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Research Article

Cognitive Processing of Miscommunication in Interactive Listening: An Evaluation of Listener Indecision and Cognitive Effort

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Purpose: The purpose of the current study was to evaluate the social and cognitive underpinnings of miscommunication during an interactive listening task.
Method: An eye and computer mouse–tracking visual-world paradigm was used to investigate how a listener's cognitive effort (local and global) and decision-making processes were affected by a speaker's use of ambiguity that led to a miscommunication.
Results: Experiments 1 and 2 found that an environmental cue that made a miscommunication more or less salient impacted listener language processing effort (eye-tracking). Experiment 2 also indicated that listeners may develop different processing heuristics dependent upon the speaker's use of ambiguity that led to a miscommunication, exerting a significant impact on cognition and decision making. We also found that perspective-taking effort and decision-making complexity metrics (computer mouse tracking) predict language processing effort, indicating that instances of miscommunication produced cognitive consequences of indecision, thinking, and cognitive pull.
Conclusion: Together, these results indicate that listeners behave both reciprocally and adaptively when miscommunications occur, but the way they respond is largely dependent upon the type of ambiguity and how often it is produced by the speaker.

Important communication is often one-sided, commonly preventing listeners from seeking clarification from the speaker when something is misunderstood. For instance, social protocols in educational settings may prevent students from asking professors for clarification when something is misunderstood (e.g., to avoid social ridicule for not understanding; Ryan et al., 1998; or because social protocols tell us not to question authority; Milgram, 1965). Given the importance of such communications, having a listener pay attention to what the speaker says really matters. If listeners disengage from their speaker during one-sided communication, this can have grave and negative impacts on listeners (e.g., failing grades). One-sided communication does occur not only in educational contexts but also in other communication domains. We see this most prevalently in current times, like those surrounding the COVID-19 pandemic. We see that, when clarification is not available, listeners may decide to disengage from those who confuse them in favor of communicators that are more easily understood. This may lead them to ignore scientists and medical experts in favor of information that fits nicely within their current belief systems especially when they come from communicators (e.g., politicians) who may be more easily understood because they find utility in using colloquialism over jargon (i.e., driven by confirmation bias; Nickerson, 1998). Choosing to disengage may have downstream effects on understanding and decision making, and in the COVID-19 example, we see that this is resulting in risky health-related behaviors, such as illness, death, and infection of others. In educational and public health communication, miscommunications can have dire effects on performance and health-related decisions (i.e., to wear or not to wear a mask). Many factors impact the degree to which miscommunication occurs, but understanding how a person's social-communicative heuristics drive interpretation and decision

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making when partiality of comprehension occurs is extremely important.

In the current study, a contrived and one-sided communication task is implemented to evaluate cognition and decision making when miscommunication occurs. We show that a listener's understanding of why a miscommunication occurs differentially impacts how they approach language processing and decision making. We frame our understanding of how listeners approach miscommunication in a one-sided communication in terms of general communication principles that may be shared by dialogic communication processes. Garrod and Pickering (2007) note that though monologue and dialogue have often been assumed to use the same processing mechanisms (especially with reference to language production), there may be certain contexts that differentiate the magnitude and strategic use of these mechanisms to be general communication heuristics. For example, interlocutors' monologue and dialogue should engage both controlled and automatic processes, but the degree of automaticity is likely to be higher in dialogue due to the benefit of interactive alignment (Garrod & Pickering, 2007). Therefore, we frame listeners' response to miscommunication in a pseudo-interactive task (i.e., one-sided, not permitting requests for clarification) via sociopragmatic theories that are often discussed in sentence processing (i.e., visual world paradigms) and dialogic interactions of successful communication.

Background

Miscommunication is a failure to communicate all necessary information needed to correctly interpret a speaker's message (McTear, 2008). Miscommunications are pervasive in interactive communication (e.g., Roche et al., 2013) and are often seen as noise in the communication channel. Healey, de Ruiter, and Mills (2018) argue, however, that miscommunication is essential to the communication system, as it may be consequential for flexibility and adaptation. Miscommunication has received a great deal of attention with respect to repair mechanisms used specifically to resolve it (e.g., see Healey, Mills, et al., 2018). However, less research to date has focused on the impact of miscommunication on global social interaction, cognition, and decision making. Here, we evaluate the social, cognitive, and behavioral impacts of miscommunication due to conversational ambiguity on listeners' language comprehension and decision making.

Ambiguity sometimes leads to miscommunication and misunderstanding (Keysar, 2007). Because communicating is a cognitively demanding activity, interlocutors are likely attempting to reduce the expenditure of cognitive resources while speaking (e.g., ambiguity; Piantadosi et al., 2012) and listening (e.g., passive recipiency; Jefferson, 1993). Ambiguity that leads to miscommunication may occur because the speaker has difficulty in perspective-taking (Keysar, 2007) or reduced cognitive resources during message formation (Roßnagel, 2004). Listeners, on the other hand, may feign engagement by passively attending during conversations through the use of response tokens (e.g., *uh-huh*; Jefferson, 1993). When speakers unsuccessfully produce ambiguous statements, this could lead to different types of message formation errors. Two key types of errors are speaker-extrinsic, that is, due to circumstances beyond the speaker's control, and speaker-intrinsic, that is, due to circumstances within the speaker's control. These two types of errors may differentially affect how much effort listeners are willing to exert to maintain the conversation (e.g., passive vs. active engagement), in turn differentially affecting their language comprehension and decision making.

Critically, for a listener to address a miscommunication, a triggering cue (cf., Brennan et al., 2010; Chaiken et al., 1989) might need to be present for it (the miscommunication) to be noticed (see Bjørndahl et al., 2015), and it is possible that context (e.g., speaker contexts) may drive heuristics (i.e., cognitive shortcuts) associated with handling the communication breakdown. At present, there are no known theoretical accounts regarding what happens to cognitive and decision-making processes when a listener misunderstands what a speaker says. Therefore, the purpose of the current study is to evaluate two types of triggering cues that may impact a listener's cognitive and decision-making processes when experiencing ambiguity leading to a miscommunication: (a) speaker miscommunication characteristics (i.e., extrinsic/intrinsic to the speaker) and punitive feedback (i.e., positive or negative feedback cue).

There are a number of reasons why local levels of miscommunication may be rarely and completely deleterious to an eventually successful conversation. As noted above, ambiguity, a prominent reason for miscommunication (Keysar, 2007), is a natural outgrowth of establishing reference, common ground, and collaboration, making it integral to language (Piantadosi et al., 2012). Ambiguity may only be problematic when it causes confusion and is unresolvable, but there are a number of contexts in which disambiguation occurs. In some contexts, ambiguity may be disambiguated by taking a communication partner's perspective (Clark & Marshall, 1981), tracking a speaker's conversational precedents (i.e., speaker-specific conversational patterns; Kronmüller & Barr, 2007), using language to recruit joint attention in the visual world (e.g., "look here!"; Sedivy et al., 1999), discussing previously shared experiences (e.g., "remember when…"; Metzing & Brennan, 2003), but also in the ability to repair through a request for clarification (Levelt, 1983; White, 1997). Ambiguity has the potential to be a tool that helps streamline communication by reducing cognitive effort for both speakers and listeners who share common ground (e.g., Clark & Brennan, 1991; Piantadosi et al., 2012; Zipf, 1949).

Though there are a number of strategies to handle problematic ambiguity when it is noticed, there are a number of contexts that may never promote resolution of miscommunication. For instance, one may fail to initiate a repair for cognitive and sociopragmatic purposes, such as lacking the information necessary to diagnose the miscommunication (Kruger & Dunning, 1999) or being afraid (or unable) to ask the expert (Jadad et al., 2003; Marvel et al., 1999). If never addressed, the potential long-range effects may have far more severe outcomes than if handled locally when the miscommunication occurs. Many areas of research focus on either the descriptive aspects of miscommunication in real-world contexts (e.g., medical settings; Healey, Mills, et al., 2018; Isaacs & Creinin, 2003; Sutcliffe et al., 2004) or how listeners request and resolve miscommunication through repair (e.g., Bazzanella & Damiano, 1999; Dingemanse & Enfield, 2015; Kitzinger, 2013; Purver et al., 2018; Schegloff et al., 1977). At present, the effects of unresolved miscommunication on language processing, cognition, and decision making are relatively understudied.

Nevertheless, there are some significant studies evaluating the social and cognitive underpinnings of responding to miscommunication, suggesting that listeners are capable of flexibly adapting to speakers' infelicitous use of language. For instance, listeners tend to suspend their expectations about the correctness of word usage when speakers mislabel common words and misuse modifiers (Grodner & Sedivy, 2011). Interlocutors may also benefit from requests for repair when they signal that a miscommunication has occurred because the requests enhance detection of miscommunication and improve recovery from communicative errors (Mills, 2014). Young children are also sensitive to the reliability of a speaker's message based on miscommunication. For example, with respect to word learning, preschool children who detect inaccuracies in adult references will override the tendency to rely on adults (over peers) to learn new words (Jaswal & Neely, 2006). Likewise, children prefer to learn words selectively from more (vs. less) reliable speakers based on demonstrated reliability over time (Birch et al., 2008; Scofield & Behrend, 2008). Though this list of studies is not all-encompassing, these findings suggest that, by encouraging flexible adaptation to infelicitous language use, miscommunication may be important for communication (see Healey, de Ruiter, & Mills, 2018).

Despite these findings, it is less clear whether listeners take into account why speakers are sometimes confusing through their use of ambiguity, and whether or not this impacts their processing heuristics and approach to communication. In order for miscommunication to be noticed, its consequences may need to become evident (Bjørndahl et al., 2015). In a scenario in which a miscommunication and its consequences are recognized, heuristics may drive the way we process the incoming information. Dual process models of information processing (e.g., Monitoring and Adjustment: Horton & Gerrig, 2005; Heuristic-Systematic Model: Chaiken et al., 1989) argue that information processing occurs along two potential paths: (a) a heuristic—implicit or (b) systematic—explicit path. A critical feature of these dual process models, with reference to communication, is that social cues typically trigger the cognitive processing path to be taken (implicit or explicit). The heuristic-systematic model (Chaiken et al., 1989) and one-bit model (Brennan et al., 2010) suggest that external environmental cues (typically social) will be the triggering mechanism for processing along the explicit or implicit path. The heuristic-systematic model suggests that a triggering cue needs to be present, whereas the one-bit model suggests that the triggering cue acts as an on–off switch for the selected/unselected path.

During information processing, the listener may choose the path of least resistance (e.g., heuristic), as a way to save precious cognitive resources, until a triggering cue requiring a change to a more effortful or systematic path of information processing is presented to the listener. These dual process models suggest that we may have modes of processing that help us communicate more efficiently, which may alternatively help us approach conversation cooperatively (i.e., cooperative principle; Grice, 1975) but also engage reciprocally (theory of reciprocity; McCroskey & Richmond, 2000) with one's communication partner. With regard to miscommunication, dual process models of information processing may help explain how interlocutors handle ambiguity appropriately and efficiently in the face of miscommunication.

For instance, the reason someone has chosen an ambiguous description paired with punitive feedback (together) may trigger different processing heuristics listeners have available to handle the communication breakdown. A listener may be more cooperative with a speaker if she is not penalized for the speaker's unintentional miscommunication stemming from a perspective mismatch. Alternatively, if a speaker seems to be largely uncooperative or tends to avoid exerting effort to be clear, and the listener incurs punitive feedback, then the listener may reciprocally disengage to save precious processing resources. If the communication error goes unnoticed, however, its type may not matter. An environmental triggering cue, such as feedback indicating whether the miscommunication is speaker-extrinsic or -intrinsic, may be necessary to bring the miscommunication and the reason for it to the listener's attention so that the listener can selectively adapt their processing effort in the future (*heuristic-systematic model*; Chaiken et al., 1989; *one-bit model*: simple cues may trigger responses on an as-needed basis; Brennan et al., 2010). This, in turn, may impact the processing heuristic initiated to handle future communication breakdowns.

In the current study, we implement a computer mouse- and eye-tracking paradigm to assess listeners' willingness to put forth processing effort to interpret an ambiguous message that sometimes leads to a miscommunication. Eye- and computer mouse–tracking methods were chosen because they have the potential to reveal underlying cognitive and decision-making processes (eye-tracking: Tanenhaus et al., 1995; mouse-tracking: McKinstry et al., 2008). Eye-tracking and computer mouse–tracking techniques have been shown to be highly correlated measures of underlying cognition (Chen et al., 2001). Gaze dwell time is associated with cognitive processing effort (reading: Ehrlich & Rayner, 1981; Rayner & Duffy, 1986; mental rotation and sentence processing: Just & Carpenter, 1976; visual search: Tikhomirov & Poznyanskaya, 1966; problem-solving: Grant & Spivey, 2003).

Mouse-tracking has been shown to reveal multiple parallel cognitive processes that converge to be integrated into action dynamics over time (see Spivey & Dale, 2004) revealing both implicit (i.e., automatic, heuristic-based, early) and explicit (i.e., systematic, effortful, late) processing (Wojnowicz et al., 2009). Mouse-tracking also has the potential to show the "mind in motion" (Freeman et al., 2011), revealing indecision, hesitation, and cognitive competition (e.g., Dale et al., 2008; Freeman & Ambady, 2010; McKinstry et al., 2008). Therefore, pairing mouse-tracking with eye-tracking may provide a more comprehensive account of the impact that ambiguity leading to miscommunication exerts on cognition (processing effort – eye-tracking) and decision making (hesitation, indecision, and cognitive competition – mouse-tracking) along the two paths of information processing: heuristic–implicit; systematic–effortful.

We were explicitly interested in evaluating two potential triggering cues to change information processing effort: (a) speaker miscommunication type (Experiment 1) and speaker miscommunication proclivity (Experiment 2), and (b) the effect of punitive feedback on future language comprehension and decision making. Additionally, we were interested in how speaker communication characteristics and feedback impacted decision-making processes during language processing of confusing instructions. The working hypothesis tested in this article is that listeners will differentially consider speaker communication characteristics (type and style), impacting their heuristics associated with reciprocity and cooperation. However, this may be mediated by the strength of the feedback cue, all of which will impact the action dynamics of the decision-making process. Specifically, more cooperation should result in deeper, systematic processing, while reciprocity would drive shallower, automatic, and less effortful processing.

Experiment 1

Miscommunication often goes unnoticed and could have little impact on communication unless it creates some type of explicit consequence for the interlocutor (e.g., request for clarification, disagreement, etc.; Bjørndahl et al., 2015; Brennan & Schober, 2001; Mills, 2014). We, therefore, consider how differences in language processing effort may be impacted by feedback that results in an explicit consequence while preventing the initiation of a repair. Listeners may be more willing to put forth language processing effort if feedback communicates that the error was extrinsic to the speaker, with the error being outside of the speaker's control. Second, it was expected that action dynamics, which were evaluated via measurement of mouse-cursor trajectories and perspective-taking effort, would reveal differences in underlying decision-making complexity when a consequence was made explicit (McKinstry et al., 2008).

Method

Participants

Sixteen undergraduate students from a university in the Midwestern United States (M_{age} = 21.5 years) participated in the experiment. A priori 2 between × 2 within groups mixed repeated-measures power analysis (60 experimental critical trials) using G*Power (Faul et al., 2007) with a moderate-to-large effect size (partial η^2 = .14, equivalent to f = .40, α = .05, power 1-ß = .95) revealed that N = 8 was sufficient, but this number was doubled to increase generalizability. All participants were native speakers of American English with no reported hearing or speech impairments and normal to normal-corrected vision. One participant was removed from the analysis due to corrupt eye-tracking data.

Materials: Equipment and Stimuli

Equipment included an EyeLink 1000 eye-tracker, 21-in. iMac computer, noise-reducing headphones, wireless mouse, and a CAD-U37 studio condenser microphone.

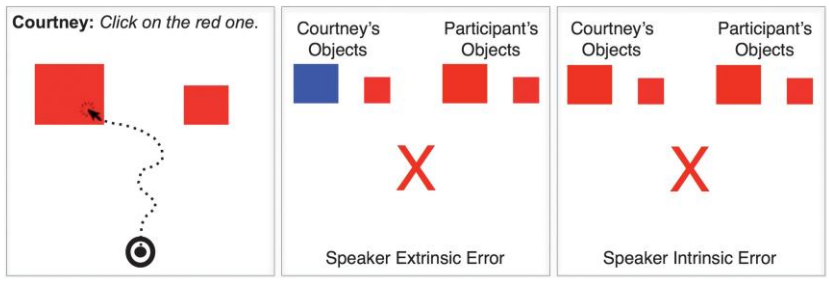
Visual stimuli included 32 shapes: 4 shapes (circle, star, square, and triangle) × 4 colors (blue, green, purple, and red) × 2 sizes (big and small). In each trial, two shapes were paired, such that zero, one, or two features overlapped (see Figure 1, left panel).

Auditory stimuli included 280 statements prerecorded from an adult woman ("Courtney") with an inland North American accent (Labov et al., 2005). The statements included instructions referencing one, two, or three of the target object's features: for example, *Click on the red shape/ big red shape/ big red triangle.* To prevent listeners from guessing the upcoming trial structure, a fully crossed list of possible visual stimulus pair combinations was created (N = 1,964), and items used for the experimental session were pseudorandomly selected from this list (one feature = 114, two features = 103, three features = 63). All recordings were adjusted to the same comfortable listening level.

Procedure and Design

A 2 (negative vs. positive feedback; between subjects) × 3 (error type: no error [NE]—filler, speaker extrinsic error [SEE]—critical, speaker intrinsic error [SIE]—critical; varied within subjects) design was used. A subset of the filler trials and all of the critical trials contained an ambiguous instruction. Ambiguous statements on filler trials (NE) included a temporarily ambiguous statement that could easily be resolved based on visual context (e.g., *Click on the big red shape* in a trial containing a big red and big blue square). However, the critical trials always contained a globally ambiguous statement that could never be resolved by the sentential or visual context, requiring the participant to guess which object Courtney referenced. For example, on some critical trials in which two red shapes were present, Courtney instructed the listener, "*Click on the red shape*" (see Figure 1). However, after listeners made a selection, they implicitly learned via feedback that Courtney had either produced the ambiguity because of a perspective difference (SEE) or because of imprecise language use (SIE). Thus, listeners were never provided with any information from the experiment in reference to an SEE or SIE's meaning.

Figure 1. Example trial including the instruction screen (left) and two possible feedback screens with negative feedback: speaker extrinsic error (middle) and speaker intrinsic error (right). The current example only shows negative feedback, but on some trials, participants would have seen a green check, representing positive feedback. Additionally, mouse cursor trace and text were not present in trials.



When Courtney made an SEE, the participants learned she failed to consider that the listener saw different objects than her (i.e., a perspective mismatch). On the other hand, the participant learned that Courtney made an SIE when she referenced an overlapping feature instead of the distinguishing referent, which occurs when a speaker is distracted or cognitively loaded (Becic et al., 2010; Ferreira & Griffin, 2003; Fromkin, 1973). However, these errors may only be impactful if the listener recognizes an explicit consequence of misunderstanding. To determine the consequences of listeners being told that they guessed incorrectly on critical trials, participants were randomly assigned to a negative/positive feedback condition. In the negative feedback condition, participants were always told they had chosen the incorrect object (indicated by a large red X; 100% of critical trials). The X acted as the feedback, while the color red served as the penalty associated with the feedback (see Mehta & Zhu, 2009). In fact, Mehta and Zhu provide evidence that the color red has punitive properties that impact behavior during cognitive tasks. Specifically, they found that participants tended to engage in avoidant behaviors on cognitive tasks when the color red was paired with a feedback cue. Therefore, the redness of the X acted as an explicit consequence paired with the feedback to cue listeners that they had guessed incorrectly—this may be analogous to a professor's use of red ink on a thesis or dissertation paired with feedback that something was incorrect. Alternatively, in the positive feedback condition, participants were told they had always chosen the correct object (indicated by a large green check; 100% of critical trials).

It was always clear which object Courtney referenced in NE trials because a large green check was displayed unless the participant accidentally clicked the wrong object. There were a total of 280 trials, which included 220 filler trials (NE) and 60 critical trials (30 SEE, 30 SIE trials).[1] For both conditions, listeners experienced an SIE as the first communicative error, which did not occur until Trial 57. After Trial 57, the global ambiguity (SIE, SEE) errors and filler trials were pseudorandomly presented to the listener. It should also be noted that ambiguity is a natural aspect of language and the filler trials contained completely felicitous uses of ambiguity—such that the ambiguity is likely to go unnoticed because it is easily resolved by the visual context. No participants indicated any surprise or mention of an overuse of ambiguity.

Measures

Over the course of the experiment, eye and mouse cursor movements were recorded on the instruction screen (see Figure 1, left panel) and the feedback screen (see Figure 1, middle/right panel). The recording was implemented via EyeLink Experiment Builder software. Based on the eye and mouse cursor recordings, we calculated eye dwell times (*is_dwell*, instruction screen; *fs_dwell*, full screen) and mouse trajectory measures (*x-flips, maximum deviation*).

Dwell times were calculated using the EyeLink DataViewer software to reflect the amount of time a participant fixated on a given interest *area* on the instruction screen and the previous trial's feedback screen. Eye fixation dwell time is a well-established measure of cognitive processing effort across many domains, such as reading (Rayner & Duffy, 1986), visual search (Tikhomirov & Poznyanskaya, 1966), problem solving (Grant & Spivey, 2003), mental rotation, sentence processing, and quantitative comparisons (Just & Carpenter, 1976). Two dwell time measures were collected to represent cognitive processing effort during two domains of cognitive processing: language processing and perspective taking effort (i.e., how much cognitive effort was exerted when listening to language on the instructions screen or taking the speaker's perspective on the feedback screen). The is_dwell time measure refers to instruction screen dwell time, in which we measured how long listeners looked at both objects on the instruction screen when Courtney provided her verbal instruction (*is_dwell*; dependent variable; see Figure 1, left panel). The second measure, perspective taking effort, was measured when the listener looked at Courtney's objects on the feedback screen following

[1]The number of filler trials was much larger to mitigate the effects of negative emotional response to being penalized in critical trials (e.g., extreme and unnecessary frustration), as found by piloting and suggested by Paxton et al. (2014, accepted.).

a decision made on the prior instruction screen (*fs_dwell*; predictor of *is_dwell* on the subsequent trial; see Figure 1). The measurement of *is_dwell* began on Trial 2 because listeners would not have experienced feedback until the completion of Trial 1 (an NE trial). We were explicitly interested in how much cognitive processing effort listeners exerted on the listening trial following a miscommunication. This should have been directly impacted by the amount of time they spent considering why Courtney had miscommunicated on the previous trial. Therefore, we measured the fs_dwell measure to give us a measure of perspective taking effort, with the logic that when the listener looked at Courtney's objects on the feedback screen, they would be investing precious cognitive resources to understand why she said what she did (44% of participants indicated that they attempted to take Courtney's perspective).

X-flip and maximum deviation measures (Freeman & Ambady, 2010) were derived from mouse trajectories to gauge complexity of the decision-making process. *X-flips* consist of the number of reversals in direction of the mouse movement along the horizontal axis; they provide a measure of indecision and hesitation (see Dale et al., 2008; McKinstry et al., 2008; Roche et al., 2015). That is, the more the listener flips back and forth between two response options, the more indecision they express in their decision making. *Maximum deviation* characterizes how much a trajectory deviates from the ideal, straight-line path between the bull's-eye button and the chosen object, measuring cognitive pull or competition between the response options. More pull toward the response option that was not selected indicates that it was actively competing for activation and selection. As noted by McKinstry et al. (2008), in action dynamics of decision making, mouse-cursor trajectories reveal cognitive pull toward contrasting responses, indicating thinking and cognitive competition. Because the eyes tend to guide the hands (Land & Hayhoe, 2001), measures of action dynamics here represent an online measure of processing during decision making. Pairing these measures with eye-tracking, which measures cognitive processing effort, provides a more comprehensive understanding of language comprehension and decision-making processes when decoding ambiguous language.

Analytic Approach

Growth curve models (Mirman, 2017) were implemented using the lme4 package in R (R Development Core Team, 2012). These models included the maximum random effect structure permitting model convergence, with item and/or participant set as random intercept(s) (Barr et al., 2013). When a growth model was implemented (Mirman, 2017), we attempted to evaluate linear change over time. A linear model, rather than an orthogonal polynomial model, was selected because we were interested in linear change over time and allowed for reduction in model complexity. In accordance with the recommendation of Barr et al. (2013), we attempted to implement a fully maximal random effect structure in which all random effects were modeled as random slopes, given that all factors in our design were varied within subject. Failure to implement random slopes in such a design results in a random intercepts-only model, increasing the likelihood of Type I error (Barr et al., 2013). Therefore, when the model failed to converge, a leave-one-out method of random slope removal was implemented until the model converged, as prescribed by Barr et al. (2013). All data and analysis files are provided on the Open Science Framework (https://osf.io/tejnr).

Results

In the current context, the listener may be confused by the pseudoconfederate's use of ambiguous language. However, when the consequence of the infelicitous ambiguity is not made explicit, the miscommunication may have little impact on listeners' cognition and decision making (Bjørndahl et al., 2015). In this task, we intend to show that, by penalizing the listener (i.e., use of a red X), this should create a context in which listeners are negatively impacted for guessing incorrectly, likely to result in task disengagement (as discussed by Mehta & Zhu, 2009). When listeners are made aware of their incorrect guess (i.e., through feedback and in some cases penalty), this added information should act as a triggering cue (cf., heuristic-systematic and one-bit models; Brennan et al., 2010; Chaiken et al., 1989, respectively) to listeners to change their cognitive and decision-making approach to the miscommunication (e.g., maintain engagement or disengage; easier or more difficult decision making) on future language comprehension.

To evaluate this hypothesis, we evaluated language processing effort (instruction screen dwell time; *is_dwell*) as a function of what occurred on the previous trial, in which a consequence of a prior miscommunication may or may not have been explicit. It was expected that a prior miscommunication would impact future language comprehension effort. In the analyses that follow, *is_dwell* is assumed to depend on the error type and feedback experienced on the previous trial. In a second analysis, *fs_dwell* (dwell time on the pseudoconfederate's objects displayed on the feedback screen) and the mouse trajectory (decision making) metrics were assumed to be predictor of *is_dwell* on the next listening trial. Previous error type (PET) refers to the type of error (NE, SEE, or SIE) the participant experienced on the previous trial. PET was chosen because we were interested in how a previous error impacted processing effort on the next language trial.

Manipulation Check

To begin, we first evaluate whether or not SIE and SEE trials produced longer dwell times relative to NE (filler trials). The model set *is_dwell* as the dependent variable and PET as the fixed effect using the maximal random effect structure with random intercepts for listeners. Results indicated that SEE trials differed significantly from the NE trials (ß = 195.60, SE = 46.32, t = 4.22, p < .001), but SIE trials did not (ß = 5.55, SE = 46.36, t = 0.12, p = .9);

22% (R^2) of the variance in instruction screen dwell time (*is_dwell*) was accounted for by PET. In what follows, we evaluate language processing differences in the trials following SIE and SEE trials.

Language Processing Effort Over Time

We analyzed local dwell time differences on the instruction screen objects (*is_dwell*) by PET (critical trials: SEE, SIE; within-participant) and previous feedback type (PFT; negative vs. positive; between-participant) using three linear mixed-effects models and a growth model. The initial models included (a) a base model representing time (i.e., trial number), (b) a model that evaluated PFT, and (c) a model evaluating PET. These three models were then compared to (d) a growth model using a linear mixed random effects structure (see Mirman et al., 2008) with time (trial number), PFT, and PET set as fixed effects.

The three linear mixed-effects models were compared to the growth model implementing a linear mixed-effects structure to evaluate local changes in *is_dwell* during language comprehension over the course of the experiment as a test of model fit. The model with the smallest Akaike information criterion (AIC) was retained for interpretation. A test of the model fit indicated that the model evaluating PET and the growth model produced the best fit, but further evaluation indicated that the growth model produced a significantly better fit than the linear model only including PET (AIC = 14,869, $\chi^2(10) = 35.94$, $p = .001$). Results from the growth model using the maximal random effect structure was implemented ($R^2 = .29$).

Results indicated a marginal main effect of PFT and a marginal PFT × PET × Trial interaction (see Table 1). However, significant main effects of PET and trial were observed in addition to a significant interaction between PFT × Trial and PET × Trial. Only the significant interactions between PFT/PET and trial were interpreted to reduce redundancy in interpretation.

Consistent with our hypothesis, we observed that listeners put in increasingly less (language comprehension) processing effort over the course of the experiment after experiencing SIEs, whereas (language comprehension) processing effort after experiencing SEEs did not change over time (see Figure 2).

Additionally, there was a marginal main effect of PFT (see Table 1 above), indicating that listeners exerted marginally more processing effort after receiving negative feedback ($M = 2260.21$, $SD = 992.66$) relative to the positive feedback condition ($M = 2197.92$, $SD = 1173.37$). As seen in Figure 3, there were significant differences in processing effort over time as a function of the negative feedback participants experienced on the previous trial. Listeners tended to disengage from the task (shorter dwell times on instruction objects) following critical trials, but only in the positive feedback condition. In contrast, there was no evidence of disengagement following critical trials with negative feedback (i.e., when participants learned that they guessed incorrectly after a speaker miscommunication). This result is consistent with our hypothesis in that negative feedback seemed to recruit and maintain more processing resources than positive feedback.

Exploratory Evaluation of Perspective-Taking Effort and Decision-Making Complexity

We analyzed whether instruction screen dwell time (*is_dwell*) is associated with PFT (negative, positive), PET (SEE, SIE), dwell time on the feedback screen (*fs_dwell*) on the previous trial, *x-flips,* and *maximum deviation*. The variables *fs_dwell, x-flips, maximum deviation,* and *PET* were set as random slopes, and participant and trial were set as random intercepts. This random effect structure was determined by using backward removal of random slopes to reach model convergence (per Barr et al., 2013; $R^2 = .49$). NE (NE—filler) trials were dropped from the model to reduce the degrees of freedom and because we were only interested in how decision-making metrics differed between the two error types (SEE, SIE). Results indicated a main effect of *x-flips* and four interactions: PET × PFT; PET × *maximum deviation*; PET × *fs_dwell*; and PFT × *fs_dwell* (see

Table 1. Experiment 1, Analysis 1: estimates, standard errors, *t*, and *p* values for the growth curve model of is_dwell as a function of PFT (previous feedback type), PET (previous error type), and trial number.

Effect	ß	*SE*	*t*	*p*
PFT	−229.14	122.18	−1.88	.06
PET	200.93	86.36	2.33	.02*
Trial	−1.46	0.49	−2.97	.003**
PFT × PET	82.33	86.38	0.95	.34
PFT × Trial	1.40	0.49	2.85	.004**
PET × Trial	−1.78	0.49	−3.62	< .001***
PFT × PET × Trial	−0.85	0.49	−1.72	.09

Note. p < .10.
**p* < .05. ***p* < .01. ****p* < .001.

Figure 2. Experiment 1: average dwell time on objects presented on the instruction screen (is_dwell) as a function of previous error type. SEE = speaker extrinsic error; SIE = speaker intrinsic error.

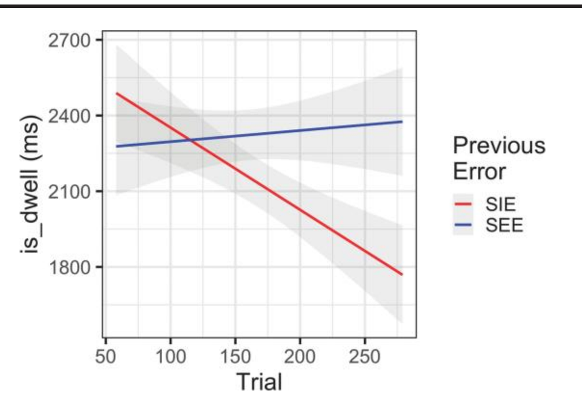


Figure 3. Experiment 1: average dwell time on objects presented on the instruction screen (is_dwell) in the critical trials as a function of feedback condition over time.

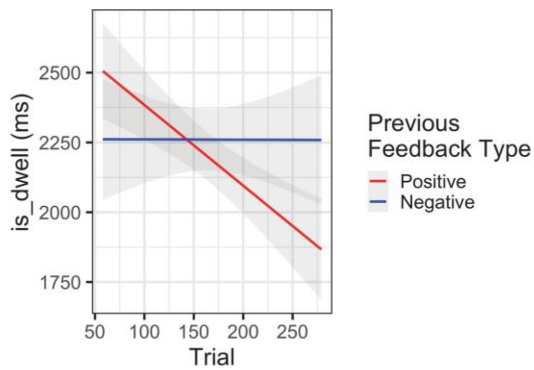


Table 2), which accounted for 49% (R^2) of the variance in *is_dwell*.

We were interested in whether or not perspective-taking effort (*fs_dwell*) and decision-making metrics (mouse-movement measures) predicted language (comprehension) processing effort (*is_dwell*). As seen in Table 2, a positive relationship existed between *x-flips* and *is_dwell,* indicating that more hesitation was associated with longer dwell times. The interaction between PET and PFT indicated significantly longer dwell times for SEE trials, but only if negative feedback was experienced. Additionally, there was a positive relationship between *maximum deviation* and *is_dwell* for SEE trials and a negative relationship between *maximum deviation* and *is_dwell* for SIE trials (see Figure 4A). Moreover, a stronger positive relationship existed between *fs_dwell* and *is_dwell* after trials with negative feedback relative to trials with positive feedback (PFT × *fs_dwell*; see Figure 4B) and SEE trials (PET × *fs_dwell*; see Figure 4C).

Table 2. Experiment 1, Analysis 2: estimates, standard errors, *t*, and *p* values for the linear mixed-effects growth model of is_dwell as a function of PFT (previous feedback type), PET (previous error type), mouse cursor measures (x-flips, maximum deviation), and *fs_dwell*.

Effect	ß	*SE*	*t*	*p*
PET	−91.72	64.59	−1.42	.16
PFT	−128.70	102.80	−1.25	.21
Maximum deviation (max d)	22.25	32.51	0.68	.49
x-flips	112.39	37.48	3.00	.003**
fs_dwell	−68.64	39.30	−1.75	.08
PET × PFT	−73.10	28.23	−2.59	.01**
PET × max d	−79.34	30.91	−2.57	.01**
PET × x-flips	38.87	30.78	1.26	.21
PET × fs_dwell	−79.02	30.71	−2.57	.01**
PFT × max d	−12.55	31.62	−0.40	.69
PFT × x-flips	44.04	35.79	1.23	.22
PFT × fs_dwell	−114.08	38.76	−2.94	.003**
PET × PFT × max d	18.22	30.28	0.60	.55
PET × PFT × x-flips	18.50	29.59	0.63	.53
PET × PFT × fs_dwell	−14.03	30.61	−0.46	.65

Note. $p < .10$.

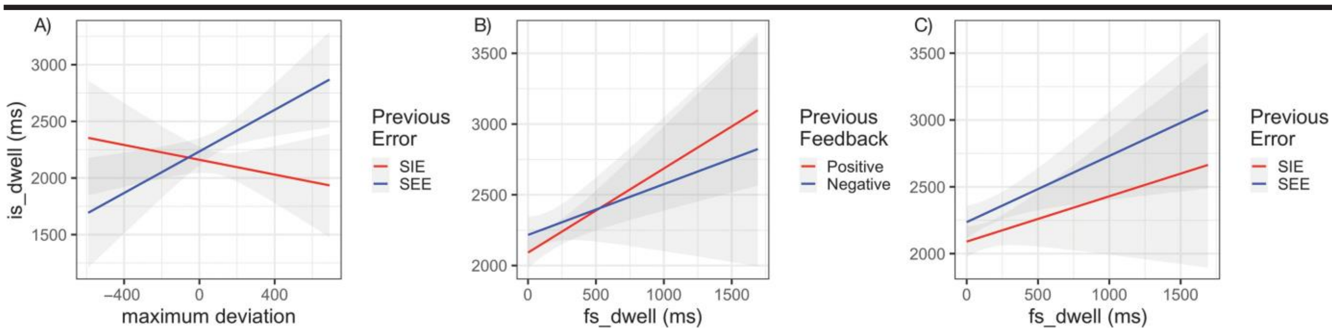
$^{**}p < .01$.

Discussion

Experiment 1 sought to evaluate differences between miscommunication error type and feedback condition in addition to establishing whether or not perspective-taking effort and decision-making metrics were related to processing effort. Specifically, our results indicated that listeners' language comprehension effort was impacted by the presence of negative feedback and the type of error produced by the pseudoconfederate on the previous trial and was related to decision-making complexity. When listeners experienced an SIE or consistently experienced no negative feedback, listeners tended to disengage from the experimental task over time. In contrast, listeners exerted significantly more language (comprehension) processing effort when the pseudoconfederate produced an SEE on the previous trial, that is, an error extrinsically related to her language processing effort. A reduction in language processing effort after SIE trials may be attributed to the listener reciprocally engaging with the speaker (*theory of reciprocity*; McCroskey & Richmond, 2000), meeting the speaker with reduced language processing effort in the face of the speaker's reduced production effort (*principle of least effort*; Zipf, 1949). With respect to the observed increase in language processing effort after SEEs, there are two potential explanations: (a) Intermixing SEEs with SIEs may have differentially engaged attention (e.g., *one-bit model*; Brennan et al., 2010; visual salience hypothesis; Treisman & Gelade, 1980); (b) listeners were naturally cooperative (i.e., *cooperative principle*: making a contribution as required by context; Grice, 1975). In the case that the SEE was attention-grabbing after a miscommunication occurred, the error may have acted as a prompt to the listener to exert more processing effort. The information about the pseudoconfederate's objects displayed on the feedback screen may have made the SEE more explicit, which may have immediately drawn the listener's attention to the item that did not match their display. The attention drawn to the salient item may have then acted as a trigger to more effortful engagement in cognitive processing on the next trial (e.g., *heuristic-systematic model*: Chaiken et al., 1989; *one-bit model*: Brennan et al., 2010). On the other hand, if listeners were engaging in the conversation cooperatively, they may have interpreted these errors as accidental and not the fault of the pseudoconfederate, thus engaging her more effortfully. These two alternatives are revisited in Experiment 2.

The results also seemed to indicate that listeners likely perceived the red X displayed in the negative feedback condition as an explicit indicator that a misunderstanding of the speaker's message had occurred, invoking more language processing effort on the next trial. Not only did the type of error and the feedback type impact listener effort, but it affected listeners' perspective-taking (*fs_dwell*), with measures of decision-making complexity contributing

Figure 4. Experiment 1: average dwell time (*is_dwell;* ms) on objects presented on the instruction screen as a function of (A) previous error and maximum deviation, (B) previous feedback and feedback screen dwell time (fs_dwell ms), and (C) previous error and feedback screen dwell time (*fs_dwell* ms). SEE = speaker extrinsic error; SIE = speaker intrinsic error.



approximately 49% of the variance found in dwell time on objects on the instruction screen (*is_dwell*).[2] Specifically, hesitation (*x-flips*) and cognitive competition (*maximum deviation*) on the current trial and longer dwell times on pseudoconfederate objects on the feedback screen (*fs_dwell*) during the previous trial were significantly related to dwell time on the instruction screen, as these measures interacted with the error and/or feedback type.

A limitation of this experiment is that participants were presented with a mixture of SEE and SIE trials, which could potentially impact how each error is processed. Additionally, only the impact of extreme rates of negative feedback (0% and 100%) was considered. It is unlikely that, in a naturalistic communicative interaction, the result of a miscommunication would never or always negatively impact the person who misunderstood. In a follow-up analysis, we separately tested a negative feedback rate of 50% on miscommunication trials. Results indicated that listeners treated SIEs and SEEs similarly when negative feedback was presented on 50% of trials (see section I.D. in Supplemental Material S1 at https://osf.io/tejnr), implying a moderate amount of negative feedback was helpful to recruit cognitive processing resources. In Experiment 2, we consider speaker-specific proclivities toward one type of miscommunication and variable rates of feedback (0%, 50%, and 100%) on listeners' language processing and decision-making complexity.

Experiment 2

It is unlikely that speakers uniformly produce both speaker-extrinsic and -intrinsic errors during an interaction. Some interlocutors may naturally be more egocentric than others (see Duran et al., 2011), while others may be more likely to simply say the wrong thing (e.g., when cognitively loaded or distracted; Becic et al., 2010; Ferreira & Griffin, 2003; Fromkin, 1973). Experiment 1 was conducted specifically to determine listeners' sensitivity to different types of miscommunication. Because there were clear differences in how listeners processed these errors, which impacted their decision making, the primary goal of Experiment 2 was to determine whether global cognitive and decision making differed in processing effort as a function of speaker miscommunication proclivity. To do this, we first evaluated the local effects of PET and PFT over time as listeners interacted with a speaker who was largely egocentric or simply less careful in their communication (similar to Experiment 1). We then considered the effect of miscommunication on decision-making complexity by evaluating differences in action dynamics and perspective-taking effort to determine whether language processing effort and decision-making hesitation and competition were related during interaction with these types of speakers.

We also aimed to determine whether speaker-specific proclivities to produce a certain type of miscommunication error differentially impacted listeners' overall cognitive processing effort (a global effect). We also considered the global effect of variable feedback (0%, 50%, and 100%) to determine how variable probabilities of penalization may interact with PETs during communication.

Overall, it was hypothesized that the results of local level analyses in Experiment 2 would produce effects similar to those observed in Experiment 1. With regard to global processing differences, it was hypothesized that interaction between speaker proclivity and feedback type would likely differentially impact global processing effort, triggering different processing heuristics to handle the different conversational contexts.

Based on findings from Experiment 1, (local) SEE trials and negative feedback should recruit more processing resources. Recall that Brennan et al. (2010) argue that listeners do not need to build complex situation models for their interlocutors; rather, salient cues may help the listener keep track of conversational context (i.e., *one-bit model*). Therefore, if a listener makes inferences about the speaker communication proclivities, the feedback may differentially trigger a processing heuristic that will allow the listener to modify and adapt their processing effort to the needs of the

[2]Because of the relatively small sample size used in Experiment 1, this result should be taken with caution and should be treated as exploratory.

conversational context (e.g., establishing conversational precedents; Kronmüller & Barr, 2007).

Participants

Eighty-five undergraduate students from a midwestern university (M_{age} = 19.94 years) participated in the experiment. An a priori between-subjects 6-group × within-subject 3-group repeated-measures power analysis with 60 experimental (critical) trials using G*Power (Faul et al., 2007) based on moderate-to-large effect size (partial η^2 = .14, or f = .40), α = .05 and power 1-ß = .95 indicated N = 36 was sufficient, but we oversampled to increase generalizability. All participants were native speakers of American English with no reported hearing or speech impairments and normal- to corrected-to-normal vision. A total of 13 participants were excluded: five due to corrupted mouse cursor data, seven due to eye-tracking data quality, and one due to a decision to leave the experiment half-way through (final N = 72, M_{age} = 19.54 years).

Materials: Equipment, Stimuli, and Procedure

All equipment, stimuli, and procedures were identical to the task described in Experiment 1.

Design

A 2 (error distribution: majority SEE [MSEE], majority SIE [MSIE]) × 3 (negative feedback probability: 0%, 50%, or 100%) between-subjects design was used, resulting in six conditions: MSIE_0%, MSIE_50%, MSIE_100%, MSEE_0%, MSEE_50%, and MSEE_100%. The MSEE condition included more SEEs than SIEs, whereas the MSIE condition included more SIEs relative to SEEs (see Table 3 for trial structure). The number of NE trials was decreased[3] from 220 to 145 to reduce the time listeners spent in the task, whereas the number of critical trials was kept the same (60) as in Experiment 1 (total trials = 205, one feature = 90 trials; two features = 81 trials; three features = 34 trials). The listeners experienced the first error on Trial 34, which was an SEE trial in the MSEE condition and an SIE trial in the MSIE condition. After Trial 34, the global ambiguity (SIE; SEE) errors and NE trials were presented to the listener pseudorandomly. We kept the nonmajority error trials in this task to prevent listeners from anticipating the type of error they would experience on a given trial.

Measures

Measures were identical to those described above and included two dwell time measures (*is_dwell*: dwell time on the objects on the instruction screen; *fs_dwell*: dwell time on the pseudoconfederate's objects on the feedback screen from the previous trial) and two decision-making complexity measures (*x-flips*: measure of indecision and hesitation; *maximum deviation*: measure of thinking and/or option competition resulting in cognitive pull).

[3]This reduced the time in the task from 1 hr 15 min to approximately 50 min. No listeners reported more frustration with the task because the number of no error trials was reduced by 75 trials.

Results

Manipulation Check

As in Experiment 1, outliers in the *is_dwell* data were removed for the following analysis (see https://osf.io/tejnr for violin plots), producing results similar to a model that included outliers. As in Experiment 1, we also performed a manipulation check to determine whether, relative to NE trials, SIE (ß = −295.60, SE = 42.33, t = −14.42, p < .001) and SEE trials (ß = −110.26, SE = 21.01, t = −5.25, p < .001) produced differences in *is_dwell*. Results indicated that SEE and SIE trials differed significantly from NE trials, with 15% (R^2) of the variance in instruction screen dwell time (*is_dwell*) accounted for by PET. In what follows, we evaluate the data set without outliers.

Local Differences in Language Processing Effort Over Time

Similar to Experiment 1, we analyzed how dwell time on the instruction screen (*is_dwell*) changed as a function of PET (critical trials: SEE, SIE; within-participant) by PFT using three linear mixed-effects models and a growth model. The initial models included (a) a base model representing time (i.e., trial number), (b) a model evaluating PFT, (c) a model evaluating PET, and (d) a model evaluating the interaction between PFT and PET. These four models were then compared to (e) a growth model using a linear mixed-effects structure with time (trial number), PFT, and PET set as fixed effects (see https://osf.io/tejnr).

The four linear mixed-effects models were compared to the growth model, which implemented a linear mixed-effects structure to evaluate changes in *is_dwell* during language comprehension over the course of the experiment as a test of model fit. The model with the smallest AIC was retained for interpretation. A test of the model fit indicated that the model evaluating PET (Model 2), PFT × PET (Model 3), and the growth model (Model 4) produced the best fit, but further evaluation indicated that the growth model produced a significantly better fit than the other two models (AIC = 70,466, $\chi^2(4)$ = 111.83, p < .001). Results from the growth model indicated two significant effects: time (trial) and PET over time (trial; R^2 = .16; see Table 4 for model results).

The effect of time (trial) suggests that listeners reduced processing effort over the course of the experiment. Critically, the effect of PET over time replicated from Experiment 1, such that listeners produced increased language processing effort for SEE trials relative to SIE trials over time (see Figure 5); however, language processing effort decreased rather than remained stable, as found in Experiment 1. Local instances of negative feedback failed to replicate from Experiment 1. This is likely related to our manipulation of the global impact of negative feedback probability (0%, 50%, and 100%) in this analysis, which

Table 3. Total number of trials containing negative feedback as a function of speaker proclivity and negative feedback probability (between-subjects) and previous error type (within-subject).

Speaker proclivity	Previous error type	Negative feedback probability	No. of trials with negative feedback
MSEE	SEE	0%	0
		50%	22
		100%	30
	SIE	0%	0
		50%	7
		100%	30
MSIE	SEE	0%	0
		50%	7
		100%	30
	SIE	0%	0
		50%	22
		100%	30

Note. MSEE = major speaker extrinsic error; SEE = speaker extrinsic error; SIE = speaker intrinsic error; MSIE = major speaker intrinsic error.

will be reconsidered in a subsequent analysis of global differences in language processing effort.

Perspective-Taking Effort and Decision-Making Complexity

A linear mixed-effects model evaluated *is_dwell* in critical trials as a function of PET (SEE, SIE), PFT (negative, positive), perspective taking effort (*fs_dwell*), and decision-making complexity metrics (*x-flips*, *maximum deviation*; $R^2 = .48$). The results included four significant interactions: Speaker Proclivity × Maximum Deviation (ß = −32.49, $SE = 12.51$, $t = -2.60$, $p = .009$), Speaker Proclivity × PET × *fs_dwell* (ß = −42.27, $SE = 21.64$, $t = -1.95$, $p = .05$), Speaker Proclivity × PFT × X-Flips (ß = 24.44, $SE = 12.40$, $t = -1.97$, $p = .05$), and Speaker Proclivity × PET × PFT × Maximum Deviation (ß = −26.23, $SE = 12.29$, $t = -2.13$, $p = .03$; output and figures can be found in Supplemental Material S1, available at https://osf.io/tejnr). Each of these effects is interpreted in what follows.

Cognitive Competition (Maximum Deviation)

There were two significant interactions associated with maximum deviation. Because we observed a higher order interaction, the lower order interaction will not be interpreted (i.e., Speaker Proclivity × Maximum Deviation). The test of simple slopes for the Speaker Proclivity × PFT × PET × Maximum Deviation interaction indicated differences in slopes for two conditions: MSEE, SIE trials, positive feedback; MSIE, SEE trials, negative feedback.

Listeners who were assigned to the MSEE speaker but experienced positive feedback during SIE trials exhibited a positive relationship between maximum deviation and *is_dwell* (ß = 102.35, $SE = 46.33$, $t = 2.21$, $p = .03$), indicating that additional effort was required to process language during these trials. The opposite occurred for listeners who were assigned to interact with the MSIE speaker but experienced negative feedback on SEE trials (ß = −88.21, $SE = 43.50$, $t = 2.03$, $p = .04$; all other simple slopes not significant), indicating that less effort was required to process language during these trials. Recall that, in Experiment 1, there was a positive relationship between maximum deviation /*is_dwell* for SEEs but a negative relationship between maximum deviation/*is_dwell* for SIEs. In Experiment 2, this effect flipped when the speaker had a proclivity to produce one type of error over another, indicating greater indecision during SIEs when interacting with the MSEE speaker and less indecision during SEEs when interacting with the MSIE speaker. Keep in mind that the speaker context was very different in Experiment 1 (random SIE and SEEs) relative to Experiment 2 (biased toward egocentrism vs. being less careful or even distracted), such that listeners may have been able to successfully build a situation model associated with the speaker proclivity, which would have changed the processing heuristics needed to engage in the task. Therefore, when listeners experienced more cognitive competition at selection, they seemed to reduce language processing effort expenditure on SEE trials when interacting with the MSIE speaker. This effect provides further support that listeners differentially adapt not only their language processing effort expenditure but also their decision-making metrics based on conversational context, specifically related to speaker-specific behaviors.

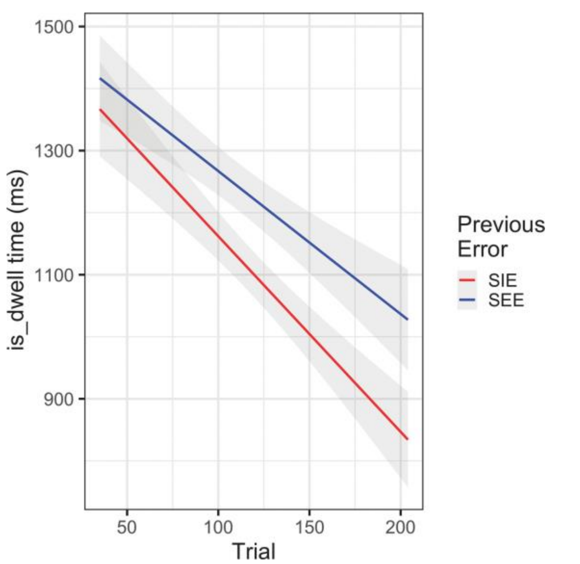
Table 4. Experiment 2: estimates, standard errors, *t*, and *p* values for the linear mixed-effects growth curve model of is_dwell as a function of PFT (previous feedback type) and PET (previous error type) over time.

Effect	ß	*SE*	*t*	*p*
PET	23.52	94.87	0.25	.80
PFT	−48.49	103.25	−0.47	.64
Trial	−3.16	0.56	−5.69	< .001***
PET × PFT	47.93	132.19	0.36	.72
PET × Trial	1.82	0.75	2.43	.02*
PFT × Trial	−0.15	0.77	−0.20	.85
PET × PFT × Trial	−1.61	1.07	−1.50	.13

Note. $p < .10$.

*$p < .05$. ***$p < .001$.

Figure 5. Experiment 2: average dwell time on objects presented on the instruction screen (is_dwell) as a function of previous error type. SEE = speaker extrinsic error; SIE = speaker intrinsic error.



Perspective-Taking Effort (*fs_dwell*)

Listeners assigned to interact with the MSEE speaker who experienced an SEE on a previous trial put in more perspective-taking effort on the subsequent feedback screen and exerted more language processing effort on the next trial. This effect replicated the PET × *fs_dwell* interaction in Experiment 1. Moreover, this suggests that SEE feedback recruited more attentional resources that shifted listeners' attention to the objects the speaker saw. When listeners looked at the speaker's objects, this, in turn, promoted expenditure of additional language processing effort on the next trial.

Hesitation (X-Flips)

A test of simple slopes indicated a positive relationship between x-flips and language (comprehension) processing effort (i.e., more language processing effort was expended when more x-flips occurred, but only for listeners who were penalized during MSIE trials; ß = 38.56, SE = 19.18, t = 2.01, p = .04, all other slopes *n.s.*). This result suggests that listeners who were penalized when interacting with the MSIE speaker experienced more hesitation when making a response selection, impacting their language processing effort expenditure.

Summary

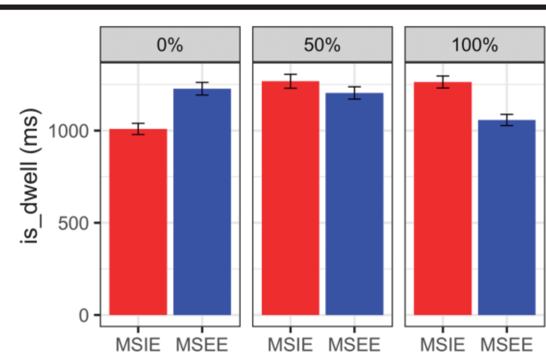
As seen in Experiment 1, perspective-taking effort (*fs_dwell*) and decision-making metrics (x-flips; maximum deviation) were predictive of language processing effort. In Experiment 2, we also see that perspective taking effort (*fs_dwell*) and decision-making metrics (x-flips; maximum deviation) were also predictive of language processing effort. Specifically, cognitive competition was positively related to language processing effort only when the listener interacted with an MSEE speaker, an SIE, and the listener was not penalized. We also saw that listeners exhibited more hesitation (x-flips) after a penalty from an MSIE speaker. This suggests that listeners' decision-making processes have an impact on language processing effort such that listeners adapt their processing heuristics based on contingencies in the conversational context.

Global Differences in Language Processing Effort

We investigated whether listeners' dwell time on instruction screen objects (*is_dwell*) depended on the pseudo-confederate's error distribution and the probability of negative feedback. We were explicitly interested in whether or not processing effort differed globally as a function of speaker proclivity and negative feedback probability. To test this question, we used a linear mixed-effects model with *is_dwell* as a dependent variable and error distribution (MSEE, MSIE) and negative feedback probability (0%, 50%, 100%) as between-subjects factors. The maximal random effect structure permitting model convergence was implemented with participant and trial number set as random intercepts.

Results indicated a significant interaction between miscommunication error distribution and negative feedback probability (ß = 86.58, SE = 37.39, t = 2.32, p = .02; R^2 = .44). As seen in Figure 6, listener language processing effort (*is_dwell*) significantly increased when negative feedback probability for listeners in the MSIE condition increased (MSIE_0% relative to MSIE_50%: mean difference = 258.49 ms, p < .001; MSIE_0% relative to MSIE_100%: mean difference = 254.59 ms, p < .001). However, listener language processing effort decreased for listeners assigned to the MSEE condition when negative feedback probability reached 100% (MSEE_0% vs. MSEE_100%; mean difference = −169.31 ms; p < .01), and no difference was observed when negative feedback probability increased to 50% from 0% negative feedback (MSEE_0% vs. MSEE_50%; mean difference = −22.63 ms; p = .99). Additionally, when MSEE trials reached 100% negative feedback probability (relative to 50%), listeners decreased language processing effort

Figure 6. Experiment 2: dwell time on the instruction screen (is_dwell) as a function of error distribution (MSIE, MSEE) by negative feedback weighting (0%, 50%, and 100%). MSEE = major speaker extrinsic error; MSIE = major speaker intrinsic error.



significantly more (mean difference = 146.68; p = .02; note: MSIE 50%–100% n.s.). It was expected that listeners would adapt their language processing effort depending on the speaker's communication style, which was confirmed by the results discussed here. Specifically, speaker miscommunication proclivity and global negative feedback differentially impacted listeners' language processing effort.

These results were somewhat surprising as the results from the local analysis in Experiments 1 and 2 suggested that SEE trials would be more likely to recruit extra language processing effort. We consider the implications of this finding in the Discussion section.

Discussion

Three analyses were conducted to evaluate listener processing effort when speaker miscommunication proclivity was manipulated: (a) local effects of communication errors and negative feedback, (b) effects of decision-making complexity metrics on local processing effort, and (c) global effect of speaker proclivity to miscommunicate. Based on the results of Experiment 1, it was found that SEE trials recruited significantly more language processing effort than SIE trials over time. This effect was replicated in Experiment 2; however, the effect of PFT did not replicate. We also saw that maximum deviation, x-flips (hesitation), and *fs_dwell* were predictive of *is_dwell*, replicating findings from Experiment 1. Listeners interpreted speech produced by speakers with different proclivities to miscommunicate in different ways, and negative feedback probability associated with miscommunication also impacted processing effort.

The observed global differences in the way listeners handled different types of speaker proclivities to produce communication errors is consistent with heuristic-systematic models of information processing (Chaiken et al., 1989) as well as the one-bit model (Brennan et al., 2010). For listeners assigned to the MSIE condition, negative feedback presented with the more salient communication error cue in SEE trials may have acted as a salient cue to disrupt simple processing heuristics through engagement of attentional resources. Visual cues presented on the feedback screen (communication error and negative feedback cues) together may have produced an additive effect that triggered a change from heuristic to systematic processing, resulting in a global increase of processing effort. However, for listeners assigned to the MSEE condition, processing effort decreased regardless of negative feedback from communication errors. Perhaps because listeners learned that the majority of the errors produced by the MSEE speaker were SEEs (i.e., due to perspective mismatch), they could simplify their processing heuristic because no additional environmental cue on SIE trials triggered them to change their approach. When the error type switched to SIE, listeners who were assigned to the MSEE condition experienced more cognitive pull, which came at more of a cost than it did for listeners assigned to the MSIE condition. This may have occurred because listeners in the MSEE condition were balancing cognitive costs when they were required to expend more decision-making effort, which may have been more computationally expensive.

General Discussion

In the current study, we investigated whether listeners differentiate their localized language processing effort depending on speakers' prior miscommunication type in a one-sided communicative task (Experiment 1) and whether listeners' processing effort was globally affected by a speaker's proclivity to produce one type of error over another (Experiment 2). In both experiments, it was hypothesized that listeners would adapt their language (comprehension) processing effort based on the type of error that occurred, but also that a speaker's proclivity to produce one error over another would also differentially impact this language processing effort. In both Experiments 1 and 2, listeners put forth significantly more language processing effort after experiencing a (local) speaker-extrinsic error. Global differences occurred as a function of speakers' proclivity to produce one error over another (Experiment 2). Together, these results confirm our hypotheses by providing evidence of both localized and global effects of speakers' miscommunication on listeners' language processing effort.

We were also interested in whether or not listeners differentiated language processing effort as a function of negative feedback from a previous miscommunication. Listeners must assess the impact of miscommunication on understanding. It was expected that the perceived impact of negative feedback would differentially impact processing effort; indeed, results from both studies confirm this hypothesis. The additive effect of SEE paired with penalization for guessing incorrectly in the MSIE condition may have triggered listeners' cognitive system to expend more language processing effort because the cues were attentionally salient. By contrast, listeners in the MSEE condition consistently and regularly received SEE cues, which may have helped them reduce language processing effort when paired with negative feedback. Additionally, SIE trials may not have elicited an attentional processing boost in the MSEE condition similar to that elicited by SEE trials in the MSIE condition because SIE trials did not provide a salient environmental cue to recruit processing resources over and above SEE trials. This may have helped reduce processing resources globally because they were not intermittently triggered to pay more attention. Taken together, listeners seemed to consider the conversational precedents set by the speaker and adapted their language comprehension effort accordingly.

Another goal of the current study was to examine whether or not perspective-taking effort and response dynamics during decision making predicted language processing effort. It was hypothesized that, when a cue to attend is received, listeners' processing heuristics should be adapted to meet the needs of the conversation. It was hypothesized that error type, feedback, and feedback screen dwell times (*fs_dwell, perspective taking effort*) would impact language processing effort on the next language trial. Moreover, longer dwell times during active language processing should then be impacted by decision-making processes. Results from Experiment 1 confirmed this hypothesis, such that longer *fs_dwell* times, more hesitation (x-flips), and more cognitive pull (maximum deviation) occurred when the error was made more salient (i.e., through feedback and/or communication error cues). These effects were replicated in Experiment 2 except that listeners adapted their decision-making metrics based on the speaker's proclivity to produce a specific error type. For example, listeners in the MSIE condition seemed to put forth less language processing effort when they experienced cognitive pull after SEE trials in which a penalty was incurred, whereas the opposite occurred for SIE trials in the MSEE condition. It is unclear why the amount of language processing effort expended differed between the two speaker proclivity conditions, but this finding warrants future exploration into the action dynamics associated with understanding confusing language.

In summary, local miscommunications did not prevent listeners from completing the task successfully, but they did exert compounding effects that impacted the effort listeners expended when comprehending a confusing speaker. The results indicate that, locally, (a) listeners are sensitive to different types of miscommunication, (b) negative feedback differentially affects effort depending on the type of miscommunication experienced, and (c) decision-making complexity is affected by the type of miscommunication and the explicit consequence experienced. Moreover, miscommunications exerted global effects on language comprehension, triggering different cognitive processing heuristics that, in turn, helped listeners adapt to the communicative context.

These findings may be applicable to a number of real-world contexts, especially when social rules or opportunity prevent the listener from asking clarification questions (e.g., in a classroom, doctor's office, interpreting public health information surrounding COVID-19, or being unaware of one's own misunderstanding). In a situation where a speaker has a different perspective than the listener and the listener is excessively penalized for misunderstanding, there may be global effects on cognition that lead the listener to disengage from expending language comprehension effort. This has important implications for education and health care, as seen in the lower global language (comprehension) processing effort in the MSEE 100% condition in Experiment 2. For instance, experts often fail to recognize the jargon they use may be confusing (e.g., Ali et al., 2006), and novices may not know what to ask or may be afraid to ask for clarification (Kruger & Dunning, 1999; Sheridan et al., 2015), or may favor information (even if inaccurate) from sources that confirm their own biases because it is easier (Nickerson, 1998). When this happens, novice listeners may disengage, resulting in potentially harmful outcomes such as missed learning or educational opportunities (Ryan et al., 1998). For instance, students in a classroom or patients in a doctor's office may lower their language comprehension effort when educators and health care providers speak with ambiguity that may never be resolved until a negative outcome occurs (e.g., failing a test or taking medication incorrectly; Isaacs & Creinin, 2003).

Nevertheless, when the consequences of miscommunication are made explicit, listeners tend to recruit additional language processing effort. Experiencing a speaker-extrinsic error on a previous trial may have caused participants to recruit more processing resources because it was more salient (Experiments 1 and 2), but this effect changed when the speaker had a higher proclivity to produce a speaker-extrinsic error and a penalty *excessively* interfered with language comprehension (Experiment 2). This was also the case when negative feedback was experienced by listeners. This suggests that the effect of miscommunication on subsequent communication is influenced not only by the type of miscommunication but also by how salient the miscommunication is made by the context and speaker-specific proclivities associated with miscommunicating. These results are consistent with findings from Bjørndahl et al.'s (2015) study suggesting that making a miscommunication explicit is important for adaptation. This is likely because the cue that makes the miscommunication salient (i.e., in the case of the current experiment, a penalty or a salient visual change) may have acted as a cue to disengage automatic language processes to engage more effortful processes needed to recruit more cognitive resources, in line with heuristic-systematic models of information processing (Chaiken et al., 1989) and the one-bit model proposed by Brennan et al. (2010).

One potential limitation of this study is ecological validity. We did not explicitly ask participants if they felt that the task approximated real-life miscommunication; however, we did ask participants if they tried to take the perspective of the pseudoconfederate, which some of the participants reported doing (~44%). Therefore, real-world miscommunication may not exert the same impact on language comprehension that we show in this task (e.g., face-to-face misunderstandings are more serious than computer-mediated miscommunications; see Edwards et al., 2017). Future studies planned to evaluate this effect in naturalistic contexts should help to advance our understanding of miscommunication, cognition, and decision making. A second possible limitation is related to the sample size in Experiment 1, which could have limited the generalizability of the mouse-tracking results. However, the mouse-tracking measures (*maximum deviation* and *x-flips*) were reliable predictors of processing effort in Experiment 2. This study also does not evaluate long-term effects of miscommunications on higher level cognitive behaviors (e.g., learning); thus, future studies should address this. Additionally, we did not permit listeners to repair the miscommunication (e.g., asking for clarification). Lastly, it is important to consider that the communicative heuristics listeners used in the interaction may have varied based on some type of coping strategy, which was not directly addressed or measurable in the current study. Although there are many contexts that would prevent listeners from engaging in repair, future studies should also evaluate cognitive and decision-making metrics in a similar paradigm when requests for repair are permissible and the coping strategies listeners may use to handle misunderstanding.

Conclusions

How listeners are affected by miscommunication seems to shape how they engage their interlocutors immediately thereafter (e.g., disengagement due to a breakdown in understanding). The current results contribute to our understanding of miscommunication by providing further evidence that the salience of miscommunication promotes behavioral change that functionally triggers a process that forces a listener to re-engage processing effort (*one-bit model*; Brennan et al., 2010). These findings have important implications for everyday life, but may also benefit the field of communication sciences and disorders specifically because of the potential educational implications for clinical practice and instruction, as well as communication with parents and caregivers in a clinical setting. If we know that miscommunication has the potential to re-engage processing effort in contexts in which automaticity (Bargh & Chartrand, 1999) and heuristics (Tversky & Kahneman, 1974) are typically relied on to process the world, then we may be able to add to literatures that discuss the strategic use of miscommunication to facilitate learning and better decision making and communication practices in health care (e.g., McCabe, 2016; McCabe & Healey, 2018) and educational contexts.

Author Contributions

Jennifer M. Roche: Conceptualization (Primary), Formal analysis (Primary), Investigation (Primary), Methodology (Primary), Writing – original draft (Primary), Writing – review & editing (Primary). Arkady Zgonnikov: Formal analysis (Supporting), Methodology (Supporting), Writing – original draft (Supporting), Writing – review & editing (Supporting). Laura M. Morett: Writing – review & editing (Equal).

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