bin. Shaded areas represent ± 1 standard error of the mean.

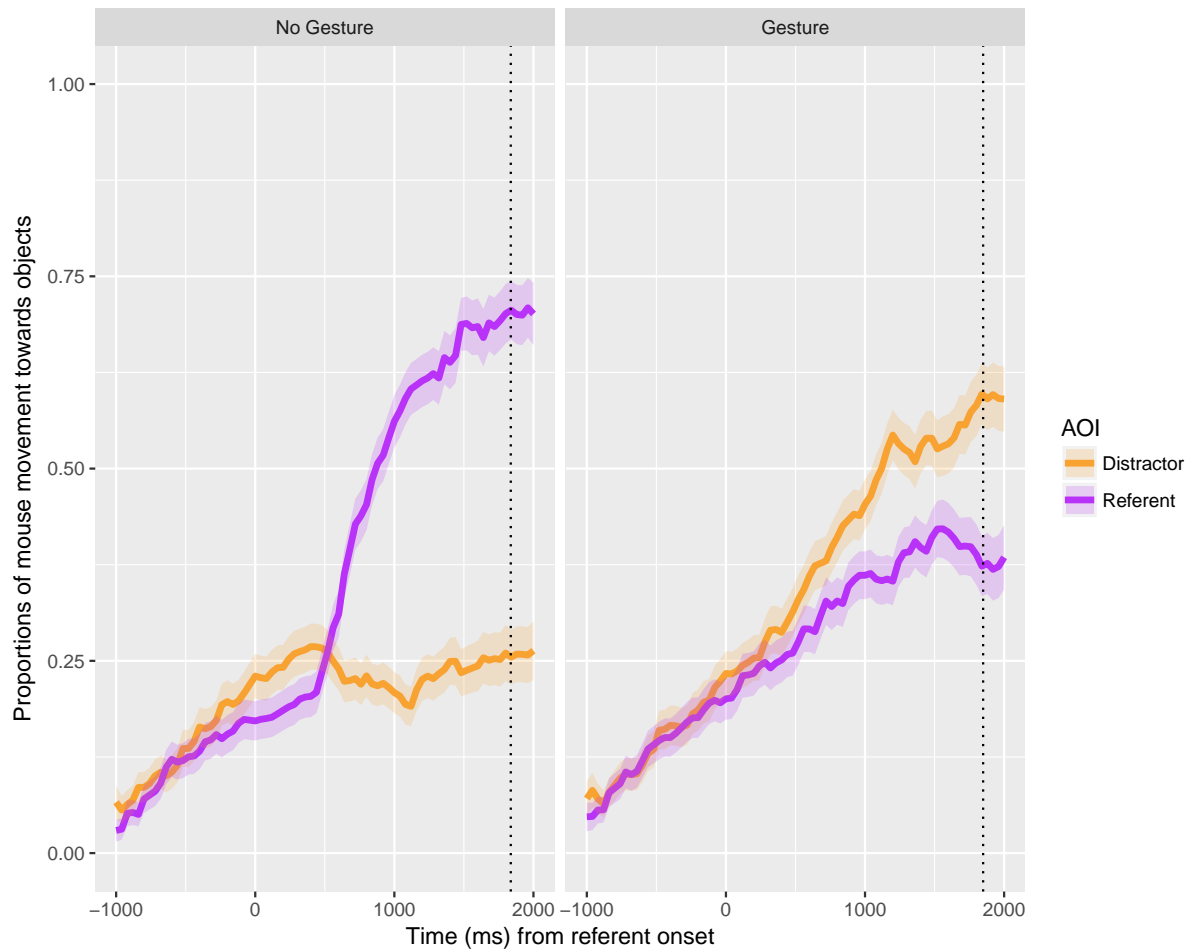


Figure 7. Mouse-tracking results for Experiment 2: Proportion of cumulative distance traveled toward each object from 0 to 2000 ms post-referent onset. Proportions were calculated from the total cumulative distance participants moved the mouse until that time bin (from speech-onset, when cursor was made visible). Shaded areas represent ± 1 standard error of the mean.