¹ Pragmatics as social inference about intentional action

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Abstract

Pragmatic inferences are based on assumptions about how speakers communicate: speakers are taken to be cooperative and rational; they consider alternatives and make intentional choices to produce maximally informative – linguistic or non-linguistic – utterances. We test key implications of this view across six experiments with American-English speaking adults (N = 231). Experiments 1a and 1b showed that participants made pragmatic inferences based on different types of communicative actions, some being non-linguistic. In Experiment 2, pragmatic inferences were found to be conditional on the speaker's epistemic states. Finally, Experiments 3a to 3c showed that pragmatic inferences were made only when the communicative signal was produced intentionally. Taken together, these results strengthen the view of pragmatics as social inferences about cooperative communicative behavior.

Keywords: Pragmatics, gesture, inference, communication

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Introduction

Human communication is not reducible to the words and sentences being uttered: there is an inferential gap between what a speaker said and what they meant. We use pragmatic inferences to close this gap and recover the intended meaning. As such, pragmatics is thought to have a central role in everyday language as well as in language learning (Bohn & Frank, 2019; Clark, 1996). Pragmatic inferences are computed in a social-cognitive reasoning process based on assumptions about how speaker's communicate (Levinson, 2000; Sperber & Wilson, 2001). On a Gricean view, these assumptions entail that the speaker communicates in a rational and cooperative way (Grice, 1991). The speaker is assumed to consider multiple possible utterances from which they intentionally choose the one that is maximally informative to the listener.

The pragmatic inference process can be described as follows. The listener assumes that in order to communicate an intended meaning, the speaker considers multiple possible utterances. The speaker assesses how informative each utterance is – how likely it is to convey the intended meaning – given the context. Finally, the speaker intentionally chooses the most informative utterance. The listener works backwards through these steps and thereby recovers the speaker's intended meaning.

Traditionally, utterances are taken to be linguistic expressions (Sauerland, 2012). Yet, inspired by evolutionary and developmental thinking, the idea has been put forward that pragmatic inferences are more general and can be derived from all sorts of communicative behaviors, verbal or non-verbal (Heintz & Scott-Phillips, 2023; Moore, 2017; Sterelny, 2017; Tomasello, 2008). According to Sperber and Wilson Tomasello (2008), any kind of behavior can be used communicatively as long as it is intentionally produced for this purpose (and recognized by the listener as produced that way) (Csibra & Gergely, 2009). As a consequence, pragmatic inferences should depend on intentionally produced non-linguistic

50 aspects – movements, gestures or eye gaze – of an utterance in just the same way as on

51 linguistic aspects.

52   Our goal in this paper is to experimentally test three key implications of this view.

53 First, we test if pragmatic inferences can be derived from non-linguistic acts of

54 communication alone. Kampa and Papafragou (2023; see also Kampa, Richards, and

55 Papafragou, 2024) have shown that adults and children make pragmatic inferences based on

56 drawings. We advance this work to other non-linguistic expressions such as eye gaze or

57 gestures. Second, we ask if listeners base their inferences on the speaker's epistemic states.

58 This question is central because what the speaker knows determines what alternative

59 utterances they could have used. In other words, intentionally choosing to produce an

60 utterance instead of an alternative requires being aware of the alternative. This step

61 replicates and extends earlier work documenting the use of epistemic states in pragmatic

62 inference (Bergen & Grodner, 2012; Breheny, Ferguson, & Katsos, 2013; Kampa &

63 Papafragou, 2020; Wilson, Lawrence, & Katsos, 2023). Finally, we assess the importance for

64 pragmatic inference of whether the non-linguistic aspects of a communicative act were

65 produced intentionally or not; an aspect that has not been studied intensely thus far.

66   In our experimental setup, we focused on how listeners make pragmatic inferences to

67 identify the referent of a novel word (Bohn, Tessler, Merrick, & Frank, 2022; Frank &

68 Goodman, 2014). As in previous work, a simple pictorial vignette showed a speaker

69 requesting objects; in our case, the objects were lying on tables to either side of the speaker.

70 On one table, there was an object of type A while on the other table was an object of type A

71 and one of type B (see Figure 1). The speaker always referred to the table with the two

72 objects and – ambiguously – requested an object using a non-word (e.g. dax). Based on the

73 analysis above, we expected listeners to reason as follows: the speaker had the option to refer

74 to one of the two tables. The most informative way to refer to object A would have been to

75 refer to the table with only object A on it. The speaker intentionally chose to refer to the

⁷⁶ other table instead which suggests that they want object B. In the following six experiments

⁷⁷ we tested if this inference depends on the type of (non-)linguistic signals the speaker used

⁷⁸ (Experiments 1a and 1b), the speaker's epistemic state (Experiment 2), and the intentional

⁷⁹ production of all aspects of the utterance (Experiments 3a - 3c).

Experiment 1a

⁸¹   Our first experiment tested whether participants made similar pragmatic inferences

⁸² from linguistic and non-linguistic signals, comparing 1) looking and labeling the object and

⁸³ 2) pointing at and labeling the object with 3) pointing alone and 4) looking alone.

Methods

⁸⁵   The experiment was pre-registered at: https://osf.io/qcwr8. The code to run all

⁸⁶ experiments reported in this paper are available in the following public repository:

⁸⁷ https://github.com/manuelbohn/prag-int.

⁸⁸   **Participants.**   Participants in all experiments were recruited via Amazon Mechanical

⁸⁹ Turk (MTurk) and required to have US IP addresses. They received payment equivalent to

⁹⁰ an hourly wage of ~ \$9. The sample size for all experiments (except Experiment 1b) was

⁹¹ planned so as to have 120 observations (total number of trials) per cell. Participants were

⁹² excluded when they failed to select known objects (a car and a ball) during training trials.

⁹³ The planned sample size for Experiment 1a was 60. Three participants did not provide valid

⁹⁴ data so that the final sample size for Experiment 1 was 57. Data was collected in March

⁹⁵ 2018.

⁹⁶   **Material.**   All experiments were framed as word learning games in which animal

⁹⁷ characters would make requests and participants would have to select the corresponding

⁹⁸ objects. They were implemented as a website using `HTML` and `JavaScript` to which

⁹⁹ participants were directed via MTurk. Animals were cartoon figures that could be animated.

¹⁰⁰ Objects were novel objects drawn for the purpose of the study. For each animal, we recorded

¹⁰¹ a set of utterances (one native English speaker per animal). The scene for all experiments

involved the animal standing between two tables, one with two novel objects (A and B), and
the other with one novel object (A) (see Figure 1A). Each trial involved a different animal
and different objects. Participants responded by clicking on objects on the screen.
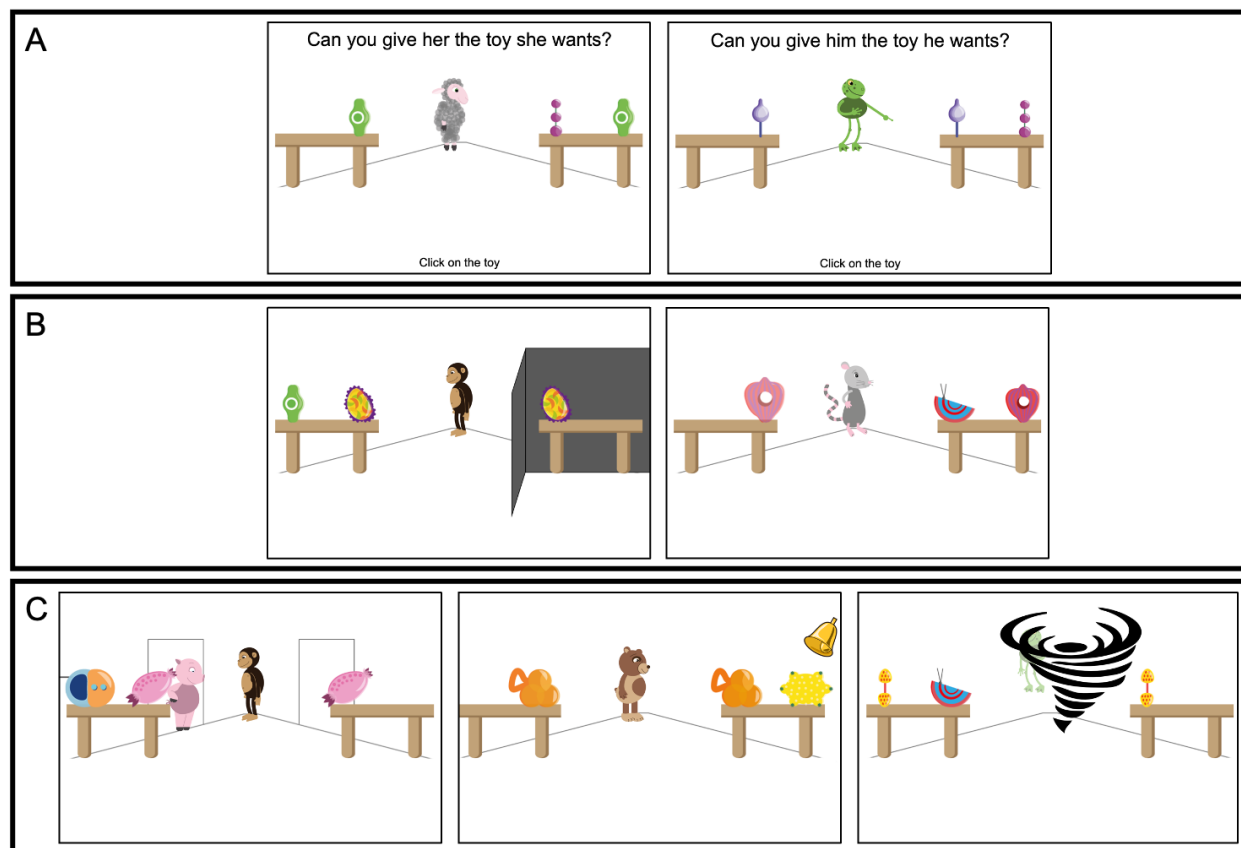
Figure 1. Screenshots from the experiments. Panel A shows the look (left) and point (right)
configuration, which were either paired with a verbal utterance or not to yield the four
conditions of Experiment 1a and 1b. Panel B shows the two control conditions barrier (left)
and later (right - note that the object on the left table is slightly transparent to show that it
is just appearing) from Experiment 2. Panel C shows the three control conditions: person
(left), bell (middle) and tornado (right) from Experiments 3a to 3c.

Procedure.   All experiments started with an introduction to the animals and two
training trials in which familiar objects were requested (car and ball). Next, the animal
turned to the table with the two objects (A and B). At this point, participants had to select
which object they thought the animal had requested. The four conditions differed in how

animals made the request. In the *look and label* condition – the reference condition – the animal turned towards the table with the two objects and said "Oh cool, there is a [non-word] on the table, how neat, can you give me the [non-word]?". In the *point and label* condition, in addition to turning, the animal pointed towards the table while making the same request. In the *point* condition, the animal turned and pointed but did not utter the request. In the *look* condition, the animal only turned towards the table, without pointing or uttering. In all conditions, "Can you give [him/her] the toy she wants" was written above the animal as soon as they turned.

In all conditions, participants could infer that the animal requested object B via the counter-factual inferences that, if the animal had wanted to request object A, they would have pointed to the table with only object A (this being the most informative way to refer to object A). Thus, we coded as "correct" when participants selected object B. Participants completed two trials per condition and thus eight trials in total. The order of conditions was randomized.

Analysis. All analyses were run in `R` (R Core Team, 2024). To compare performance against a level expected by chance (50%), we used one-sample Bayesian t-tests via the function `ttestBF` from the `BayesFactor` package (Morey & Rouder, 2024). To compare conditions, we used Bayesian generalized linear mixed models fit via the function `brm` from the `brms` package (Bürkner, 2017). Regression models for all experiments included fixed effects for condition and random effects for participant and item with random slopes for condition within each of them (`brms` notation: `correct ~ condition + (condition |id) + (condition |agent)`). All analysis used default priors implemented in the respective packages.

Results

Participants performed above chance in all four conditions, that is, all Bayes Factors indicated very strong evidence in favor of the hypothesis that performance was different from

Table 1

Comparison against chance level.

Experiment	Condition	Mean	SD	BF
Experiment 1a	Test - Look	0.81	0.30	7.5e+07
	Test - Look + Label	0.80	0.28	1.3e+08
	Test - Point	0.77	0.30	1.9e+06
	Test - Point + Label	0.79	0.33	1.1e+06
Experiment 1b	Test - Look	0.80	0.32	8.52
	Test - Look + Label	0.78	0.25	13.56
	Test - Point	0.78	0.22	38.97
	Test - Point + Label	0.80	0.22	8.94
Experiment 2	Control - Barrier	0.51	0.37	0.17
	Control - Later	0.45	0.42	0.22
	Test - Look + Label	0.67	0.40	3.52
Experiment 3a	Control - Person	0.64	0.38	1.24
	Test - Look + Label	0.75	0.33	93.07
Experiment 3b	Control - Bell	0.59	0.34	0.5
	Test - Look + Label	0.74	0.29	303.12
Experiment 3c	Control - Tornado	0.53	0.32	0.23
	Test - Look + Label	0.80	0.28	7.5e+03

Note. BF = Bayes factor in favor of the hypothesis that performance is different from chance (50% correct).

50% correct (Lee & Wagenmakers, 2014, see Table 1 and Figure 2). Performance in none of the conditions was reliably different (i.e. all 95% CrI included zero) from the *look and label* condition (reference condition); *point and label*: $\beta = 0.29$, 95% CrI (-0.75 - 1.72); *point*: $\beta = 0.10$, 95% CrI (-0.92 - 1.53); *look*: $\beta = 0.26$, 95% CrI (-0.64 - 1.42). Bayes Factors for the direct comparisons to the *look and label* condition were all smaller than 1, suggesting moderate evidence in favor of the null hypothesis of no difference (*point and label*: 0.15, *point*: 0.17, *look*: 0.15; note that this analysis was not pre-registered).
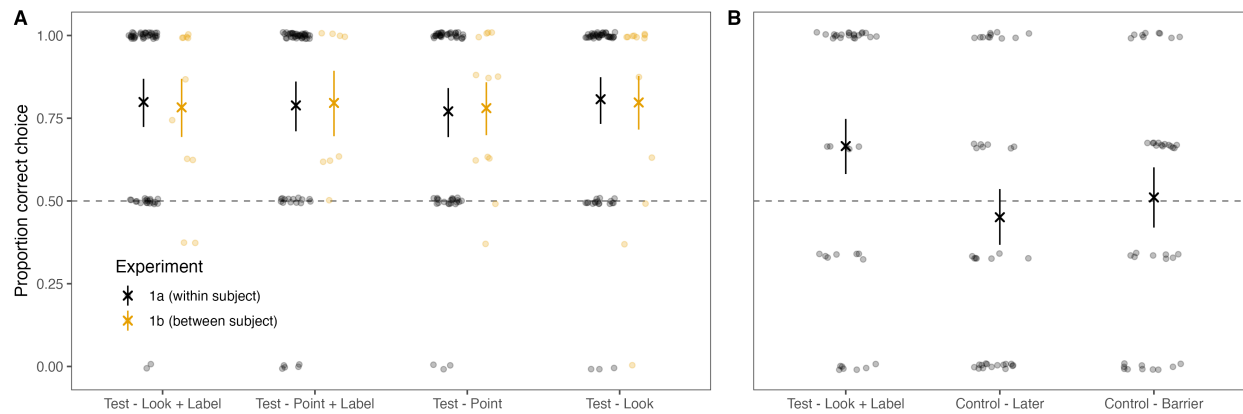

Figure 2. Results for Experiment 1a and 1b (A) and Experiment 2 (B). Transparent dots show aggregated data from individual participants (slightly jittered to avoid overplotting), crosses represent condition means, error bars are 95% CIs. Dashed line indicates performance expected by chance. Color in A shows the two experiments.

Discussion

The results of Experiment 1a showed that the way in which the speaker made a request, be it verbal or non-verbal or including pointing or not, did not affect participants' inferences. In all conditions, performance was clearly above chance. Taken together, this suggests that informativeness inferences are general inferences about (rational) intentional behavior and not bound to a particular class of communicative signals. However, an object to this result could be that the similarities between conditions was a carry-over effect of out within-subject design. That is, the inference might have carried over from e.g. the *look and label* conditions

¹⁵⁰ to conditions involving no labels. To rule out this objection, we conducted Experiment 1b.

Experiment 1b

¹⁵² Experiment 1b was a between-subject replication of Experiment 1a. It was
¹⁵³ pre-registered at: https://osf.io/3vpqb.

¹⁵⁴ **Participants.**   The planned sample size for Experiment 1b was 60. Sixteen
¹⁵⁵ participants did not provide valid data so that the final sample size for Experiment 1b was
¹⁵⁶ 44. Data was collected in March 2018.

¹⁵⁷ **Material.**   The material was the same as in Experiment 1a.

¹⁵⁸ **Procedure.**   The procedure was identical to Experiment 1a, except that participants
¹⁵⁹ were randomly assigned to one of the four conditions.

¹⁶⁰ **Analysis.**   The only difference in the analysis was that the regression model did not
¹⁶¹ include random slopes for condition within subject because subjects only completed one
¹⁶² condition.

¹⁶³ **Results.**   The results mirrored those of Experiment 1a. Performance was above
¹⁶⁴ chance (see Table 1 and Figure 2) and none of the conditions was reliably different from the
¹⁶⁵ *look and label* condition; *point and label*: $\beta = 0.28$, 95% CrI (-2.59 - 3.04); *point*: $\beta = $ -0.15,
¹⁶⁶ 95% CrI (-2.72 - 2.40); *look*: $\beta = 0.53$, 95% CrI (-2.09 - 3.18). Bayes Factors for the direct
¹⁶⁷ comparisons to the *look and label* condition were all smaller than 1 and suggested anecdotal
¹⁶⁸ evidence in favor of the null hypothesis of no difference (*point and label*: 0.41, *point*: 0.38,
¹⁶⁹ *look*: 0.38; note that this analysis was not pre-registered).

Discussion

¹⁷¹ Experiment 1b suggests that the results of Experiment 1a do not reflect simple
¹⁷² carry-over effects and supports the conclusion that informativeness inferences are computed
¹⁷³ independent of particular communicative signals.

₁₇₄   **Experiment 2**

₁₇₅   In Experiment 2, we tested whether the pragmatic inference of Experiment 1 involves

₁₇₆ reasoning about the speaker's epistemic states. The counter-factual inference involves that

₁₇₇ the speaker is aware of object A on both tables: roughly, if the speaker had wanted object A,

₁₇₈ they would have looked at the table with only object A on it (which they were aware of).

₁₇₉ Thus, if this would not be the case, the inference should go away. We tested this hypothesis

₁₈₀ by contrasting the *look and label* condition from Experiment 1a with two control conditions,

₁₈₁ one in which a barrier blocked the speaker's view and one in which an object appeared only

₁₈₂ after the speaker made their request. Experiment 2 was pre-registered at https://osf.io/c2gjf.

₁₈₃   **Participants.**   The planned and achieved sample size for Experiment 2 was 40. Data

₁₈₄ was collected in May 2018.

₁₈₅   **Material.**   The material was the same as in Experiment 1a.

₁₈₆   **Procedure.**   The procedure for the *look and label* condition was identical to

₁₈₇ Experiment 1. In the *later* condition, the table containing only object A was empty when

₁₈₈ the animal turned and made their request. After the request was made but before

₁₈₉ participants could make a choice, object A appeared on the previously empty table. Thus,

₁₉₀ when selecting, the scene was identical to the *look and label* condition – but the speaker

₁₉₁ could not have taken into account the presence of object A on the other table when making

₁₉₂ the request. In the *barrier* condition, a black barrier was blocking the agent's (but not the

₁₉₃ participants) view to the table with only object A (see Figure 1B). Participants completed

₁₉₄ three trials per condition and thus nine trials in total. The order of trials was randomized.

₁₉₅   **Analysis.**   The analysis was identical to Experiment 1a. The reference category for

₁₉₆ condition in the regression model was the *look and label* condition.

₁₉₇   **Results.**   The Bayes factors suggest that performance was different from chance in

₁₉₈ the *look and label* condition but not in the two control conditions. (see Table 1 and Figure 2).

₁₉₉ Note that performance in the *look and label* condition was somewhat lower compared to

₂₀₀ Experiment 1a and 1b. We suspect this to be random fluctuation because the procedure and

201 stimuli were identical to all other experiments. Importantly, however, object B was select

202 less frequently in the two control conditions compared to the *look and label* condition; *later*:

203 β = -2, 95% CrI (-3.78 - -0.49); *barrier*: β = -1.39, 95% CrI (-2.66 - -0.30).

Discussion

205   Experiment 2 suggests that participants do indeed take the speaker's epistemic state

206 into account when computing informativeness inferences. In situations when the speaker was

207 unaware of object A on the second table (and could thus not have referred to object A in a

208 more informative way), participants did not make the inference that the speaker was

209 referring to object B. The second critical component of the inference is that the

210 communicative signal is produced intentionally. In Experiment 3, we varied whether or not

211 the utterance reflected an intentional action.

Experiment 3a

213   In the previous experiment, before producing the verbal utterance, the speaker

214 intentionally turned, gestured and gazed towards one of the tables. As outlined above, we

215 see these actions as an essential part of the utterance that play a crucial role in deriving the

216 pragmatic inference. In the following three experiments, we systematically tested this idea

217 by manipulating whether or not the speaker produced the movements and gestures preceding

218 the verbal utterance intentionally and communicatively. In Experiment 3a, the agent's

219 turning was not part of an intentional communicative action: the agent turned towards the

220 table with the two objects because a second agent appeared there. Experiments 3a was

221 pre-registered together with 3b an 3c at: https://osf.io/nr3da.

Participants

223   The planned and achieved sample size for Experiments 3a was 30. Data was collected

224 in May 2018.

₂₂₅   **Material.**   The material was the same as in Experiment 1a except that a schematic

₂₂₆ door was added to the left and right of the speaker (see Figure 1C).

₂₂₇   **Procedure.**   The procedure for the *look and label* condition was identical to previous

₂₂₈ experiments except that after turning to the table with the two objects, the object on the

₂₂₉ other table disappeared. Only after that did the animal make the request. In the *person*

₂₃₀ condition, a second animal appeared next to the table with the two objects, saying "hi".

₂₃₁ Next, the speaker animal turned towards this second animal (as if reacting to the "hi").

₂₃₂ Then, the object on the table containing only object A disappeared and so did the second

₂₃₃ animal. The object was removed so that the speaker animal could not have turned back to

₂₃₄ the table with the single object in case they wanted to request object A. Then the speaker

₂₃₅ animal made the request. Thus, in both conditions, the test situation was identical (the

₂₃₆ speaker animal facing the table with the two objects while the other table was empty) but

₂₃₇ differed in whether or not the turning of the animal was apparently part of the utterance or

₂₃₈ had a different potential explanation. Participants completed four trials per condition and

₂₃₉ thus eight trials in total. The order of conditions was randomized.

₂₄₀   **Analysis.**   The analysis was identical to Experiment 1a and 2. The reference category

₂₄₁ for condition in the regression model was the *look and label* condition.
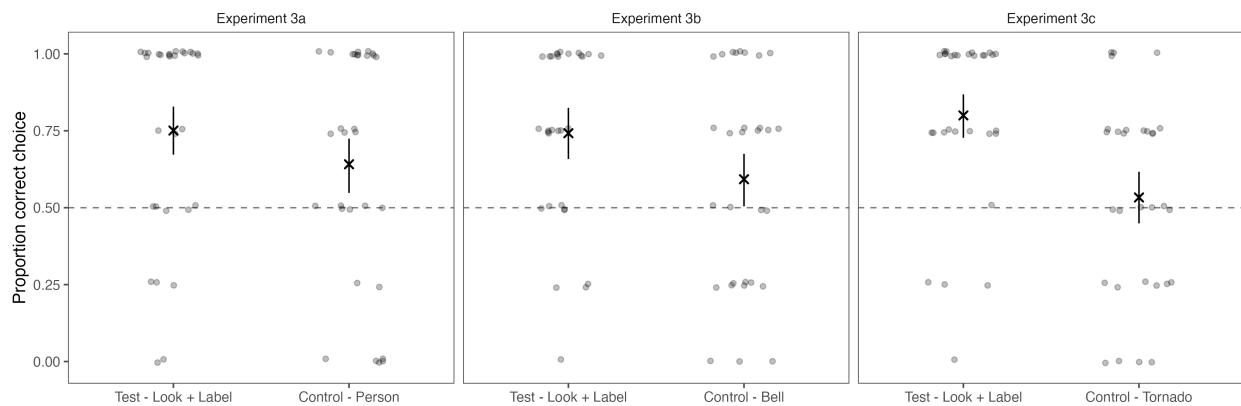
Figure 3. Results for Experiment 3a, 3b and 3c. Transparent dots show aggregated data from individual participants (slightly jittered to avoid overplotting), crosses represent condition means, error bars are 95% CIs. Dashed line indicates performance expected by chance.

²⁴² **Results.**   Performance was clearly above chance in the *look and label* condition.

²⁴³ There was considerably less evidence for performance being above chance in the *person*

²⁴⁴ condition (see Table 1 and Figure 3). However, performance in the *person* condition was not

²⁴⁵ reliably different from the *look and label* condition: β = -0.86, 95% CrI (-2.74 - 0.86).

Discussion

²⁴⁷   The results of Experiment 3a were somewhat inconclusive. Performance was

²⁴⁸ numerically better in the *look and label* condition but it was not reliably so compared to the

²⁴⁹ control condition. One potential explanation for this result could be that participants

²⁵⁰ assumed the second animal's actions were not independent of the speaker animal's request

²⁵¹ but were deliberate attempts to draw the speaker animal's attention to the table with the

²⁵² two objects, perhaps because this would be the one the speaker animal had a preference for.

²⁵³ Of course, alternative explanations are possible. Thus, in Experiment 3b, we removed the

²⁵⁴ second animal.

<div align="center">²⁵⁵ Experiment 3b</div>

Participants

²⁵⁷   The planned and achieved sample size for Experiment 3b was 30. Data was collected in

²⁵⁸ May 2018.

²⁵⁹   **Material.**   The materials were the same as in Experiment 1a and 2. The schematic

²⁶⁰ door introduced in Experiment 3a was removed (see Figure 1C).

²⁶¹   **Procedure.**   The procedure for the *look and label* condition was identical to

²⁶² Experiment 3a, that is after turning to the table with the two objects, the object on the

²⁶³ other table disappeared. In the *bell* condition, a bell appeared on the side with the table

²⁶⁴ with objects A and B, accompanied by a ringing sound, upon which the animal turned to

²⁶⁵ that side. Next, the object on the table containing only object A disappeared and the animal

²⁶⁶ made the request. Once again, the test situation was identical in both conditions but differed

in whether or not the turning of the animal appeared to be part of the utterance or whether

it had a plausible alternative explanation. Participants completed four trials per condition

and thus eight trials in total. The order of conditions was randomized.

Analysis.   The analysis was identical to previous experiments. The reference

category for condition in the regression model was again the *look and label* condition.

Results.   Performance in the *look and label* condition was clearly above chance. In

contrast, there was no evidence in favor of this hypothesis in the *bell* condition (see Table 1

and Figure 3). When directly comparing the conditions, we found that performance was

numerically better in the *look and label* condition but the 95% CrI overlapped with zero: β

= -0.98, 95% CrI (-2.06 - 0.07).

Discussion

Experiment 3b provides tentative support for the idea that participants take into

account whether or not a communicative signal was produced intentionally. Yet, the results

were not very strong. One reason for a weaker differentiation between the two conditions

could be that the turning was still perceived as an intentional action, which might have

coincided with the appearance of the bell. In Experiment 3c, we made it clearer that the

turning towards the table with the two objects was not an intentional action.

Experiment 3c

Participants

The planned and achieved sample size for Experiments 3c was 30. Data was collected

in May 2018.

Material.   The material was the same as in Experiment 3b (see Figure 1C).

Procedure.   The procedure for the *look and label* condition was slightly modified:

the animal first turned to the table with the two objects, then to the table with one object

and then back again to the table with the two objects. Then the animal made the usual

292 request. This turning was added to mimic the motion and timing of the *tornado* condition.

293 Here, a tornado appeared and whirled the animal around multiple times and up into the air.

294 Next the tornado disappeared, the animal landed on the ground facing the table with the

295 two objects. When the animal landed, the object on the table containing only object A

296 disappeared. Then the animal made the request. Once again, the test situation was identical

297 in both conditions. Participants completed four trials per condition and thus eight trials in

298 total. The order of conditions was randomized.

299 **Analysis.**   The analysis was identical to previous experiments. The reference

300 category for condition in the regression model was again the *look and label* condition.

301 **Results.**   Performance in the was clearly above chance in the *look and label* condition

302 but not the *tornado* condition (see Table 1 and Figure 3). When directly comparing the

303 conditions, performance was reliably better in the *look and label* condition: β = -1.79, 95%

304 CrI (-2.96 - -0.82).

305 **Discussion**

306 When it was unambiguously clear that the movements and gestures preceding the

307 verbal utterance were not produced intentionally, participants did not make the

308 informativeness inference. Together with the somewhat weaker evidence provided by

309 Experiments 3a and 3b, this result supports the interpretation that participants base their

310 pragmatic inferences based on an assessment of the speaker's intentions when producing the

311 utterance.

312 **General discussion**

313 Across six experiments, we tested the implications of construing pragmatic inference as

314 a social-cognitive reasoning process about intentional communicative action. We used

315 pragmatic word learning as a case study to test three predictions. First, we found that

316 listeners make very similar pragmatic inferences based on linguistic and non-linguistic signals.

317 This result supports the view that listeners make pragmatic inferences about many forms of

318 communicative behavior, not just language. Second, consistent with prior work, we found

319 pragmatic inferences to be conditional on what the speaker knows when producing an

320 utterance and thus which alternative utterances they could have produced. Finally, we

321 showed the importance of non-linguistic aspects of an utterance: when the movements and

322 gestures preceding the verbal utterance were not part of an intentional communicative act,

323 the pragmatic inference was lost.

324   In particular, the results of Experiments 3a to 3c contribute to connecting work on

325 pragmatic inferences to the literature emphasizing the role of intentionality in the evolution

326 of communication (Dennett, 1983; Tomasello, 2008; Townsend et al., 2017). By

327 demonstrating that pragmatic inferences are contingent upon the intentional production of

328 non-linguistic signals, we underscore the significance of communicative intentions in shaping

329 the interpretation of utterances. This finding aligns with theoretical frameworks emphasizing

330 the cooperative nature of communication, wherein speakers actively manipulate signals to

331 convey specific meanings to listeners (Grice, 1991).

332   Our analysis of the reasoning process underlying pragmatic inferences has been

333 inspired by computational cognitive models (Frank & Goodman, 2012; Franke & Jäger, 2016;

334 Scontras, Tessler, & Franke, 2021). Recent modeling studies have shown how the pragmatic

335 inference processes described here interact with social-contextual information (i.e., common

336 ground) during language learning and comprehension (Bohn, Tessler, Merrick, & Frank,

337 2021, 2022). Together with the findings reported here, these results highlight the value of

338 computational models for explicating the cognitive processes that underlie communicative

339 interactions.

340   Our study has important limitations. First, our case study was a single pragmatic

341 inference about word meaning. This phenomenon has been studied in prior work and

342 presented a convenient case study, but future work should ideally devise ways to test the

343 same manipulations in the context of other types of pragmatic inference. Additionally, we

344 tested a convenience sample of English-speaking adults with a US IP address. Our

345 parameter estimates do not represent measures of any particular population, and whether

346 the results would generalize to other languages or cultural settings is an open question. Since

347 we make our materials openly available, adaptation to other languages would be relatively

348 easy [and indeed German versions of these tasks yield interpretable data with children; Bohn,

349 Tessler, Kordt, Hausmann, and Frank (2023)]. Furthermore, it would be interesting to

350 conduct comparable experiments with children to better understand the developmental

351 trajectories giving rise to the pattern reported for adults.

352   Taken together, this study highlights how experimental, computational, and

353 evolutionary approaches can jointly elucidate the mechanisms underlying pragmatic

354 inferences and, more broadly, human communication.

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