

Social and Cognitive Influences on the Timing of Other-Initiations of Repair

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Abstract

Interlocutors tend to initiate their utterances within 250ms after the end of the previous turn. However, some speech acts are delayed. These delays may be due to preference organization: speakers display upcoming trouble by initiating their turn later. In contrast, these delays may be due to cognition: speakers may need more time to process or access information before initiating their turn. In this study, we investigate the relative contributions of social and cognitive factors to the timing of utterances in conversation.

People display their non-hearings or non-understandings by producing other-initiations of repair (OIRs). OIRs are delayed, dispreferred, and occur when information is inaccessible. Therefore, we studied whether factors that influence preference organization or information processing were related to the timing of OIRs. We found that OIRs were produced later when information was more difficult to process and when the OIR was more dispreferred. This shows that delays in conversation can be structural *and* cognitive.

Keywords: Conversation Analysis, quantification, other-initiation of repair

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Social and Cognitive Influences on the Timing of Other-Initiations of Repair

Across language and culture, people minimize the time between turns in conversation (Stivers et al., 2009). Most turns are initiated before 250ms after the previous turn (De Ruiter, Mitterer, & Enfield, 2006; Sacks, Schegloff, & Jefferson, 1974). However, some speech acts are consistently delayed. For example, qualified agreements (“yes, but...”) are initiated later than direct acceptances (“Yes.”). There are two types of explanations for this delay. On one hand, speakers delay utterances that are structurally dispreferred, or do not enhance social solidarity (see Preference Organization). On the other hand, people need more time to process, manipulate, or access more information (see Cognitive Load). Many times, dispreferred turns occur in contexts that may induce greater cognitive load. However, preference organization and information processing are almost always studied separately. In this thesis, I will examine how preference organization and information processing influence turn timing.

One study found that *other-initiations of repair* (OIRs) are most frequently initiated 721ms after the previous turn (Kendrick, 2015b). OIR is one type of *repair*, a collection of practices used to resolve problems of speaking, hearing, and understanding (Schegloff, Jefferson, & Sacks, 1977). There are different sources of positive evidence for understanding in conversation, such as backchannels (e.g., “Mhm”), but repair is the only way to show that someone has misspoken, misheard or misunderstood. OIRs provide the earliest opportunity for the listener to display their non-hearing or non-understanding of the previous turn.

Figure 1¹ shows the typical structure of an OIR sequence. Two boys had been struggling to learn a new language. Speaker B (who produces the OIR) had just told Speaker A (who produces the trouble source) that the boys were diagnosed with dyslexia. In line 1, Speaker A requests confirmation of this fact. Line 1 becomes a trouble source when, after 300ms, Speaker B produces an OIR with “Pardon?” In line 4, Speaker A produces a repair solution by repeating the trouble source. When Speaker B continues the conversation with line 5, this repeat is implicitly accepted as an adequate solution. OIR sequences are very common, appearing once about every 84 seconds of conversation, across language and culture (Dingemanse et al., 2015). Not only are OIRs fundamental to resolving problems in conversation, they are frequent and universal. One primary goal of this thesis is to begin to explain the psychological mechanisms behind this fundamental, frequent and universal conversational behavior.

In addition, OIRs illuminate the mechanisms underlying typical conversation. First, not all comprehension problems result in OIRs. Speaker B only initiates repair on information that is important to comprehend (see Preference Organization). Second, Speaker B must be confident of the information implied in their OIR. For example, “Who?” is only felicitous when the trouble source contains a subject with agency. If Speaker B uses “Who?” but there is no subject with agency, the problems escalate. Therefore, OIRs show what Speaker B believes they have heard and understood correctly.

¹ All example transcripts are from the Conversation Analytic British National Corpus (Albert et al., 2015). See “Data Source” for a detailed explanation of the corpus. Light blue rows mark the surrounding conversation, while the dark blue rows mark the OIR sequence.

Most relevant for this thesis is *when* Speaker B initiates their OIR. OIRs are unique actions because they are (1) delayed, (2) dispreferred, and (3) the outcome of information processing. Therefore, OIRs are a perfect test case for determining the relative contribution of preference and processing to delays in conversation. This analysis will show whether delays in conversation can be attributed to processing and/or preference organization.

Cognition and Preference Organization

Broadly, cognition is how people interpret, manipulate, store and use information. For a factor to be considered cognitive, it must involve (1) what information speakers have access to, (2) how that information is presented, or (3) the manipulation or storage of information. These effects should be present even when the participant is alone. For example, when someone speaks more quickly, there is a higher information density. This is true when the participant is in an interaction, listening to the radio, or listening to isolated sentences in an experimental setting.

Psychologists try to control for experimenter behavior to minimize social influences on their results. To this end, research assistants follow scripts, participants read instructions, and stimuli are controlled. Despite these attempts, experiments are still subject to pragmatics. For example, infants tend to search for an object in the wrong location repeatedly. This effect has been attributed to infants' early cognitive development. However, infant perseveration may be an artefact of experimenter behavior. Infants look where experimenters gaze and

gesture, and stop perseverating when the experimenter behavior changes (Topal, Gergely, Miklosi, Erdohegyi, & Csibra, 2008).

In addition, laboratory experiments alter the participants' goals and resources. This affects how the participant comprehends and produces utterances. Not only are there social effects in controlled laboratory experiments, the researcher changes the mechanism they are interested in studying. The end result is that psychologists document cognition that never occurs in conversation. For example, psycholinguists based theories of word production on the finding that people require 600ms to begin initiating an utterance (Indefrey & Levelt, 2004). Until recently, this field largely neglected the short turn transitions in conversation. Floor Transfer Offsets (FTO; De Ruiter, Mitterer, & Enfield, 2006) are the time between the end of the first turn and the start of the second turn. A cross-language study found that FTOs in every language have means between 0ms and 400ms (Stivers et al., 2009). Word production in conversation is earlier and different than picture naming. To understand interaction, we must study both social and cognitive effects at once.

Social factors describe how the 'self' is influenced by the presence or behavior of an 'other.' The same person, presented with the same information, behaves differently alone than with friends or strangers. While there are many different types of social effects in conversation, this thesis will focus on *preference organization*. Conversational preferences are conversation structures that emphasize social solidarity and alignment—not in personal attitudes, but in the actions being performed (Pomerantz, 1984; Schegloff, 2007). For example,

interlocutors are expected to accept offers (e.g., “Would you like a sandwich,” is expected to be followed with something like, “Sure, thanks,”). Preferred actions tend to be direct and produced early. In contrast, dispreferred actions are indirect and delayed. Speakers *mark* dispreferred utterances by extending them with hedges (“Maybe later...”), prefaces (“I would love to but...”), apologies (“Sorry, but...”), explanations (“I can’t go because...”), etc. In addition, speakers mark dispreferred utterances by delaying the initiation of the turn. For this reason, delays before utterances are often attributed to preference organization.

Many times, preference organization and cognitive processing influence turns in similar ways. If the speaker is considering whether to reject a dinner invitation, they may check their mental calendar, calculate the travel time, simulate the effect of their rejection on their interlocutor, etc. The speaker may hedge or preface because they are themselves unsure or thinking through their answer. They may delay because they are processing information related to their answer. In other words, hedging, prefacing, and delays may be signals, byproducts of complex cognitive processes, or both.

In this study, factors that influence information quantity, quality, or processing will be considered cognitive. Relationships that are dependent on the ‘other’ in conversation will be considered social. In addition, we are interested in *immediate* relationships between delays in conversation. Even when cognitive and social effects are separable, they influence each other. For example, the speaker may surprise the listener by skipping a sequence (e.g., “How are you?” followed by “Where’s mom?”) or performing an unmarked, dispreferred action. As

described below, prediction is a cognitive process that facilitates information processing. When the speaker surprises the listener, the listener processes more information (Kuperberg & Jaeger, 2016). Sequence organization, a social principal, is responsible for increased information processing, which in turn may delay the next utterance. Therefore, we will consider effects of prediction cognitive, because the immediate effect on delays would be cognitive.

The opposite can also be true: a cognitive process can underly a more immediate social effect. For example, speakers have Theory of Mind, or the ability to simulate others' minds (Baron-Cohen, 2000). This simulation is a way to process information and is therefore a cognitive process. However, the speaker uses his ability to predict the influence of their turn on their social partner. If the speaker delays an OIR because of the predicted effect on the recipient, then the most immediate cause for the delay is social. In this paper, I will consider this an effect of preference organization, even though it relies on cognitive processing.

Finally, we will consider effects social or cognitive from the perspective of the producer of the OIR. If the speaker delays OIRs that ask the listener to do more work, this is a cognitive effect from the perspective of the listener—delays are related to the amount of information processing by the listener. However, in this paper, we will consider this a social effect, since we are taking the perspective of the speaker.

In the remainder of this introduction, there is a discussion of potential cognitive and social influences on the timing of delays.

Cognitive Load

As described above, we considered factors as cognitive when they influence information quantity, density, or processing. Harder tasks or tasks with more steps take longer to perform. If cognition plays a role in the timing of OIRs, then when the information quantity or density of the trouble source increases, Speaker B should initiate their OIR later. Similarly, if Speaker B has to do more cognitive processing, they should initiate their OIR later.

We will focus this analysis on three cognitive processes that are needed for short, reliable turn transitions: comprehension, prediction, and planning. When Speaker B struggles to (1) comprehend the trouble source, (2) predict the trouble source, or (3) plan their utterance, they must process more information, more quickly. In this section, we describe how comprehension, prediction and planning facilitate typical turn transition, and may influence the timing of OIR FTO.

Comprehension Difficulties. Before initiating interactive repair, comprehenders may perform *cognitive repair*. Cognitive repair is the set of strategies the comprehender uses to solve problems of hearing or understanding before initiating interactive repair. This makes language comprehension robust to loud environments, accents, or imperfect sentences. For example, comprehenders presented with ambiguous phonemes early in a sentence use *postdiction* to retroactively disambiguate that phoneme (Gwilliams, Linzen, Poeppel, & Marantz, 2018). To do this, the comprehender first activates the multiple representations that could correspond to the ambiguous phoneme. For example, a participant could be exposed to an ambiguous dental stop, halfway between voiced (/d/) and unvoiced (/t/). The comprehender will activate both /d/ and /t/.

Throughout the remainder of the sentence, the comprehender extracts information about the ambiguous phoneme. If the sentence is “Tim went to the store,” the comprehender can determine that the ambiguous phoneme was /t/ by extracting that “went” is a verb, so the first word must be the subject. If the sentence is “Dim lights are annoying,” the comprehender can determine that the ambiguous phoneme was /d/ by extracting that “lights” was a noun, so the first word is likely part of the noun phrase. Gwilliams et al. (2018) found that these comprehenders, juggling multiple representations and extracting extra information from each sound, were under greater cognitive load. Speaker B may postdict on higher levels of representation as well, by using later information to determine a missing or ambiguous word. This is not the only cognitive repair strategy—Speaker B may search through their discourse record to resolve ambiguous pronouns (e.g., “he”), or through their long-term memory for information about their social partner. Either strategy requires moving representations from short- or long-term memory into working memory, increasing cognitive load (Baddeley, 2003). Regardless of the exact strategy, cognitive repair increases cognitive load. If OIRs are delayed when Speaker B is under greater cognitive load, then cognitive repair should be related to later OIRs.

Larger comprehension problems require more cognitive repair and should be followed by longer gaps. There are at least three factors shown to increase comprehension difficulties. First, overlapping speech interferes with comprehension, even more than ambient noise of the same intensity (Koelewijn, Shinn-Cunningham, Zekveld, & Kramer, 2014; Schneider, Li, & Daneman,

2008). Not only does overlapping speech mask the trouble source, the comprehender activates their language system to process the overlapping speech. This activation interferes with the target sentence. A corpus analysis found that ‘open’ class OIRs are more common in ‘trouble prone contexts,’ or environments with noise, overlapping speech, or concurrent activities (Dingemanse et al., 2015). Second, faster speech is more difficult to comprehend (Osada, 2004), especially when the listener has fewer cognitive resources (Haake, Hansson, Gulz, Schötz, & Sahlén, 2014). In fact, faster turns have been correlated with longer FTOs (Roberts, Torreira, & Levinson, 2015). Finally, comprehenders process frequent words more quickly (Goldinger, 2002). If comprehension difficulty increases cognitive load, and cognitive load delays utterances in conversation, then Speaker B should respond more slowly to trouble sources with overlapping talk, that are produced quickly, or contain infrequent words. Further, Speaker B should be more likely to produce more ‘open’ OIRs – that require less fully processed information (see Specificity).

Turn Prediction. Comprehenders predict their interlocutors’ speech. Predicted information is processed earlier or more easily. Specifically, the comprehender pre-activates representations or facilitates processing of information that matches the prediction. Correspondingly, correct predictions decrease response times (Levy, 2013), the magnitude of brain responses (e.g., Gisladdottir, Chwilla, & Levinson, 2015; Kutas & Hillyard, 1980), and cognitive load. This effect has been found on the phonological (e.g., Balling & Baayen, 2012), lexical (e.g., “He spread his toast with socks”, Kutas & Hillyard, 1980),

syntactic (e.g., Levy, 2013), and speech act (e.g., Gísladóttir et al., 2015) levels of representation. In addition, a growing literature shows that prediction is key to the short transition times between turns. Listeners predict when their partners' turn ends, so they know when to begin speaking (Magyari & De Ruiter, 2012). Similarly, listeners predict what their partner will say, so they can begin plan their response (Barthel, Meyer, & Levinson, 2017; Bögels, Magyari, & Levinson, 2015; Magyari, De Ruiter, & Levinson, 2017). Un-prediction increases cognitive load and/or interferes with timing and planning the next turn.

In this thesis, we will focus on trouble sources with and without discourse context. Without discourse context, Speaker B cannot form predictions about the trouble source; with discourse context, Speaker B may mis-predict the trouble source to greater or lesser degrees. Prediction may influence the timing of OIRs in two ways. First, when Speaker B predicts something different than the trouble source, it may be easier to identify that there is a problem. Therefore, Speaker B may be able to start the process of cognitive repair earlier, reducing the total amount of cognitive processing needed to produce the OIR. In addition, Speaker B may be expecting a response, and therefore may be primed to begin processing earlier. If this is true, then trouble sources with less discourse context should be followed by longer gaps. Second, when Speaker B mis-predicts the trouble source, they may have to de-activate the active representations while they activate the true representations. Without a prediction, Speaker B does not have to de-activate the incorrect prediction. If this is true, trouble sources with less discourse context should be followed by shorter gaps.

The strength of a prediction in conversation is dependent on the timing of the utterance. If an utterance is initiated early, the speaker is likely to produce a preferred action—one that emphasizes social solidarity. For example, after a polar (yes/no) question, the speaker is most likely to initiate a direct acceptance (e.g., “Yes”) after 275ms (Kendrick & Torreira, 2015). If a dispreferred action (e.g., a rejection) is produced 300ms after the previous turn, the comprehender exhibits a larger amplitude brain response (Bögels, Kendrick, & Levinson, 2015). This is evidence that comprehenders predict preferred actions early on. However, as the turn transition time lengthens, the pairing between the first and second turn weakens. After a polar question, the speaker is most likely to initiate a qualified acceptance (e.g., “Maybe, if...”) after 500ms seconds (Kendrick & Torreira, 2015). There are many options for qualified acceptances, so the comprehender may not be able to predict the action. There are strong predictions for a few preferred responses early after the turn and weak predictions for many responses later after the turn.

In addition, turns after a gap of 1 second may be ‘interactionally disjointed’ (Robinson, 2013). These turns have no discourse context. Comprehenders cannot use statistical dependencies to predict what action comes after one second, as few turn transition times are over one second (Jefferson, 1989). There is some experimental evidence for this hypothesis: comprehenders show similar brain responses to preferred and dispreferred turns after a one second gap (Bögels, Kendrick, et al., 2015). The effect of prediction (or non-

prediction) should be even stronger when the turn follows a gap greater than 1 second.

Utterance Planning. Listeners begin planning their utterances halfway through their social partners' turn (Barthel et al., 2017; Magyari et al., 2017). If the trouble source is very short, Speaker B has less time to plan what they will say. Correspondingly, very short turns are typically followed by longer gaps (Roberts et al., 2015). While longer trouble utterances give the listener more time to plan their response, they also take more cognitive resources to comprehend (e.g., Piquado, Isaacowitz, & Wingfield, 2010). Roberts et al. (2015) found a non-linear relationship between turn duration and the timing of the subsequent turn—very short turns were followed by long gaps, but overall, longer turns were followed by longer gaps. However, they also found that most of the shorter turns were acknowledgements and backchannels, while most of the longer turns were questions or statements. Roberts et al. (2015) concluded that the effect of turn duration was instead an effect of social action. In this study, no trouble source was an acknowledgement or backchannel. Therefore, our analysis of trouble source duration is exploratory.

Speaker B cannot plan an OIR until they identify the problem. If the problem of hearing or understanding is located later in the trouble source turn, we expect Speaker B to initiate their OIR after a longer delay.

Preference Organization

In this section, I will describe how preference organization explains the delay before OIRs (see Progressivity and Intersubjectivity), and how features of the OIR

sequence may make an OIR more or less dispreferred (see Specificity and Trouble Source).

Progressivity. There are many preferences in conversation. In most cases, these preferences are aligned. For example, the current speaker can optionally select the next speaker by addressing them. In these cases, there is a preference for the selected speaker to respond. However, there is also a preference for *progressivity* (Stivers & Robinson, 2006). Usually, the selected speaker will respond quickly. However, if the selected speaker does not respond quickly, then another speaker will respond, maintaining the progressivity of the conversation. This response will be dispreferred, because it goes against the preference for the selected speaker to take the turn.

In short, the preference for progressivity means that interlocutors may begin speaking early on, regardless of their cognitive state. The speaker of an OIR may initiate their OIR, even if they are still processing information—cognitive state may have more to do with which OIR is produced than *when* it is produced.

While interlocutors expect progressivity in when their partner will begin speaking, they also expect progressivity in what their partner will say. Each utterance should contribute to the overall action of the talk (Schegloff, 2007). However, OIRs delay the overall action. In Figure 2, Speaker A tells a third person (not in the OIR sequence) an anecdote in line 1. This provides an opportunity for Speaker B, who knows the anecdote, to confirm or support the anecdote. Instead, Speaker B initiates repair in line 3, and the solution is provided in line 5. After the repair solution, Speaker B returns to the previous action, and

provides their confirmation of the anecdote with “Yeah.” The conversation was delayed by two turns and would make sense to an observer without lines 3 or 5. All OIRs delay conversation and are therefore all dispreferred, which may account for the delay before OIRs. This delay provides an opportunity for the producer of the trouble source to self-repair (Kendrick, 2015b), which would avoid the OIR sequence.

Intersubjectivity. If OIRs are dispreferred, why are they so common? In conversation, progressivity is balanced against intersubjectivity. Intersubjectivity is defined as “the maintenance of a world that is mutually understood by the participants as the same world,” (Schegloff, 1991). In other words, interlocutors prioritize understanding each other. The preferences for intersubjectivity and progressivity are balanced—depending on the weight of intersubjectivity and progressivity at a given moment, someone who does not hear or understand their partner may request that intersubjectivity is re-established with a repair initiation. If the repair solution is successful, intersubjectivity is re-established.

Specificity. Within OIRs, there is a preference for *specificity* (Kendrick, 2015b; Schegloff et al., 1977). More specific OIRs mark smaller parts of the trouble source as non-heard or non-understood. ‘Open’ class OIRs (Figures 1 and 5) mark the entire previous turn, and are the least specific (Drew, 1997). In contrast, wh-word OIRs (Figures 2 and 4) mark one phrase within the trouble source (e.g., a person, location, object, or time) as non-heard or non-understood.

Speakers minimize the work needed for each contribution to conversation (Clark & Schaefer, 2003), and specific OIRs reduce the work needed to solve the

problem. The maxim of quantity states that speakers should produce all information needed, and not more (Grice, 1975). Since specific OIRs target smaller problems, they request less information. The resulting solutions are shorter, because they contain less information (Clark & Schaefer, 1987; Dingemanse et al., 2015). Underlying the preference for specificity may be a preference for shorter solutions and less work. Figure 3 depicts OIRs with varying specificity and their corresponding repair solutions. If OIRs are delayed due to preference organization, then (1) specific OIRs should be initiated earlier than ‘open’ OIRs and (2) OIRs that reduce the solution length should be initiated earlier.

Face Work. One reason a turn may be dispreferred is because it is face-threatening. Participants work to maintain a positive public image, or “face” (Goffman, Best, & Goffman, 2018; Lerner, 1996). Other-initiations of repairs are preferred to other-repairs (i.e., corrections; Schegloff et al., 1977). One reason for this is that other-repairs threaten the competence of the person who produced the trouble source (Ferenčák, 2005). In contrast, other-initiations may not insinuate that the person who produced the trouble source was incompetent. However, other-initiations of repair are still face-threatening, in two ways. First, the OIR can be attributed to (1) the producer of the trouble source, for communicating poorly, or (2) the producer of the OIR, for not attending to the turn. Second, the other-initiation puts pressure on the interlocutor to stop the ongoing course of action, and respond to the OIR (Ferenčák, 2005). While other-initiations of repair

are not as face-threatening as other-repairs, they are still face-threatening, and therefore dispreferred.

Overlapping Talk. As described above, when there is concurrent talk during an utterance, the listener processes more information and is under greater cognitive load. However, overlapping talk may influence preference organization as well. OIRs are face-threatening, partially because the problem may be attributed to incompetence on the part of one of the interlocutors (see Face Work). However, when there is overlapping talk during the trouble source, the problem can be attributed to that environmental factor—not the interlocutors. Therefore, OIRs may be less dispreferred, and produced more quickly.

Questions. Questions select the next speaker (Sacks et al., 1974; Tanya Stivers & Rossano, 2010). When the trouble source is something other than a question, then Speaker B may be able to feign understanding with a minimal response (e.g., “Mm” or “Yeah”). If Speaker B is selected to respond with a question, they may be expected to provide a non-minimal response, in which case intersubjectivity becomes more important. One experiment found that preschool children initiate repair more often in responses questions (Julien, Finestack, & Reichle, 2019). In addition, a corpus analysis found that ‘open’ class OIRs are more frequent after questions (Dingemanse et al., 2015). If intersubjectivity is more important, then Speaker B may be more willing to initiate a dispreferred OIR.

Hypotheses

In this thesis, we will begin to disentangle the relative contribution of social and cognitive factors to the timing of OIRs.

Cognitive Load Hypotheses. If information processing influences the timing of OIRs in conversation, then we can make the following predictions.

1. Trouble sources that are more difficult to comprehend—trouble sources with overlapping speech, a faster speech rate, or a lower average frequency—will be followed by longer gaps and more ‘open’ class OIRs.
2. If discourse context results in more misprediction and surprisal during the trouble source, then trouble sources that occur soon after a previous turn will be followed by longer gaps. In contrast, if discourse context makes it easier to identify the problem and to begin the cognitive repair process, then trouble sources that occur soon after a previous turn will be followed by shorter gaps.
3. If longer trouble sources give the comprehender more time to plan their OIR, then longer trouble sources should be followed by shorter gaps. In contrast, if longer trouble sources are more complex and more difficult to comprehend, then longer trouble sources should be followed by longer gaps.
4. Trouble sources with late problems will be followed by longer gaps, because the producer of the OIR will have less time to plan.

Preference Organization Hypotheses. If preference organization influences the timing of OIRs in conversation, then we can make the following predictions.

1. Specific OIRs will be initiated earlier, followed by shorter gaps, and require shorter solutions than ‘open’ class OIRs.

2. OIRs should be initiated earlier when they are followed by shorter gaps and shorter solutions, regardless of OIR specificity.
3. Overlapped trouble sources will be followed by shorter gaps, because the problem is accountable to the environment, instead of the interlocutors.
4. Questions will be followed by more ‘open’ OIRs, because intersubjectivity is needed to respond to a question.

Each hypothesis will be tested separately. all the predictor variables will be included in a principal components regression to predict the timing of the OIR. Finally, all of the predictor variables relating to the trouble source will be used to predict the OIR category. These analyses will maximize statistical power while accounting for hidden relationships between predictor variables. I will analyze the effect of information processing and preference organization on the timing of OIRs alone, and then together to determine their relative contributions.

Method

Data Source

We collected repair sequences from the Conversation Analytic British National Corpus (CABNC; Albert, De Ruiter, & De Ruiter, 2015), a subset of the British National Corpus (BNC; Leech, 1992). The CABNC contains approximately 4.2 million words from 1,436 conversations recorded in the UK in the late 20th century. Participants were originally collected through stratified random sampling, across dialect and socioeconomic status. Participants were asked to record all their conversations across 3 days, as long as the other interactants gave their consent to be recorded.

OIR Collection

We were interested in two categories of factors: those that influence the cognitive load of Speaker B. and those that influence the preference of the OIR. However, OIRs differ in complexity and in how they are used. Complex utterances take longer to initiate, even when the participant is told what to say (Ferreira, 1991; Kempen & Huijbers, 1983; Sternberg, Monsell, Knoll, & Wright, 1978). OIRs can be any length—some OIRs consist of one word (e.g., “What?”) and others are even longer than the trouble source (e.g., “Did you mean to say that...”). A second confound is how the OIR is used. OIRs can mark different types of problems. Repair initiations that use repetition (e.g., “I finished my homework.” “You finished your homework?”) challenge the acceptability of the trouble source (Kendrick, 2015a; Robinson, 2013). In fact, by successfully repeating the entire trouble source, Speaker B excludes the possibility that there is a problem of hearing. In contrast, wh-word OIRs (e.g., “I finished my homework.” “Your what?”) initiate repair by marking either a non-hearing or non-understanding of the trouble source. These different connotations may have different preference organizations.

To avoid these confounds, we restricted our search to single-word ‘open’ OIRs (e.g., “Sorry?”) and single-word wh-word OIRs (e.g., “Who?”). However, many single-word ‘open’ OIRs are two syllables, and Speaker B may elongate their OIR. Therefore, we measured the duration of the OIR and included that factor as a predictor in our regression analyses.

To find OIRs, we used the Lancaster BNCWeb search tool (<http://bncweb.lancs.ac.uk>). Search tools do not require the analyst to listen to the entire conversation to find phenomena, so the analyst may not understand the entire context (Bolden, 2015). However, we needed a large collection with strict criteria, to account for small expected effect sizes (Kendrick, 2015b), many predictor variables, and the lack of experimental control. Further, single-word ‘open’ and wh-word OIRs are rare. Together, these two types of OIRs account for approximately 25% of all OIRs in English conversations (Kendrick, 2015a). If OIRs occur approximately once every 84 seconds (1.4 minutes) of conversation (Dingemanse et al., 2015), then one of these two types of OIRs occur approximately once every 336 seconds (5.6 minutes) of conversation. In addition, the CABNC included many recordings of long conversational lapses, so it would take even longer to find OIRs by listening. Despite the potential limitations to using search tools, the Lancaster BNCWeb tool enabled us to have both statistical power and strict inclusion criteria.

Each potential OIR was analyzed with the next-turn proof procedure (Edwards, 2011)—if the speakers treated the utterance as an OIR, we included it in our collection. We excluded utterances that were treated as expressing other information, e.g., disbelief (“I’m pregnant.” “What?” “I know, right?”; Wilkinson & Kitinger, 2006), or responses to pre-sequences (e.g., “Guess what?” “What?” “I’m pregnant.”). When there was no solution in the sequence, we considered the utterance an OIR if it was fitted to the trouble source (e.g., not “I went to the

store.” “When?”) and did not perform a separate action (e.g., “Guess what?” “What?”, or “Let’s go somewhere.” “Where?”).

We did not find any “How?” or “Why?” OIRs in this search. Previous analyses show that “Why?” is never an OIR, and “How?” is only an OIR on rare occasions (Kendrick, 2015a).

Our final collection consisted of 456 OIRs.

Single Measure Analysis

We did not have sufficient repeated measures to perform a repeated measure analysis. The relevant unit was not the participant in the BNC, but the dyad order in the OIR sequence. Two OIR sequences from the same unit would have the same two participants in the same order. The same individual would need to produce the trouble source in both sequences; the same individual would need to produce the solution in both sequences. The collection of 457 OIRs came from 77 different BNC participants, for an average of 6 OIR sequences per participant. However, each participant recorded multiple conversations, in different locations and with different individuals. In total, the OIRs came from 321 separate recordings, for an average of 1.42 OIRs in each recording. Most recordings—227 (70.7%)—contained only one OIR. In addition, some conversations included more than two individuals. Some OIR sequences did not even involve the main participant. In other words, even though each participant recorded an average of 6 OIRs, these OIRs are not always between the same two individuals, let alone the same individuals in the same order.

Measures

Many variables in these analyses indicate time or duration. Time-related variables were calculated in Praat (Boersma, 2006). Given the environmental noise in the CABNC, phonetic onsets and offsets were determined manually, instead of using forced alignment.

Floor Transfer Offsets before Other-Initiations of Repair. Floor Transfer Offset (FTO; De Ruiter et al., 2006) represents the turn transition time between Turn 1 and Turn 2 (Figure 7). We calculated FTO by subtracting the end time of the first turn from the start time of the second turn. Overlaps have negative FTOs, and gaps have positive FTOs. If the FTO is 0, then the transfer is simultaneous—the first turn ends right when the second turn begins. We aimed to explain OIR FTOs, the time between the end of the trouble source and the beginning of the OIR.

OIR Category. The literature suggests that specific OIRs are less dispreferred than ‘open’ class OIRs. Therefore, if preference organization influences the timing of OIRs, then wh-word OIR FTOs should be shorter than ‘open’ class OIR FTOs.

Once we identified an OIR, we classified it as either an ‘open’ class or wh-word OIR by using the next-turn proof procedure (Edwards, 2011). The OIR category was determined by the solution. Solutions that targeted the entire trouble source marked ‘open’ class OIRs. In contrast, solutions that targeted one syntactic category within the trouble source marked wh-word OIRs. If the solution was marked as inappropriate with a second OIR, we categorized the OIR based on the ostensibly successful solution. This happens in figure 4. On line 5, Speaker B

initiates repair with “Who?” Speaker A responds to the OIR as if it were open, by repeating the trouble source and including the original ambiguous referent (“he”). In line 7, Speaker B responds by initiating repair a second time. In line 8, Speaker A treats the OIR as specific, and the problem is eventually treated as solved. In this example, the first “Who?” was considered specific, even though the first solution treated the OIR as ‘open’ class.

Most OIRs consistently mapped on ‘open’ class or wh-word. “Pardon,” “sorry,” “mm?” and “ey?” were always ‘open’ class OIRs, while “who,” “when,” “where,” and “which” were always wh-word OIRs. However, “what” functioned as both ‘open’ class and wh-word. “What” can mark a single noun phrase (e.g., “Can you get **that**?” “What?”) or the entire turn (e.g., “I’m tired.” “What?”). Again, we resolved this ambiguity with the next-turn proof procedure (Edwards, 2011). If “What?” was followed by a solution matching an ‘open’ class OIR, we categorized it as ‘open.’ Otherwise, we categorized the “what” as specific. Ten (11%) of “what?” OIRs were not followed by audible solutions. In these cases, we categorized “what?” depending on the trouble source. When the trouble source contained an ambiguous inanimate referent (e.g., “Can you get **that**?”) we categorized the “what” as wh-word. Otherwise, we categorized the “what” as ‘open’ class.

The collection contained 269 ‘open’ class OIRs and 187 wh-word OIRs.

Comprehension Difficulties. We measured two variables known to increase comprehension difficulty: syllable rate and average word frequency. We used word frequencies from the Subtitle-Based Word frequencies for British

English corpus (SUBTLEX-UK; Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). The SUBTLEX-UK used subtitles on television shows and movies from 2010 to 2012 to determine word frequency. While there is a frequency analysis of words in the BNC, there were no entries for some of the proper nouns and infrequent words in this collection. In addition, SUBTLEX-UK frequency was a better predictor of frequency effects (i.e. faster processing of more frequent words) than the BNC frequency analysis (Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). Therefore, we argue that the SUBTLEX-UK corpus is an adequate substitute for the BNC corpus.

It was impossible to determine word frequency or syllable rate for inaudible trouble sources. As described above (see Trouble Source Length), inaudible trouble sources were more frequent before ‘open’ class OIRs (61, 22.7%) than wh-word OIRs (21, 12.7%, $BF_{10} = 20.18$). It is possible that these data were Missing Not at Random; the trouble source turns that were difficult to transcribe may also have been more difficult for the interlocutors to comprehend. As mentioned in Trouble Source Length, Bayesian Regression found substantial evidence that OIR FTO did not predict inaudible trouble sources ($BF_{01} = 9.13$). Therefore, while the data may be Missing Not at Random, we do not believe this would bias our analysis of OIR FTO.

Joint Work. The literature suggests that the specific OIRs are preferred because they reduce the work needed to produce the solution. If so, then (1) the solutions to specific OIRs should take less work to produce, and (2) OIRs that require more work to resolve should be delayed, regardless of OIR category.

We were interested in whether wh-word OIRs reduce the work needed to solve the problem, as compared to ‘open’ class OIRs. We operationalized work in two ways. First, we analyzed solution duration—the longer the solution, the more work needed to produce the solution. However, a trouble source with a long subject (e.g., “My aunt who went to school with your mother...”) will have a long wh-word solution, even if the wh-word solution requires less work than the ‘open’ solution. Conversely, a short trouble source (e.g., “I did!”) will have a short ‘open’ class solution, even if the ‘open’ class solution requires more work than the wh-word solution. Since we wanted to measure whether wh-word OIRs decrease work in comparison to ‘open’ class OIRs, we calculated the ratio of solution duration to trouble source duration. A value of 1 corresponded to a solution the same length as the trouble source. A value over 1 corresponded to a solution longer than the trouble source, and a value under 1 corresponded to a solution shorter than the trouble source.

In addition, we calculated the FTO before the solution by subtracting the OIRs end time from the solutions’ start time. Solution FTOs will be longer if the solution requires more processing or if the solution is more dispreferred. While longer solution FTOs do not necessarily represent more cognitive work, if ‘open’ solutions require more cognitive work, and processing increases FTOs, more difficult solutions should have longer FTOs.

We could not calculate the solution duration for 39 (14.5%) ‘open class OIRs and 39 (20.9%) of wh-word OIRs. While OIRs make solutions relevant, the recipient of the OIR may not produce a solution. Instead, the recipient may ignore

the OIR, or the producer of the OIR may eventually produce the solution themselves. In addition, we could not calculate the trouble source duration for one ‘open’ class OIR, because the participant began recording partway through the trouble source. Therefore, we could not calculate the ratio of solution duration to trouble source duration for 40 (14.9%) ‘open’ class OIRs and 39 (20.9% wh-word OIRs. A two-sided Bayesian Contingency Table found anecdotal evidence for the null, that there was no difference in missingness between ‘open’ and wh-word OIRs ($BF_{01} = 1.62$).

For an additional 4 wh-words OIRs, and one ‘open’ OIR, the OIR began and ended before the trouble source finished. In those cases, there was a solution duration, but no solution FTO. A two-sided Bayesian Contingency Table found anecdotal evidence that solution FTO was missing for more wh-word OIRs (43, 23.0%) than ‘open’ class OIRs (40, 14.9%; $BF_{10} = 1.5$). However, a Bayesian Regression found that OIR FTO did not predict the probability of missing data ($BF_{01} = 9.60$). Therefore, we concluded that the data were likely Missing Completely at Random (MCAR) and would not bias results.

Trouble Source Length. We measured trouble source length in duration and number of words. While a trouble source with more words will tend to be longer, these two measures are not identical. A trouble source with many short words may have the same duration as a trouble source with a few long words. Further, the speaker may pause while producing the trouble source, increasing the trouble source duration without adding words. Given these differences, we included both variables in our analyses. The trouble source for one ‘open’ OIR

was only partially recorded—the recording began partway through the trouble source. Therefore, that OIR did not have a value for trouble source length.

If any part of the trouble source was inaudible, we could not calculate the number of words in the trouble source, or the syllable rate of the trouble source. Sixty-one (22.6%) of ‘open’ class OIRs and 21 (11.3%) of wh-word OIRs fell into this category. A two-sided Bayesian Contingency Table found strong evidence that more ‘open’ class OIRs missed these variables ($N = 457$, $BF_{10} = 20.18$). However, a Bayesian Regression found substantial evidence that OIR FTO did not predict inaudible trouble sources ($BF_{01} = 9.13$). While ‘open’ class OIRs may be more likely when the trouble source is inaudible, these OIRs do not necessarily follow longer FTOs.

Planning Time. For wh-word OIRs, we marked the location of the problem within the trouble source. This allowed us to measure the time between the end of the problem and the end of the trouble source. The longer this time, the more time Speaker B has to plan their OIR. ‘Open’ class OIRs mark the entire trouble source, regardless of the location of the exact word that is not understood. Therefore, we could not reliably mark one problem in the trouble source for ‘open’ class OIRs.

Thirteen (7.0%) of the wh-word OIRs marked a syntactic category that was inaudible within the trouble source (e.g., a loud noise covered the subject of the trouble source, followed by “Who?”). Therefore, we could not reliably calculate the time between the end of the problem and the end of the trouble source for these data.

Discourse Context. To determine the strength of the discourse context, we measured the trouble source FTO by subtracting the end time of the turn before the trouble source from the start time of the trouble source. A short or negative trouble source FTO indicates that the trouble source is placed within surrounding talk; a long trouble source FTO indicates that the trouble source begins a conversation or is disjointed from previous talk.

In addition, we calculated a binary variable indicating if the trouble source was disjointed. As described above, there is a standard one second limit on gaps in conversation (Jefferson, 1989)—after one second, comprehenders cannot predict the preference of the upcoming speech act (Bögels, Kendrick, et al., 2015). In this paper, we marked operationalized disjointed trouble sources as those following FTOs at least 1.5 seconds long. We chose this threshold because the original one second delay was based on beat timing, or the syllable rate of the previous turn. This method is known to undershoot machine timing (Kendrick & Torreira, 2015).

In addition, we calculated the trouble source FTO, or the time between the end of the turn before the trouble source and the beginning of the trouble source. We analyzed both continuous and binary variables to ensure that the effect of context on FTOs was robust. If so, we should see an effect for both continuous and binary measures of discourse context.

For one ‘open’ class OIR, the recording began after the trouble source turn began. This datum did not have a value for trouble source FTO or disjointed trouble source. Three ‘open’ class OIRs and one wh-word OIR were disjointed,

but the trouble source was the first utterance in the recording. Therefore, we could not calculate the trouble source FTO for four (1.5%) ‘open’ class OIRs, and one (0.5%) wh-word OIR.

Overlapped Trouble Sources. We measured three types of overlapping speech: (1) talk by someone within the conversation, (2) talk in a simultaneous but separate conversation, or (3) talk on the radio or television. We directly measured the duration of the overlapping talk. First, we calculated the percent overlap in the trouble source. If another interlocutor overlapped during the entire trouble source, percent overlap would be 100%. Second, we calculated a binary variable indicating whether there was any overlap in the trouble source. We included percent overlap and the binary overlap indicator in our analyses. All trouble sources had values for the continuous and binary indicators of overlap.

Interrogatives. We coded a binary variable indicating whether the trouble source was a question or non-question. A trouble source was a question if it had questioning syntax and/or it was eventually treated as a question by Speaker B. We were able to determine whether some partially inaudible trouble sources were questions. Still, we could not determine whether or not forty-seven (17.4%) of ‘open’ class OIRs or 16 (8.6%) of wh-word OIRs were questions. A two-sided Bayesian Contingency table found substantial evidence that a greater proportion of trouble sources that lead to ‘open’ class OIRs were unclear as to whether they were questions ($BF_{10} = 5.12$). However, a Bayesian Regression found substantial evidence that OIR FTO did not predict missingness ($BF_{01} = 6.18$).

See Figure 6 for a visual depiction of all directly measured variables, excluding the gap before the trouble source and the location of the problem within the trouble source.

Results

All tests were performed using Bayesian analyses in JASP (JASP Team, 2018). We interpreted the strength of the Bayes' factors using the guidelines in (Robert & Adrian, 1995). OIR FTO was positively skewed, so we performed several tests for each effect to ensure that the effect was robust. We tested replicated effects on OIR FTO with the log transform of OIR FTO, as well as with parametric and non-parametric tests. Unless otherwise specified, the results for each test were in the same direction.

OIR Category

We hypothesized that OIR FTOs before 'open' class OIRs would be longer than those before wh-word OIRs. To directly replicate Kendrick (2015b), we conducted a one-sided Bayesian Mann-Whitney U test. We used a prior of a Cauchy distribution with a location of 0.15, the effect size found in Kendrick (2015b), and a scale of 0.7. We found positive evidence that 'open' class OIRs (Mdn = 606) were longer than wh-word OIR FTOs (Mdn = 499, $BF_{+0} = 3.95$, $W = 28871$, $r = 0.23$, 95% CI = 0.05 – 0.42), supporting previous literature (Kendrick, 2015b; Schegloff et al., 1977). See Figure 8 for the distribution of OIR FTOs split by category.

Trouble Source Length

We tested whether trouble source length—in either number of words or duration—were associated with longer or shorter OIR FTOs. While longer trouble sources allow for more time to plan the OIR, they also require more processing.

First, we tested whether the number of words in the trouble source was related to OIR FTO. We used a uniform prior from $r_\tau = -1$ to $r_\tau = 1$. A two-sided Bayesian Kendall correlation found positive evidence for the null ($r_\tau = -0.05$, $BF_{01} = 7.08$, 95% CI = $-0.12 - 0.01$). Second, we tested whether trouble source duration related to OIR FTO. A two-sided Bayesian Kendall correlation found positive evidence for the null ($r_\tau = -0.06$, $BF_{01} = 5.14$, 95% CI $-0.12 - 0.00$). Trouble source length was not related to OIR FTO. This is in contrast to previous findings that longer turns are typically followed by longer FTOs (Roberts et al., 2015). Future analyses will determine whether OIRs have a different relationship with surrounding talk than other actions.

Discourse Context

We hypothesized that discourse context would influence how the comprehender processes the trouble source. If discourse context facilitates processing, we should see that shorter gaps before the trouble source are followed by specific, early OIRs. If discourse context interferes with processing the trouble source, we should see that shorter gaps before the trouble source are followed by ‘open’ class, delayed OIRs.

First, we tested whether discourse context was related to OIR category. A two-sided Bayesian Contingency Table found positive evidence that ‘open’ class OIRs followed a greater proportion of disjointed trouble sources (112, 70.1%)

than non-disjointed trouble sources (57.7%, $BF_{10} = 5.85$). A Bayesian Regression found positive evidence that when the trouble source FTO was one second longer, ‘open’ class OIRs were 1% more likely ($BF_{10} = 8.45$, $R^2 = 0.02$). Therefore, a lack of discourse context was followed by more ‘open’ OIRs.

We declared a uniform prior from $r = -1$ to $r = 1$. A two-sided Bayesian Kendall Correlation found very strong evidence for the alternative. When the trouble source was one second longer, the OIR FTO was approximately 160ms longer ($r_t = 0.16$, $BF_{+0} = 38290.53$, 95% CI = 0.10 – 0.22). Second, we tested whether OIR category was related to discourse context.

Third, we tested whether disjointed trouble sources were followed by longer FTOs. Since OIR FTO is known to differ between OIR category, and OIR category was influenced by discourse context we performed a Bayesian 2 (disjointed trouble source) by 2 (OIR category) ANOVA. First, we performed an ANOVA with raw OIR FTO, but the residuals were positively skewed. Therefore, we report the results from an ANOVA predicting the log transformation of the OIR FTO. However, the two ANOVAs showed similar results. We used a prior of $r = 0.5$ for all effects. There was very strong evidence that disjointed trouble sources (Mdn = 674ms) were followed by longer FTOs than other trouble sources (Mdn = 503ms; $BF_{10} = 1535.13$). The model with only disjointed trouble sources was 1.14 times more likely than a model that included both disjointed and OIR category as predictors, and 591.12 times more likely than model that included only OIR category as a predictor. Disjointed trouble sources were followed by longer OIR FTOs, regardless of OIR category. In fact, once disjointed trouble

sources were included in the model, OIR category explained little additional variance.

See Figure 9 for histograms of the ‘open’ and wh-word OIR FTOs, split by interactionally disjointed and non-disjointed trouble sources.

Turn Planning

We hypothesized that trouble sources with more time after the problem would be followed by shorter OIR FTOs. As a prior, we used a uniform distribution ranging from $r_\tau = 0$ to $r_\tau = -1$. A one-sided Bayesian Kendall correlation found positive evidence for the null ($r_\tau = -0.03$, $BF_{0-} = 9.30$, 95% CI = $-0.14 - -0.00$). A follow-up two-sided Bayesian Kendall correlation, with a uniform prior from $r_\tau = 1$ to $r_\tau = -1$, found positive evidence for the null ($BF_{01} = 13.35$). Time after the problem was not related to OIR FTO.

Comprehension Difficulties

We hypothesized that trouble sources with higher syllable rates and lower average word frequencies would be harder to comprehend and would be followed by longer OIR FTOs. First, we tested whether trouble sources with higher syllable rates were followed by longer OIR FTOs. We used a uniform prior from $r_\tau = 0$ to $r_\tau = 1$. A one-sided Bayesian Kendall Correlation found strong evidence for the null ($r_\tau = 0.00$, $BF_{0+} = 23.23$, 95% CI = $0.00 - 0.11$). Second, we tested whether trouble sources with a lower average word frequency were followed by longer OIR FTOs. A one-sided Bayesian Kendall Correlation found positive evidence for the null ($r_\tau < 0.01$, $BF_{0-} = 15.23$, 95% CI = $-0.08 - -0.00$). Follow up two-sided Bayesian Kendall Correlations, with a uniform prior from $r_\tau = -1$ to $r_\tau = 1$, found

strong evidence that OIR FTO was not related to the syllable rate of the trouble source ($r_\tau = 0.00$, $BF_{01} = 23.15$, 95% CI = $-0.07 - 0.07$) or the average word frequency in the trouble source ($r_\tau = 0.00$, $BF_{01} = 23.15$, 95% CI = $-0.07 - 0.07$). A faster speech rate and lower average word frequency, variables thought to make comprehension harder, were not related to OIR FTO.

Overlapping Speech During the Trouble Source

We hypothesized that overlapping speech during the trouble source would either increase cognitive load or make ‘open’ OIRs less dispreferred. If overlapping speech increases cognitive load, we would expect that overlapped trouble sources would be followed by longer OIR FTOs. In contrast, if overlapping speech makes ‘open’ OIRs less dispreferred, we would expect that overlapped trouble sources would be followed by shorter OIR FTOs. In either case, we should expect more ‘open’ OIRs in response to overlapped trouble sources.

First, we tested whether overlapping speech in the trouble source was related to OIR category. ‘Open’ class OIRs followed 89 (63.8%) of overlapped trouble sources and 180 (56.8%) of non-overlapped trouble sources. A two-sided Bayesian Contingency Table with a prior concentration of 1 found anecdotal evidence for the null ($BF_{01} = 2.65$). A Bayesian Regression found anecdotal evidence that the percent overlap during the trouble source did not predict OIR category ($BF_{01} = 1.33$). In contrast to previous literature (Dingemanse et al., 2015), ‘open’ OIRs were not more common after overlapped trouble sources.

Second, we tested whether overlapping speech in the trouble source was related OIR FTOs. We used the default prior of a Cauchy distribution with a scale of 0.7. A two-sided Bayesian Mann-Whitney U test found strong evidence that OIR FTOs were shorter after trouble sources with overlaps (Mdn = 477ms) than trouble sources without overlaps (Mdn = 596ms, $BF_{10} = 53.43$, $W = 27328.00$). Second, we tested whether the percentage overlap during the trouble source was related to OIR FTO. A two-sided Bayesian Kendall Correlation between found very strong evidence for the alternative ($r_{\tau} = -0.13$, $BF_{10} = 980.00$, 95% CI = -0.19 – -0.07). This effect was maintained when we performed a two-sided Bayesian Kendall Correlation with the log transformed OIR FTO, but not when we performed two-sided Pearson Correlations. This is because most trouble sources (316, 69.3%) were not overlapped, corresponding to a value of 0% overlapped. When we removed the non-overlapped trouble sources, a two-sided Bayesian Kendall Correlation found positive evidence for the null ($BF_{01} = 12.53$). Trouble sources with any overlap were followed by shorter FTOs, but the degree of overlap did not influence OIR FTO.

See Figure 10 for the histograms of ‘open’ and wh-word OIR FTOs, split by trouble sources with and without overlaps.

Linguistic and Psychological Work

We hypothesized that ‘open’ class OIRs would be followed by more linguistic and psychological work to resolve the problem. First, we tested whether ‘open’ class OIRs were followed by longer solutions. A one-sided Bayesian Mann-Whitney U test found very strong evidence for the alternative hypothesis

($BF_{+0} = 4.159e+7$, $W = 25447$). Solutions after ‘open’ class OIRs were approximately the same length as trouble sources ($Mdn = 0.93$), while solutions after wh-word OIRs were approximately half as long as the trouble source ($Mdn = 0.46$). In other words, ‘open’ class solutions are approximately twice as long as wh-word solution.

We performed post-hoc analyses to determine *how* the solution is shorter for specific OIRs—do specific OIRs have less content or are they produced more quickly? To address this question, we counted the number of syllables in the solution and calculated the solution syllable rate. Given that the number of syllables in the solution is dependent on the number of syllables in the trouble source, we also calculated the number of syllables in the trouble source. First, we determined whether the wh-word solutions had fewer syllables than ‘open’ class solutions. We performed a Bayesian Linear Regression in which we regressed the syllables in the solution on three predictors: OIR category, the number of syllables in the trouble source, and their interaction. The best model consisted of syllables in the trouble source and the interaction term as predictors. There was very strong evidence that this model was better than the null ($BF_{10} = 2.319e+21$, $R^2 = 0.32$). As predicted, longer trouble sources were followed by longer solutions. For wh-word OIRs, when the trouble source was one syllable longer, the solution was 0.1 syllables longer. Within the ‘open’ class category, when the trouble source was one syllable longer, the solution was 0.5 syllables longer. Therefore, the ‘open’ class solutions increased in length 5 times more than the

wh-word solutions. On average, wh-word solutions had fewer syllables ($Mdn = 3$) than ‘open’ solutions ($Mdn = 7$).

Second, we tested whether wh-word OIRs were shorter because they were produced more quickly. In contrast to our hypothesis, a two-sided Bayesian Mann-Whitney U test found very strong evidence that wh-word solutions have slower syllable rates ($Mdn = 4.8$ syllables per second) than ‘open’ class solutions ($Mdn = 5.78$ syllables per second, $BF_{10} = 275.39$, $W = 15630$). Wh-word solutions were shorter because they are composed of fewer syllables, despite being produced more slowly. Figure 11 displays the distribution of solution duration to trouble source duration ratios.

We measured solution FTO as an operationalization of cognitive work. If ‘open’ class solutions require more cognitive work, then they should be produced later. However, a two-sided Bayesian Mann-Whitney U test found strong evidence for the opposite—solution FTOs after ‘open’ class OIRs ($Mdn = 300ms$) were shorter than those after wh-word OIRs ($Mdn = 393ms$, $BF_{10} = 26.02$, $W = 13420$). While ‘open’ class OIRs were followed by longer solutions, they may be followed by shorter solution FTOs.

We hypothesized that shorter OIR FTOs would be followed by shorter solution FTOs and would have smaller duration ratios. First, we tested whether shorter OIR FTOs had shorter duration ratios. A one-tailed Bayesian Kendall correlation found positive evidence for a small correlation ($r_{\tau} = 0.11$, $BF_{+0} = 13.58$, 95% CI = 0.04 – 0.17). Longer OIR FTOs were followed by longer solutions. Second, we tested whether longer OIR FTOs were followed by longer

solution FTOs. A one-tailed Bayesian Kendall correlation found anecdotal evidence for the alternative ($r_t = 0.08$, $BF_{+0} = 1.70$, 95% CI = 0.02 – 0.14). While the duration ratio was smaller after wh-word OIRs and is related to shorter OIR FTOs, the solution FTO is shorter after ‘open’ class OIRs and was only weakly related to shorter OIR FTOs. See “Analyses Within ‘Open’ or Wh-word OIRs” for how this changes between ‘open’ and wh-word OIRs.

Interrogatives

We hypothesized that questions would be followed by more ‘open’ class OIRs. ‘Open’ class OIRs followed 84 (61.3%) of questioning trouble sources, and 185 (53.9%) of non-questioning trouble sources. A one-way Bayesian Contingency Table found positive support for the null ($N = 395$, $BF_{0-} = 3.46$). A follow-up two-sided Bayesian Contingency Table found positive evidence for the null ($BF_{01} = 5.23$). Questioning trouble sources may be followed by either type of OIR.

Bayesian Principal Components Regression on FTO

Preliminary Analyses. Before regressing OIR FTO on our predictor variables, we assessed the relationships between our predictor variables. First, we conducted two-sided Bayesian Kendall Correlations between all continuous predictor variables. We found very strong evidence that the more overlap during the trouble source, the shorter the trouble source FTO ($r_t = -0.298$, $BF_{10} = 3.17e+19$, 95% CI = -0.25 – -0.37). Further, we found very strong evidence that the more overlap during the trouble source, the shorter the OIR FTO ($r_t = -0.13$, $BF_{10} = 490.00$, 95% CI = -0.07 – -0.19), and the longer the trouble source FTO, the

longer the OIR FTO ($r_\tau = 0.16$, $BF_{10} = 43875$, 95% CI = 0.22 – 0.10). These relationships are partially due to how trouble source FTO and percent overlap are calculated. By definition, if the trouble source FTO is negative, there will be overlap during the trouble source. Therefore, these variables are multicollinear – they may account for the same variance in the data.

There were several correlations between continuous predictor variables that were not correlated with OIR FTO. For the correlation matrix, see Tables 4 and 5.

We examined relationships between categorical (OIR category, overlap in the trouble source, and disjointed trouble source) and continuous predictors with two-sided Bayesian Mann-Whitney U tests. See Table 6 for the summary of tests that support the alternative.

Finally, we examined relationships between categorical predictors with two-sided Bayesian Contingency Tables. We found very strong evidence that a greater proportion of non-overlapped trouble sources (46.0%) than overlapped trouble sources (14.9%) were also disjointed ($N = 456$, $BF_{10} = 4.219e+6$). As described above, overlapped trouble sources were followed by shorter OIR FTOs, and disjointed trouble sources were followed by longer OIR FTOs.

Given the multicollinearity in this data, we decided to use a Principal Components Regression (see Jolliffe, 1982 and papers cited within). First, we conducted a principal component analysis. This reduced the number of predictor variables and ensured that the predictor variables were not correlated with each other. Then, we regressed OIR FTO on the resulting components.

OIR FTO Principal Components Analysis. We performed a Principal Component Analysis on all predictor variables. The analysis generated five components with eigenvalues greater than 1.

The first component was negatively related to overlap in the trouble source, and positively related to trouble source duration, the number of words in the trouble source, and shorter solutions. This component represented non-overlapped, long trouble sources followed by shorter solutions. The larger this component, the less overlapping speech in the trouble source, and the shorter the solution in comparison to the trouble source.

The second component was negatively related to gaps and trouble source FTO, and positively related to overlapped, longer trouble sources. This component represents non-disjointed, overlapped, long trouble sources. The larger this component, the ‘busier’ the sequence – the earlier and longer the trouble source, and the more overlapping talk during the trouble source.

The third component was positively related to the average frequency and syllable rate of the trouble source, and the likelihood that the trouble source was a question. The larger this component, the greater average frequency of the trouble source, the faster the speech rate of the trouble source, and the more likely the trouble source was a question.

The fourth component was positively related to disjointed trouble sources and ‘open’ class OIRs. The larger this component, the more likely it is for the sequence to consist of a disjointed trouble source and an ‘open’ class OIR.

The final, fifth component was positively related to the solution FTO, and negatively related to the OIR duration. The larger this component, the shorter the OIR and the longer the solution FTO.

See Table 7 for the component loadings, and Figure 12 for the path diagram.

OIR FTO Regression. A Bayesian Linear Regression found that OIR FTO was best predicted by the combination of component 2 (non-disjointed, overlapped trouble sources) and component 4 (disjointed trouble sources and ‘open’ class OIRs). There was very strong evidence that this model predicted more variance than the null ($BF_{10} = 50263.77$, $R^2 = 0.10$). There was positive evidence that larger values for component 2 (non-disjointed, overlapped trouble sources) was related to shorter OIR FTOs (Mean $B = -0.01$, 95% CI = $-0.01 - 0.00$, $BF_{inclusion} = 3.74$), and strong evidence that larger values for component 4 (disjointed trouble sources and ‘open’ class OIRs) was related to longer OIR FTOs (Mean $B = 0.03$, 95% CI = $0.02 - 0.05$, $BF_{inclusion} = 132.35$). However, the residuals were positively skewed, so the longest FTOs were not explained well by this model.

Since the residuals were positively skewed, we performed a second Bayesian Linear Regression. Specifically, we regressed the log transformed OIR FTO on the same 5 principal components. The best model consisted of component 1 (non-overlapped, long trouble sources followed by smaller solutions), component 2 (non-disjointed, overlapped, long trouble sources), and component 4 (disjointed trouble sources and ‘open’ class OIRs). The Bayes Factor indicated

very strong evidence that this model was better than the null ($BF_{10} = 16460.63$, $R^2 = 0.10$). There was anecdotal evidence that larger values for component 1 (non-overlapped, long trouble sources followed by smaller solutions) were related to shorter OIR FTOs (Mean $B = -0.00$, 95% CI = $-0.01 - 0.00$, $BF_{inclusion} = 1.58$). There was positive evidence that larger values for component 2 (non-disjointed, overlapped, long trouble sources) were related to shorter OIR FTOs (Mean $B = -0.00$, 95% CI = $-0.01 - -0.00$, $BF_{inclusion} = 6.10$). Finally, there was strong evidence that larger values for component 4 (disjointed trouble sources and ‘open’ OIRs) were related to longer OIR FTOs (Mean $B = 0.01$, 95% CI = $0.01 - 0.04$, $BF_{inclusion} = 21.41$). The resulting residuals approached normality. See Table 8 for the regression table.

The Bayesian Principal Components Regression on OIR FTO found two types of sequences: (1) overlapped, long trouble sources followed by slightly shorter OIR FTOs, and (2) disjointed trouble sources followed by longer OIR FTOs and ‘open’ class OIRs. When we analyzed the log transformed OIR FTO, the evidence for these two effects weakened, but we found a third type of sequence: non-overlapped, long trouble sources followed by shorter OIR FTOs and smaller solutions.

Bayesian Principal Components Regression on Category

Principal Components Analysis. First, we performed a principal components analysis on all trouble source predictors: continuous and binary indicators of the gap before the trouble source (trouble source FTO) and disjointed trouble source), continuous and binary indicators of overlapping talk

during the trouble source (percent overlap during the trouble source and overlapped trouble source, and, trouble source duration, average word frequency, syllable rate, and the number of words in the trouble source.

This analysis identified four components with eigenvalues over 1. The first component was negatively related to both binary and continuous variables representing overlap during the trouble source, and positively related to both binary and continuous variables representing longer gaps before the trouble source. In addition, the first component was positively related to longer trouble sources. When this component was larger, there is less surrounding speech and the trouble source was longer.

The second component was positively related to the binary variable indicating overlap and longer trouble sources. This component represented long trouble sources that were overlapped.

The third component was positively related to questioning trouble sources with a high syllable rate and average word frequency.

Finally, the fourth component was positively related to trouble sources that were both overlapped and disjointed. See Table 9 for the component loadings.

Category Regression. We regressed OIR Category on the four components identified by the Principal Components Analysis. A Bayesian regression found that the best model contained all four components. There was very strong evidence for this model over the null ($BF_{10} = 1725$, $R^2 = 0.08$). There was very strong evidence that larger values for component 1 (longer trouble sources surrounded by less talk) were associated with more ‘open’ OIRs (Mean B

= 0.00, 95% CI = 0.00 – 0.01, $BF_{inclusion} = 974.45$). There was very strong evidence that larger values for component 2 (long, overlapped trouble sources) were related to more wh-word OIRs (Mean $B = -0.01$, 95% CI = -0.02 – -0.01, $BF_{inclusion} = 861.32$). There was anecdotal evidence that larger values for component 3 (questioning trouble sources that are produced quickly, with high frequency words) were related to more ‘open’ class OIRs (Mean $B = 0.01$, 95% CI = 0.01 – 0.02, $BF_{inclusion} = 1.61$). Finally, there was very strong evidence that larger values for component 4 (overlapped and disjointed trouble sources) were related to more ‘open’ OIRs (Mean $B = 0.01$, 95% CI = <0.01 – 0.01, $BF_{inclusion} = 248.50$). See Table 10 for the regression table.

Long OIR FTOs

After collecting OIRs and measuring the FTOs, we noticed that the OIR FTO distribution was positively skewed. To ensure that our results were not driven by these outliers, we performed the same tests without the OIRs with FTOs greater than 2.5 seconds. Eight ‘open’ class OIRs and one wh-word OIR were removed. The remaining collection contained 262 ‘open’ class OIRs and 186 wh-word OIRs remained.

We found many similar effects within this group. However, with the outliers removed, Bayesian’s Kendall’s correlations found anecdotal evidence that solution FTO was positively correlated with OIR FTO ($r_{\tau} = 0.09$, $BF_{10} = 1.52$, 95% CI = 0.15 – 0.02). In addition, there was positive evidence that the longer the solution in proportion to the trouble source, the longer the OIR FTO ($r_{\tau} = 0.10$, $BF_{10} = 5.31$, 95% CI = 0.17 – 0.03). Finally, in the principal components

regression on OIR FTO, disjointed trouble sources with ‘open’ OIRs were no longer a predictor of OIR FTO.

Analyses Within ‘Open’ vs. Wh-word OIRs

We performed exploratory analyses to determine whether ‘open’ and wh-word OIRs have differing relationships with the predictor variables. If ‘open’ OIRs are more dispreferred, then they should only be produced when the speaker of the OIR is cognitively overloaded, and cannot produce a specific OIR (Clark & Schaefer, 1987). If this is true, then the producer of the OIR may engage in cognitive repair until they (1) can produce an ‘open’ OIR, and (2) approach the threshold of how long they can wait to speak. Then, and only then, Speaker B initiates repair with an ‘open’ OIR. If this is true, then ‘open’ OIR FTOs should not be modulated by preference organization. Instead, ‘open’ OIR FTOs should be modulated only by cognitive factors.

However, ‘open’ OIRs are sometimes used to repair more delicate material (Svennevig, 2008). In these sequences, ‘open’ OIRs give the producer of the trouble source an opportunity to change their original turn, or revise what they are on the record for saying. Therefore, it may be that ‘open’ class OIRs, and their OIR FTOs, are modulated by preference organization.

Wh-word mark smaller problems of comprehension, as evidenced by the more information about the trouble source included in the OIR. When speakers produce specific OIRs, they must entail accurate information. If the trouble source was, “The television is coming tomorrow,” and the OIR was, “Who?” the OIR exacerbates the original problem of comprehension because the person producing

the solution targets the wrong type of information. Therefore, the speaker of the OIR is motivated to only include correct information.

Therefore, it may be that the producer of a wh-word OIR may not be cognitively overloaded, and therefore has the freedom to time their OIR based on preference organization. In this case, wh-word OIR FTOs should vary with preference organization and not cognitive processing. In contrast, the problems marked by wh-word OIRs may be smaller because the speaker of the OIR engaged in cognitive repair. Therefore, OIR FTOs could be longer when the OIR speaker is under cognitive load.

Within each OIR category, we correlated OIR FTO with each continuous predictor. In addition, we analyzed how OIR FTO within each category varied depending on the binary predictors (disjointed, overlapped, or questioning trouble sources). We only found one difference between the two categories. A two-sided Bayesian Kendall's Correlation found positive evidence that wh-word OIR FTOs were longer when solution FTOs were longer ($r_{\tau} = 0.17$, $BF_{10} = 10.35$, 95% CI = 0.28 – 0.06). Within 'open' OIRs, we found positive evidence for the null, that OIR FTO and solution FTO were unrelated ($r_{\tau} = 0.05$, $BF_{10} = 6.21$, 95% CI = - 0.04 – 0.13).

Discussion

Cognitive Processing

We found one robust effect of cognitive processing on OIR FTO: disjointed trouble sources. In our analyses, we found that the longer the gap before the trouble source, the more the comprehender delays their OIRs. In

addition, the OIRs are more likely to be ‘open’ class. This suggests that without discourse context, the comprehender is overloaded by processing—comprehenders have to realize *that* their interlocutor is speaking in order to process *what* they say. If the comprehender gets behind in processing the trouble source, because they were not prepared to process the beginning of the trouble source, they would have to process the information in a shorter period of time. Once this effect is included, there is no main effect of OIR category on OIR FTO. One possibility is that the difference in OIR FTO between categories is driven by discourse context: the less discourse context, the longer the FTO, and the more likely the OIR will be ‘open’ class.

This delay could also be attributed to preference organization—OIRs after disjointed trouble sources may be especially dispreferred. However, if this were an effect of social preference, we would still expect a sub-organization based on OIR specificity: *wh*-word OIRs should still be produced more quickly than ‘open’ OIRs when the trouble source is disjointed. To address this possibility, we conducted two-sided Bayesian Mann-Whitney U tests. There was positive evidence that ‘open’ and *wh*-word OIRs have similar FTOs after disjointed trouble sources ($BF_{01} = 5.50$, $W = 2679$). There was anecdotal evidence for the null hypothesis within non-disjointed trouble sources ($BF_{01} = 2.18$, $W = 9226$). Therefore, we conclude that when Speaker B has no discourse context to help process the trouble source, they become overloaded by cognitive processing.

Qualitative analyses of the OIR FTO distributions across OIR category and disjointed trouble sources (Figure 9) show that very few disjointed trouble

sources are followed by OIR FTOs less than 200ms. We propose that this effect is related to an inability to predict *when* the trouble source will end. Since the comprehender is overloaded early in the trouble source, they are not able to process the turn normally or predict the ending of the turn. Instead, the comprehender can only react to when the speech sound ends. In addition, Figure 9 shows that most of the longest OIR FTOs are embedded in sequences with both disjointed trouble sources and ‘open’ OIRs. When Speaker B is cognitively overloaded, they cannot repair the trouble source and must produce ‘open’ OIRs.

While other features of the trouble source influence comprehension in laboratory settings, this comprehension difficulty does not influence OIR FTO. The only effect of comprehension was that questioning trouble sourced that were produced quickly, with frequent words, were followed by more ‘open’ OIRs. This raises an intriguing question: how relevant are psycholinguistic findings to naturalistic behavior? There are several answers to this question. First, by definition, people in conversation typically use frequent words, and speak at an average rate. The ranges of frequency and speech rate found in laboratory settings may be exaggerated to find effect—these effects may not be found in speech in the ‘normal’ range of frequency and speech rate. Second, it may be that the contribution of frequency and speech rate to comprehension difficulties in natural settings are overshadowed by other effects. In other words, laboratory experiments find effects by controlling for many factors that may have large effects. In conversation, other effects—such as preference organization—may overshadow experimental effects. Third, it may be that the comprehender engages

in different repair strategies in experimental and environmental settings. For example, in lexical decision tasks, participants are asked to mark whether a string of letters is a word or non-word. However, in conversation, interlocutors assume that their partners are not intentionally producing fake words. In addition, this study shows that discourse context is vital for quick comprehension. In psycholinguistic studies, there is rarely a discourse context for the comprehender. In other words, unnatural task demands may change what the comprehender does or needs to produce utterances quickly. This study demonstrates the importance of testing experimental effects in natural settings.

Preference Organization

There are preferences to reduce the work needed to produce the solution and to affiliate with the interlocutor. These two preferences can influence the timing of OIRs.

Interlocutors delay their OIRs when they require more work to solve, regardless of OIR category. This phenomenon is likely responsible for the slightly larger FTOs before ‘open’ class OIRs. An extra delay may convey a reluctance to place more work on the interlocutor, or a demonstration of a ‘good faith effort’ in resolving the problem on their own. In addition, this extra delay distributes the apparent work more evenly across interlocutors, as a longer delay before an OIR signals more cognitive work. This suggests that the producer of the OIR simulates their interlocutors’ future work, and incorporates the results of that simulation, as they interact.

Further, speakers aim to affiliate, and produce their OIR earlier when they can do so. As described above (see Face Work) OIRs can imply that interlocutors are poor communicators. In this study, we found that overlapped trouble sources were followed by shorter OIR FTOs. Overlapping talk provides an account for the OIR. Therefore, overlapping speech during the trouble source counteracts some of the dispreferred connotations OIRs.

Comparison with Kendrick (2015b)

Kendrick (2015b) compared FTOs before all specific OIRs to all ‘open’ class OIRs in a collection of approximately 9.5 hours of English conversation. The data were 19 conversations between native speakers in the U.S. Canada, and the U.K. Kendrick (2015b) found that specific OIRs (Mdn = 633ms) had a median FTO 154ms shorter than ‘open’ class OIRs (Mdn = 787ms).

The OIR FTOs in this collection were shorter than those in Kendrick (2015b). The wh-word OIRs in this collection had a median FTO of 499ms, 134ms shorter than Kendrick’s (2015b) estimate. The ‘open’ class OIRs in this collection had a median FTO of 606ms, 181ms shorter than Kendrick’s (2015b) estimate. In this collection, wh-word OIRs had a median FTO 107ms shorter than the ‘open’ class OIRs. See Tables 1, 2, and 3 for descriptive statistics.

The difference in FTO between our collection and Kendrick (2015b) may be a consequence of preference organization. Dispreferred utterances are marked by delays, hedges (e.g., “I think”, “Maybe”), disfluencies (e.g., “Um...”), accounts (“I have a question...”) or other methods of marking a turn (Pomerantz, 1984). In this study, we restricted our analyses to single-word OIRs. This

implicitly excludes OIRs that are marked in ways other than delays. If an OIR is not marked with hedges, disfluencies, accounts, etc., it may be less dispreferred than other OIRs. Future analyses should expand the variety of OIRs in the collection.

These differences may also be cognitive. More complex utterances tend to be delayed (Ferreira, 1991; Kempen & Huijbers, 1983; Kendrick & Torreira, 2015; Sternberg et al., 1978), and the OIRs in Kendrick (2015b) are more complex than the OIRs in this collection. However, Bayesian Kendall Correlations found positive evidence for no correlation between OIR FTO and OIR duration ($r_\tau = -0.02$, $BF_{01} = 13.07$, 95% CI = $-0.08 - 0.04$), trouble source FTO and trouble source duration ($r_\tau = 0.013$, $BF_{01} = 14.97$, 95% CI = $-0.05, 0.07$), or solution FTO and solution duration ($r_\tau = 0.03$, $BF_{10} = 11.13$, 95% CI = $-0.04 - 0.09$). While these tests are not definitive, they do suggest that longer utterances are not related to longer trouble source FTOs, OIR FTOs, or solution FTOs.

Conclusion

Cognitive load and preference organization are both relevant in the timing of OIRs. Speaker B is sensitive to cognitive effort, and the future projected work on behalf of Speaker B. In other-initiated repair, Speaker B delays their OIRs when the trouble source is unpredicted, the OIR requires longer solutions, and when there is no obvious accounting for the problem.

These analyses uncovered several questions that remain unexplained. We expected that ‘open’ OIRs would be followed by more psychological work (longer solution FTOs) and more linguistic work (longer solutions). While ‘open’

OIRs were followed by longer solutions, those solutions were initiated earlier. One possibility is that delayed ‘open’ OIRs project upcoming trouble more clearly. In this case, Speaker A may have more time to predict the problem and plan their solution before the OIR is produced. If this is true, then we should find a positive correlation between solution FTO and OIR FTO—the longer it takes for Speaker B to produce their OIR, the faster Speaker A should be able to produce the solution. However, a Bayesian Kendall Correlation found anecdotal evidence for the null ($r_{\tau} = 0.08$, $BF_{01} = 1.16$, 95% CI = 0.01 – 0.14). Another possibility is that the solutions that follow ‘open’ OIRs are less cognitively demanding. ‘Open’ class solutions typically repeat the trouble source. If Speaker A repeats the same utterance a second time, those words may be pre-activated and easier to produce. In contrast, wh-word OIRs can be used both to mark problems of hearing and understanding (e.g., an ungrounded “it”). Some wh-word solutions are repeats, but others are clarifications or elaborations. In fact, a few wh-word OIRs happen when Speaker A does not have immediate access to a proper noun (e.g., “What’s his name went to the store”). Clarifications or elaborations require accessing new words, which may be more cognitively demanding than repeating the same words. A final explanation is that solutions to wh-word OIRs are dispreferred in comparison to solutions to ‘open’ OIRs. While we know of no preference organization of solution types, we know of no paper studying solutions specifically. Future analyses will be needed to determine why ‘open’ OIRs are not followed by longer solution FTOs, and why this increased solution FTO is not related to preference organization.

These analyses may shed some light on the neurobiology of language processing. Specifically, specific and ‘open’ OIRs may be related to the brain responses participants exhibit when comprehending difficult sentences. The field focuses on two brain responses: the N400, which occurs 400ms after an unexpected word, and the P600, which occurs 600ms after an unexpected word (Kutas & Hillyard, 1980). These brain responses are thought to index cognitive repair processes. One intriguing question is if, and how, these cognitive repair strategies interface with interactive repair strategies. One option is that these brain responses are artefacts of the solitary experimental environment. Participants typically read or listen to unexpected words in a room on their own. If a person can produce an OIR, they may not feel the need to engage in advanced cognitive repair strategies and may not exhibit these brain responses at all. Second, if variance in these brain responses correlates to variance in OIRs, we can learn more about the underlying mechanisms behind these brain responses. The P600 is thought to index greater problems and is seen later than the N400; ‘open’ OIRs mark greater problems and are produced later than specific OIRs. Are ‘open’ OIRs associated with larger P600s, and are wh-word OIRs associated with larger N400? In our collection, we had 43 wh-word OIRs that marked a problem at the end of the trouble source. This is the closest natural data can get to the same conditions in experimental studies. Their median FTO was 526ms (Figure 13), suggesting that wh-word OIRs may happen after the N400 but before the P600. These results are tenuous but suggest that studying the interface between cognitive and interactive repair may be productive.

These analyses will also inspire human-robot interaction experiments. First, robots should follow preference organization. Before initiating repair, robots should simulate how much work their human interlocutor will need to perform and delay their OIR accordingly. Some models implement a form of preference organization for typical, non-problematic turns (Selfridge & Heeman, 2010; Thórisson, 2002), but problems of hearing and understanding are frequent in dialogue systems. Robots need to know not only what to say, but when to say it. Second, robots should work to minimize the human interlocutors' comprehension problems. For example, if there has been a conversational lapse, the robot should secure their interlocutor's attention before giving them the relevant information. That way, the robot can avoid exacerbating comprehension difficulties by producing an unpredicted utterance. Finally, a robot with sophisticated robot-human theory of mind may be able to anticipate problems of hearing or understanding. If their interlocutor does not respond for 500ms, the robot may elect to clarify or reformulate their utterance to assist the human. Future studies will implement various OIR and repair solution strategies in robots.

This study marks the first to show that both cognitive and social factors contribute to the timing of utterances in conversation. When people initiate utterances is both dependent on (1) their cognitive load, and (2) the social implication of the utterance. Interlocutors are limited by their cognitive state, but also orient to their social partners' future work.

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Figure 1

‘Open’ Class Other-Initiation of Repair.

Line	Speaker	Utterance	Part of Conversation
1	A:	It was only partly the language then?	Trouble Source
2		0.3	FTO
3	B:	Pardon?	Repair Initiation
4	A:	It was only partly the language then?	Repair Solution
5	B:	Yes. Yes.	Answer

Notes: Light blue marks the surrounding conversation, dark blue marks the insert sequence.

Figure 2

Specific (Wh-word) Other-Initiation of Repair.

Line	Speaker	Utterance	Part of Conversation
1	A:	I say Mum calls me Antony when she's telling me off.	Trouble Source
2		1.4	FTO
3	B:	Who?	Repair Initiation
4		0.8	FTO
5	A:	Mum.	Repair Solution
6	B:	Yeah. ((laugh))	Agreement

Notes: Light blue marks the surrounding conversation and dark blue marks the insert sequence.

Figure 3

OIRs Ordered from Less to More Specific

OIR	Solution
Sorry?	It was only partly the language then?
It was what?	Only partly the language then
It was only what?	The language.
It was only partly the language then?	Yes.

Figure 4

Mismatched Solution Type

Line	Speaker	Utterance	Part of Conversation
1	A:	Gosh he looks ugly.	Assessment
2		0.5	Pause
3	A:	Bleasdale.	Increment
4		0.6	Gap
5	B:	Who?	Repair Initiation (Whword)
6	A:	He looks fat and ugly.	Repair Solution (Open)
7	B:	Who?	2nd Repair Initiation (Whword)
8	A:	Bleasdale.	Repair Solution (Whword)
9		1.1	Pause
10	A:	This writer	Repair Solution (Whword)

Notes: Light blue marks the surrounding conversation, dark blue marks the insert sequence.

Figure 5

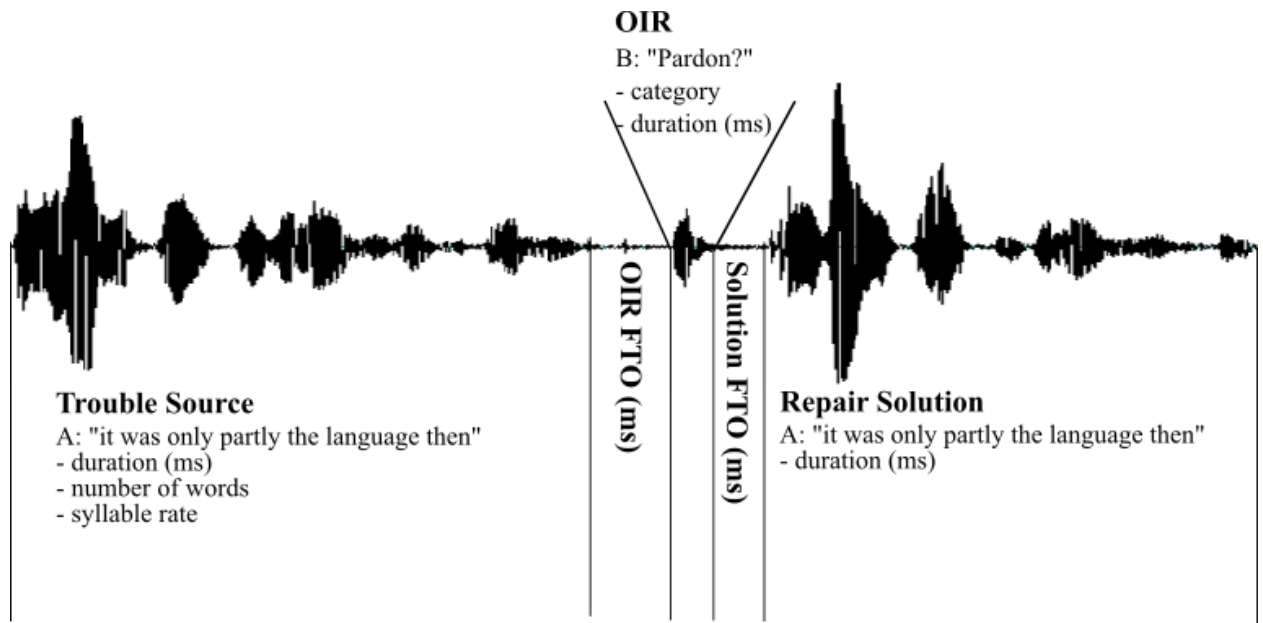
‘Open’ Class, Overlapping Talk

Line	Speaker	Utterance	Part of Conversation
1	C:	Elaine use[d to deafen them on the side there.]	Overlapping Talk
2	A:	[Why do you get do you have to retire at a certain time?]	Trouble Source
3	B:	Sorry?	Repair Initiation
4	A:	Do you have to pack it up a certain time?	Repair Solution
5	B:	Oh no.	Answer

Notes: Light blue marks the surrounding conversation, dark blue marks the insert sequence.

Figure 6

Summary of Measures



Notes: This figure excludes the trouble source Floor Transfer Offset (the time between the end of the turn before the trouble source and the beginning of the trouble source), and the time between the problem and the end of the trouble source turn.

Figure 7: Floor Transfer Offset (FTO)

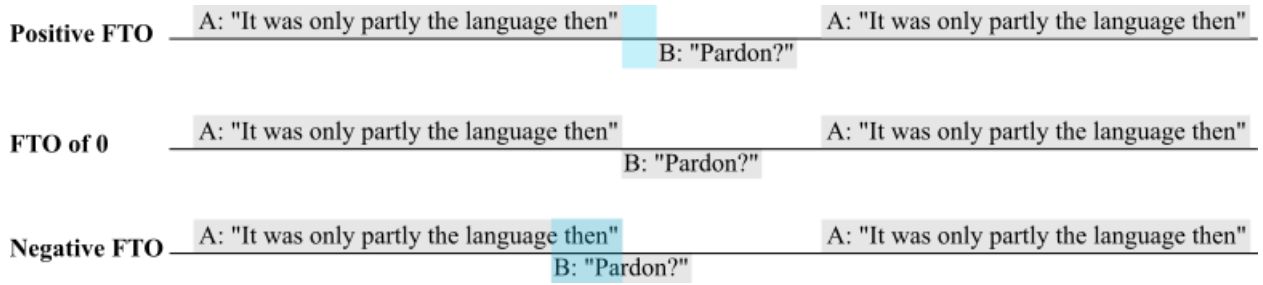


Table 1

Descriptive Statistics of Timing Variables by OIR Category

	OIR FTO		Sol FTO		Problem- TS end		TS duration		OIR duration		TS FTO	
	open	WW	open	WW	open	WW	open	WW	open	WW	open	WW
Valid	270	187	230	144	0	174	269	187	270	187	266	186
N/A	0	0	40	43	270	13	1	0	0	0	4	1
Mean	762	651	389	506	.	823	1,531	1,836	287	259	3,703	1,772
Med	606	499	300	393	.	675	1,334	1,479	281	252	1,037	530
Std. Dev.	634	577	384	431	.	796	953	1,332	86	88	8,382	3,168
Min.	-280	-646	-276	-109	.	0	148	159	92	76	-1,864	-1,050
Max.	4,327	5,130	4,222	2,309	.	4,253	5,701	12,320	592	690	59,580	17,270

Notes: OIR = Other-Initiation of Repair, FTO = Floor Transfer Offset, TS = Trouble Source, WW = Wh-word, Sol = Solution. All measurements are in milliseconds.

Table 2

Descriptive Statistics of Non-Timing Continuous Variables, by OIR Category

	TS frequency		Words in TS		TS syllable rate		Sol:TS ratio		TS overlap %	
	'open'	WW	'open'	WW	'open'	WW	'open'	WW	'open'	WW
Valid	209	165	209	167	209	167	230	148	269	187
Missing	61	22	61	20	61	20	40	39	1	0
Mean	6.00	6.11	6.55	7.47	5.75	5.60	1.10	0.66	15.53	10.29
Median	6.17	6.17	6.00	7.00	5.48	5.70	0.93	0.45	0.000	0.000
Std. Dev.	0.75	0.62	3.46	4.42	1.76	1.45	0.98	0.61	28.07	22.20
Min.	1.70	2.43	1.00	1.00	1.45	1.75	0.15	0.02	0.000	0.000
Max.	7.26	7.31	18.00	27.00	13.41	8.98	10.75	3.62	100.0	100.0

Notes: TS = Trouble Source, Sol = solution, WW = Wh-word

Table 3

Descriptive Statistics of Binary Variables, by OIR Category

	TS = overlapped		TS = disjointed		TS = question	
	'open'	WW	'open'	WW	'open'	WW
Valid	269	187	269	187	223	172
Missing	1	0	1	0	47	16
Mean	0.33	0.27	0.41	0.29	0.38	0.31
Median	0.00	0.00	0.00	0.00	0.00	0.00
Std. Deviation	0.47	0.45	0.49	0.46	0.49	0.46
Minimum	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	1.00	1.00	1.00	1.00	1.00	1.00

Notes: OIR = Other-Initiation of Repair, WW = Wh-word, TS = Trouble Source.
 All values are in proportions.

Figure 8

Probability Density of OIR FTOs by Category

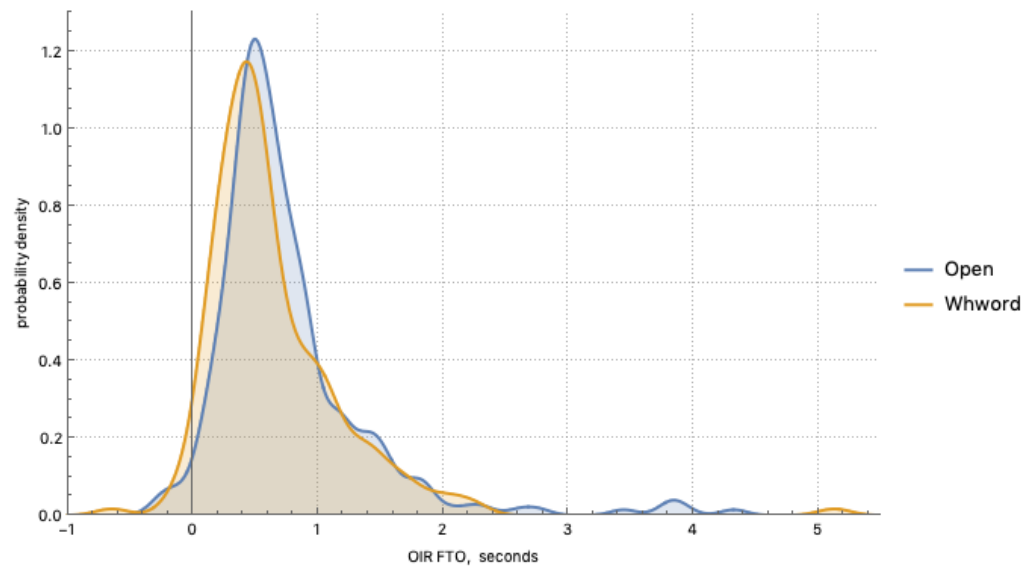
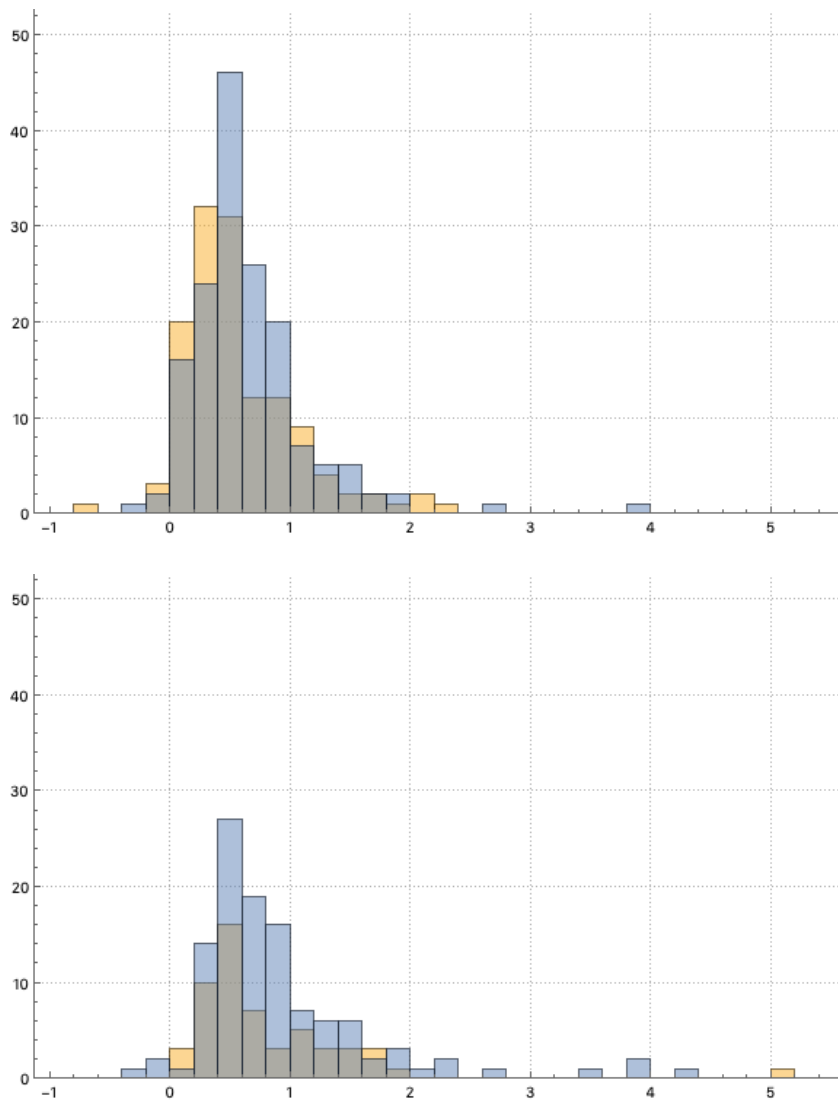


Figure 9

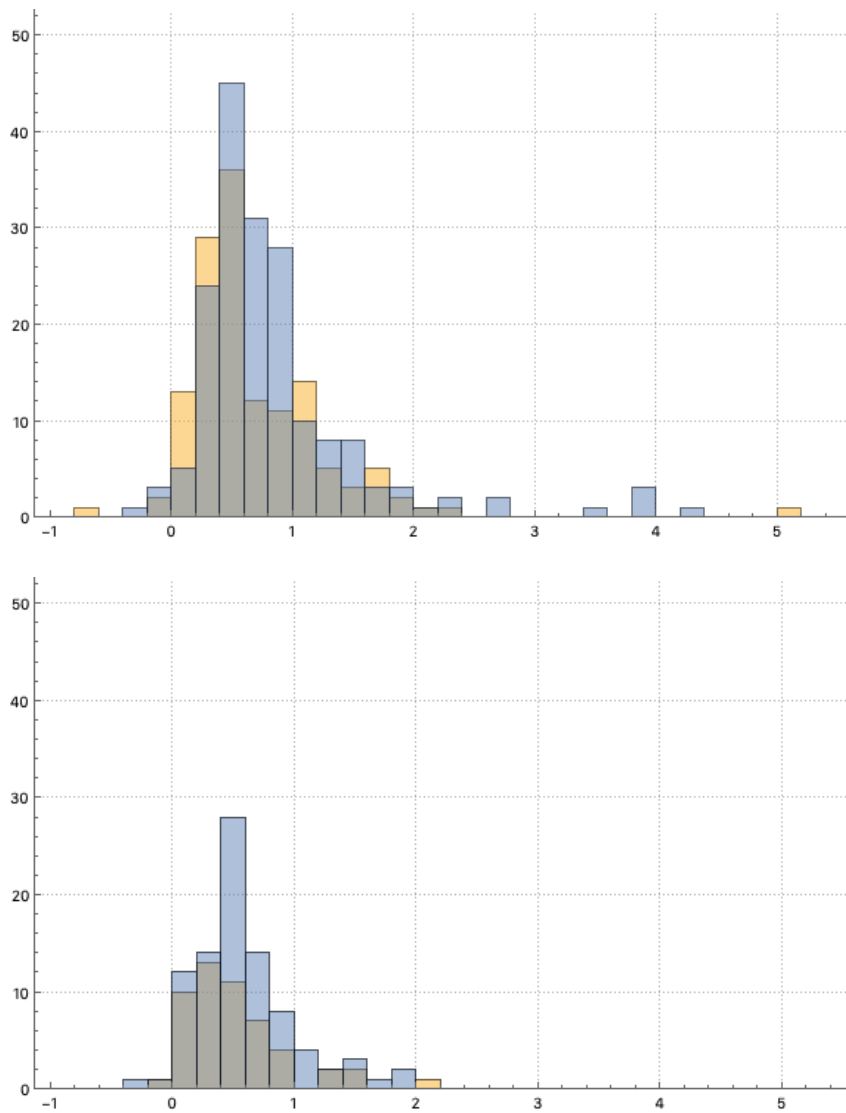
OIR FTOs by OIR Category and Disjointed Trouble Source



Notes: The X axis is OIR FTO in seconds, and the Y axis is frequency. On the top are non-disjointed trouble sources and on the bottom are disjointed trouble sources. Blue is 'open' class OIRs, and orange is wh-word OIRs. Disjointed trouble sources were followed by more 'open' OIRs, and longer OIR FTOs.

Figure 10

OIR FTOs by OIR Category and Overlapped Trouble Sources



Notes: The X axis is OIR FTO in seconds, and the Y axis is frequency. On the top are non-overlapped trouble sources and on the bottom are overlapped trouble sources. Blue is 'open' class OIRs, and orange is wh-word OIRs. Overlapped trouble sources were followed by shorter OIR FTOs.

Figure 11

Solution Duration to Trouble Source Duration Ratios by OIR Categories

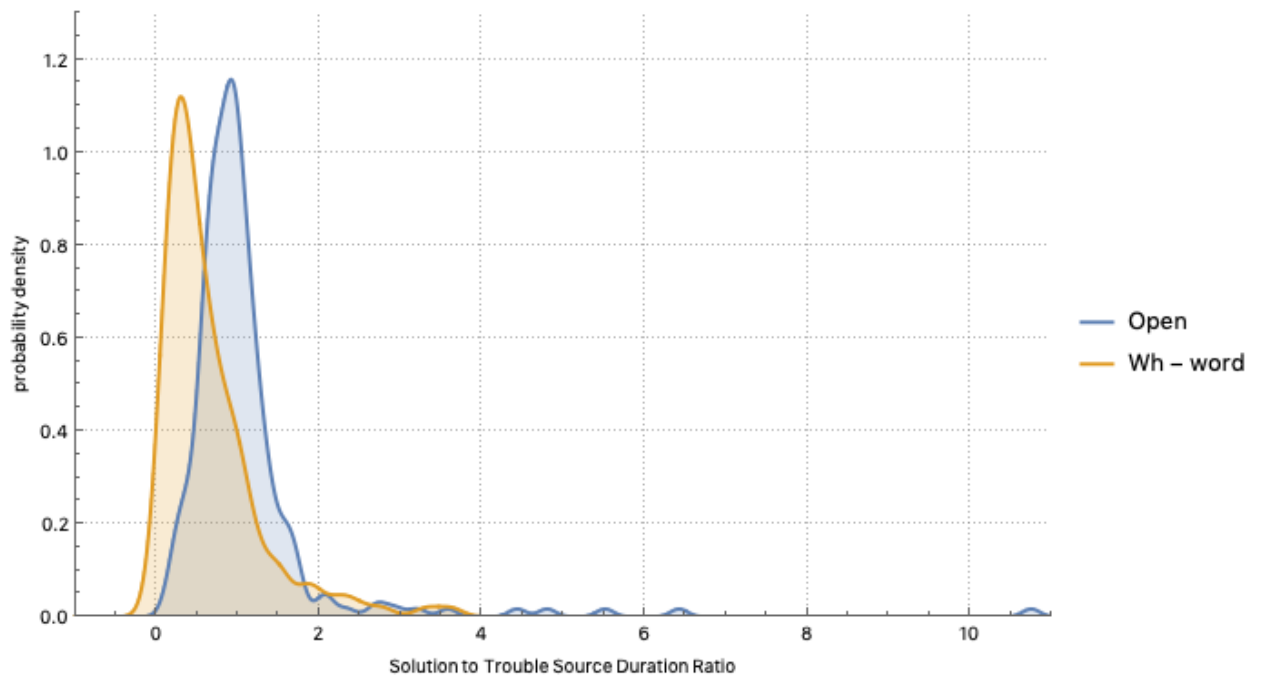


Table 4

Bayesian Kendall Correlation Table 1 for Continuous Predictors

		OIR FTO	Sol FTO	Mean TS Frequency	Problem to End of TS	Words in TS
Solution FTO	tau	0.08	—			
	BF ₁₀	0.86	—			
Mean TS Frequency	tau	< 0.01	-0.03	—		
	BF ₁₀	0.07	0.10	—		
Problem to End of TS	tau	-0.03	0.05	-0.11	—	
	BF ₁₀	0.12	0.17	0.88	—	
Words in TS	tau	-0.05	0.04	0.08	0.80	—
	BF ₁₀	0.20	0.13	1.28	5.89e +9	—
TS Duration	tau	-0.06	0.07	-0.08	0.43	0.68
	BF ₁₀	0.28	0.48	0.82	9.35e +13	3.10e +82
TS Syllable Rate	tau	0.01	0.01	0.14	-0.07	0.09
	BF ₁₀	0.07	0.08	261.91	0.26	2.75
OIR Dur	tau	-0.02	-0.10	-0.02	0.05	0.08
	BF ₁₀	0.08	5.77	0.08	0.17	1.21
Sol Dur: TS Dur	tau	0.11	-0.03	0.06	-0.28	-0.29
	BF ₁₀	6.80	0.09	0.32	10957.75	2.52e +11
TS FTO	tau	0.16	0.11	> -0.01	0.01	0.04
	BF ₁₀	43875.55	10.69	0.07	0.10	0.12
% overlap in TS	tau	-0.13	-0.10	-0.03	0.03	-0.05
	BF ₁₀	490.00	5.81	0.11	0.12	0.17

Table 5

Bayesian Kendall Correlation Table 1 for Continuous Predictors

		TS Duration	TS Syllable Rate	OIR Duration	Sol Duration : TS Duration	TS FTO
TS Syllable	tau	-0.17	—			
Rate	BF ₁₀	18643.22	—			
OIR Dur	tau	0.09	-0.07	—		
	BF ₁₀	4.81	0.39	—		
Sol Dur:	tau	-0.34	0.11	0.03	—	
TS Dur	BF ₁₀	1.95e +19	5.51	0.11	—	
TS FTO	tau	0.01	0.04	-0.02	0.04	—
	BF ₁₀	0.07	0.13	0.08	0.11	—
% overlap	tau	-0.017	> -0.00	0.07	0.01	-0.31
in TS	BF ₁₀	0.071	0.07	0.58	0.07	3.17e +19

Notes: TS = Trouble Source, OIR.= Other-Initiation of Repair, Sol = Solution, FTO = Floor Transfer Offset

Table 6

Mann-Whitney U Diagnostic Analyses

Binary Predictor	Continuous Predictor	BF ₁₀	W	Mdn, 0	Mdn, 1
TS =	TS FTO	1.353e +9	46535	313ms	3,658ms
Disjointed	Overlap %	354	17768	0%	0%
TS =	Solution FTO	1.26	17547	344ms	295ms
Overlapped	TS FTO	318802	33760	1,204ms	42ms
OIR Category	TS Duration	2.20	15642	1.48sec	1.53sec
= 'Open'	OIR Duration	33.46	30339	252ms	281ms
	Mean TS	11.36	17069	6.14	6.28
	Frequency				
TS =	Solution FTO	1.11	17069	341ms	296ms
Question	TS Syllable	101.25	11969	5.39	6.13
	Rate				
	TS FTO	2.01	16977	701ms	1,207ms

Note: TS = Trouble Source, FTO = Floor Transfer Offset, Sol = Solution, OIR =

Other-Initiation of Repair

Table 7

Component Loadings for All Predictors

	PC 1	PC 2	PC 3	PC 4	PC 5	Uniqueness
% of TS overlapped	-0.45	0.62	.	.	.	0.12
Average TS Frequency	.	.	0.48	-0.44	.	0.56
OIR Category Binary	.	.	.	0.45	.	0.43
OIR Duration	.	.	.	.	-0.60	0.45
Question (Binary)	.	.	0.57	.	.	0.56
Sol Duration : TS Duration	-0.50	.	.	.	.	0.60
Solution FTO	.	.	.	.	0.58	0.50
TS = Disjointed (Binary)	.	-0.52	.	.	.	0.32
TS = Overlapped (Binary)	-0.43	0.73	.	.	.	0.11
TS Duration	0.82	0.42	.	.	.	0.14
TS FTO	.	-0.42	.	0.53	.	0.25
TS Syllable Rate	.	.	0.55	-0.44	.	0.40
Words in TS	0.77	.	.	.	.	0.15

Notes: No rotation method applied.

FTO = Floor Transfer Offset, OIR = Other-Initiation of Repair, TS = Trouble

Source, Sol = Repair Solution

Figure 12

Path Diagram for Principle Components Analysis with All Predictors

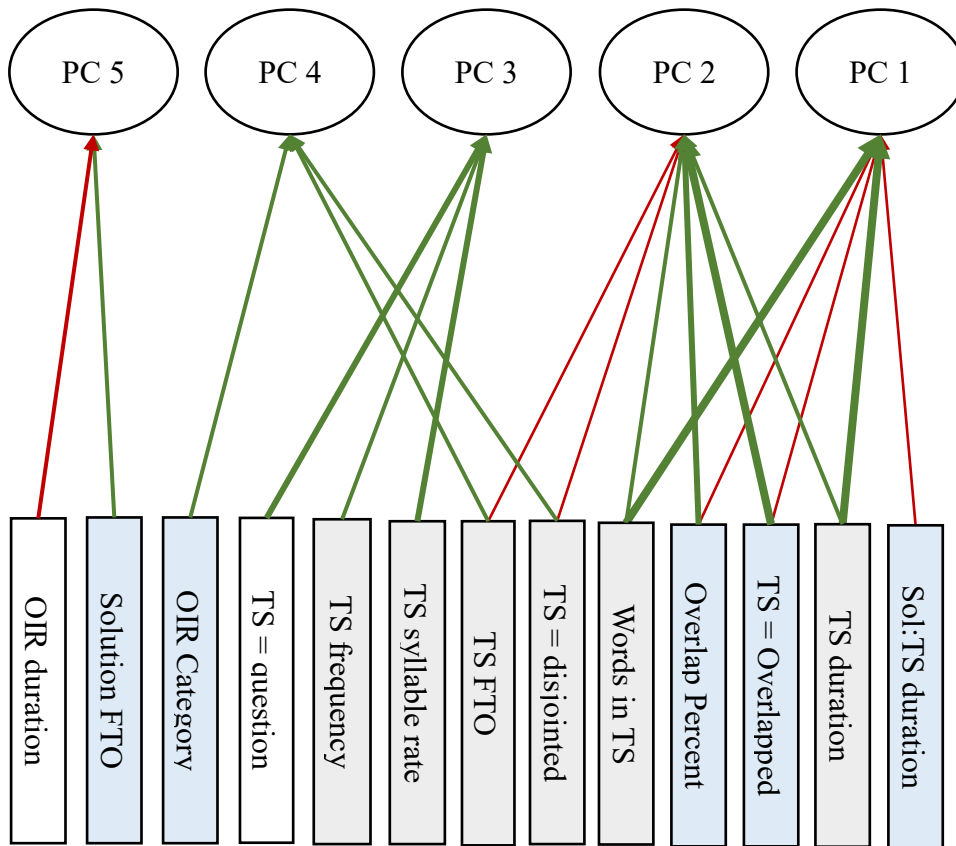


Table 8

Principal Components Regression on OIR FTO

Coefficient	Mean	SD	P(incl)	P(incl data)	BF _{inclusion}	95% Credible Interval	
						Lower	Upper
Intercept	0.101	0.009	1.000	1.000	1.000	0.084	0.118
PC_1	-0.003	0.002	0.500	0.658	1.923	-0.006	-4.692e -5
PC_2	-0.004	0.001	0.500	0.866	6.477	-0.006	-0.001
PC_4	0.006	0.002	0.500	0.955	21.417	0.002	0.010

Table 9

Component Loadings for Trouble Source Predictors

Component Loadings					
	PC 1	PC 2	PC 3	PC 4	Uniqueness
% of TS overlapped	-0.67	.	.	0.47	0.11
Average TS Frequency	.	.	0.61	.	0.54
Question (Binary)	.	.	0.62	.	0.59
TS = Disjointed (Binary)	0.54	.	.	0.57	0.25
TS = Overlapped (Binary)	-0.73	0.47	.	.	0.11
TS Duration	0.54	0.80	.	.	0.05
TS FTO	0.40	.	.	0.72	0.24
TS Syllable Rate	.	.	0.71	.	0.40
Words in TS	0.53	0.76	.	.	0.08

Note. No rotation method applied. TS = Trouble Source, FTO = Floor Transfer Offset, OIR = Other-Initiation of repair.

Table 10

Principal Components Regression on OIR Category

Coefficient	Mean	SD	P(incl)	P(incl data)	BF _{inclusion}	95% Credible Interval	
						Lower	Upper
Intercept	0.557	0.025	1.000	1.000	1.000	0.507	0.606
RC_1	-0.012	0.005	0.500	0.828	4.806	-0.023	-0.002
RC_2	0.002	0.001	0.500	0.849	5.601	4.225e -4	0.004
RC_3	0.012	0.004	0.500	0.953	20.466	0.005	0.020

Figure 13

Probability Density of OIR FTO, For Terminally-Located Problems

