How intonation constrains pragmatic inference

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Abstract

In this paper, we present two experiments that investigate how intonation can constrain pragmatic inference. While prior research has shown that intonation can increase the likelihood of an inference being made, less is known about how it affects the mechanisms involved in processing of inferences. In the first experiment, listeners had more direct mouse paths towards target responses for stronger interpretations after hearing utterances with referents with pitch accents than without. In the second experiment, we replicate the finding of the first study and found more direct mouse paths towards weaker interpretations after hearing de-accented referents Our findings suggest that intonation constrains the online processing of pragmatic inference by increasing the availability of stronger interpretations.

Keywords: Experimental Pragmatics, Psycholinguistics, Prosody, Language Comprehension, Mouse-tracking.

Introduction

The rapid nature of human communication requires speakers and listeners to be as efficient as possible. To help achieve this, listeners often rely on context to help disambiguate between different linguistic structures and meanings. However, often what a speaker intends to say is not always directly retrievable from a linguistic form; rather listeners must *infer* it. One issue concerning pragmatic inference is whether the processor can keep up with the task demands of conversation. Some have argued that linguistic inference must be quick and "cheap" (Levinson, 2000; Piantidosi, Tily, & Gibson, 2012), however others have experimentally demonstrated that some linguistic inferences can be quite costly in terms of processing (Bott & Noveck, 2004; Huang & Snedeker, 2009). In this paper, we discuss one aspect of the linguistic signal that has the potential to make certain costly pragmatic inferences quicker and more efficient: *prosody*. We report the findings from two experiments that test different accounts about how prosody affects the processing of pragmatic inferences.

Pragmatic inferences and language processing

Traditionally, linguists have treated pragmatic inferences as the interpretative process in which a speaker must reconcile how speaker's literal sentence meaning differs from his or her intended meaning. Grice (1967) initially distinguished between two types of pragmatic inferences (particularized implicatures): *conventional implicatures* and *conversational implicatures*. Conventional implicatures roughly amount to inferences about a speaker's intended meaning that can be made without accessing the conversational context. Conversational implicatures, however, require that listeners must first consider the literal sentence meaning, compare it against the context and then potentially enrich it in order to arrive at a speaker's intended meaning. Neo-Griceans have proposed an inference type that falls somewhere between Grice's original distinction: *default inferences* (Levinson, 2000). Default inferences are inferences that are computed on every occasion, but can be cancelled later. Always deriving the inference avoids costly pragmatic computations that would delay obtaining the speaker's intended meaning. According to this process, inferences are heuristic-based and therefore can become "cheap" in regards to processing resources.

Researchers in experimental pragmatics have tested whether certain implicatures classes are indeed understood as default inferences. One case that has caused some debate is the case of *scalar implicatures*. For these inferences, listeners can choose between either a weak or a strong interpretation depending on what they think the speaker intended to communicate. For example, a sentence such as "I drank some of my friend's beers last night" could either be taken to mean that I drank (1) *at least one* (and possibly all) of the beers or (2) *at least one and not all* of the beers. The difference between interpretations (1) and (2) is that to interpret "not all" in (2), the listener must infer that had the speaker meant "all," they would have said so. In other words, the listener would need to make a pragmatic inference to access the stronger interpretation. Several experimental studies have shown that understanding upper bound meanings of *some*, as in (2), takes substantially longer than the meaning in (1) (Bott & Noveck, 2004; Huang & Snedeker, 2009). As such, a default implicature account of scalar implicatures is not borne out by the majority of these findings because of the processing cost for (2). However it might be the case that this processing cost can be diminished in the right context (Grodner, Klein, Canbary, & Tannenhaus, 2010; Degen & Tannenhaus, 2011), i.e. making (2) more available or active earlier on in processing. Our studies seek to examine how processing costs can be diminished and what this means for processing accounts of pragmatic inferences. Specifically, we examine

how one prominent cue, *intonation*, affects the availability and integration of various sources of information during the processing of conversational implicatures.

Intonation and Pragmatic Inferences

Many studies have shown that intonation interacts with pragmatic processes in general, specifically those having to do with the integration of prior context to help disambiguate anaphoric reference, e.g. reference resolution, via information structure. For example, Dahan, Chambers, & Tannenhaus (2002) found that pitch accents (H*) can rapidly disambiguate referents by integrating prior discourse mention of a referent. What is less clear is whether intonation affects pragmatic processes above that of explicatures, e.g. reference resolution, namely at the level of implicatures. For example, scalar implicatures are generally thought to be defeased in the antecedent of a conditional (*if some of the…*) and under negation (see e.g., Chierchia, 2004, for a review). Scalar implicatures therefore require the integration of semantics and pragmatics in a way that other pragmatic phenomena do not (see Horn, 2006). How and at what level of interpretation intonational information is intergrated into the processing of scalar implicatures is therefore an open question.

From a processing perspective, intonation could affect implicatures in at least two ways. First, it may alter how likely people are to derive an implicature. Secondly, it may also affect the speed with which people derive them. The difference is important because it allows us to understand in more detail how intonation interacts with other processing mechanisms. In particular, intonation might act merely as a cue to derive the implicature, or it may alter the process more fundamentally. In the next section we discuss previous findings related to prosody and pragmatic inferences, before specifying our hypotheses in more detail.

The one study that has specifically investigated prosody and scalar implicatures was Chevallier et al. (2008), who tested the effects of contrastive stress on the disjunction, *or*. Disjunctions can be optionally enriched from an inclusive reading, *one or the other and possibly both*, to an exclusive reading, *one or the other but not both*. Chevallier et al. tested whether contrastive stress on "or" affected the enrichment. For example, whether sentences like, "You can have the meat course or the fish course," was interpreted differently to, "You can have the meat course OR the fish course." While they found the stress on "or" greatly increased the proportion of exclusive readings, response times for the exclusive readings were identical regardless of whether contrastive stress was used or not. This study then, found that while intonation altered how the sentence was understood, it did not alter the time-course for the inference.

While our study is primarily concerned with conversational implicatures, other studies on intonation and different sorts of pragmatic inferences are clearly relevant. These studies have produced mixed results as to the effects of intonation on the speed of inference derivation, however, and it is often difficult to see whether intonation is affecting

speed of derivation or probability of derivation. For example, Dennison (2010) found that contrastive pitch accents in conjunction with final rises increased the likelihood that upon hearing "the pencil WAS sharp", listeners were more likely to infer that pencil is now not sharp, i.e. dull. This did not, however, affect the time course of processing relative to explicit negation: listeners spent as much time looking at pictures of the affirmative state (a sharp pencil) before fixating on the intended meaning (a dull pencil) as with explicit negation. Similarly, Sedivy et al. (1999) found no difference in looks to a referent disambiguated by a non-stressed adjective, "Click in the tall glass," vs. "Click on the TALL glass". In contrast, Ito & Speer (2008) found that contrastive pitch accents (L+H*) rapidly constrain the reference resolution of an upcoming noun. When listeners heard a prior mention of a referent (green ball), listeners were more likely to make anticipatory eye-movements upon hearing a contrastive pitch accent on BLUE to an object (ball) that had a contrasting item in the set (a blue ball vs. a red ball vs. a blue star).

The literature reviewed above suggests that intonation affects how likely implicatures are to be generated, but it is unclear whether it speeds up the process of making the inference. In our experiments we test the former hypothesis, namely whether a particular intonational pattern, *focus intonation*, speeds up the process of making conversational implicatures. One possibility is that because enrichment is optional, focus intonation could make it more likely that the procedures used to derive an implicature would be triggered (e.g., exhaustivity operator, (van Rooj and Schulz, 2004); or an *only* operator, (Chierchia, 2004); or reasoning about Gricean maxims, (Grice, 1975). If this is the only effect of the focus however, processing speed will not be altered and could even be delayed, e.g. more alternatives could be generated and considered. Focus would be one more cue to derive the implicature, but would not alter any of the procedures needed to perform the implicature computations. This account is consistent with the findings from Chevalier et al. (2008) and Dennison (2010). The other possibility is that focus intonation changes how the implicature is computed, which could happen several ways. For example, focus intonation might act like an explicit *only* in the sentence. This would remove the need to consider whether the speaker was informed and reliable (Sauerland, 2004). Removing this stage would speed up processing (Bott et al., 2012, demonstrate that scalar implicatures are computed more slowly than similar sentences with an explicit *only*). A final possibility is that focus might also encourage people to start deriving the implicature earlier on in the sentence; either because the pitch accent strengthens the assertive content of the proposition, e.g. the speaker is not leaving the topic open, or because the listener recognizes that a speaker is in a position to place a pitch accent on the referent.

Overview of experiments

In this paper, we present two experiments investigating how prosody affects the processing of conversational

implicatures. At issue is whether prosody, in this case intonation, speeds up the process of making implicatures.

We used a picture-speech matching paradigm. Participants were presented with a visual display showing diverse objects. For example, a candle in one part of the screen and a dog in the other. They then heard a sentence assigning Mark ownership of one set of objects, and clicked on the image that best captured the object owned by Mark. For example, they might hear, "Mark has a candle" and then had to click on the candle image. In the critical trials, participants heard a sentence involving one object, "Mark has a candle (A)," but were presented with one image containing a candle (A), and one image containing a candle and a candy (AB). Now, in these trials, both options were logically permissible – there is a candle in both images; it is only by generating an implicature that the participant can chose the candle-only option ("the speaker must mean that Mark only has a A, and not AB, because otherwise they would have said so"). Thus, if the participant selected the candle-only option, they must have derived the implicature. We refer to the candle-only option(A) as the *strong* interpretation because it is informationally stronger than the candle and candy option (AB) (the weak interpretation).

Most importantly, we manipulated intonational focus on the referent. Participants heard either "Mark has a candle," or "Mark has a CANDLE." If focus intonation facilitates the derivation of the inference, the mouse-paths towards the stronger interpretation targets (CANDLE) should be more direct for stressed vs. unstressed referents when the two-object picture is the competitor target.

Experiment 1

In Experiment 1, the visual display involved two targets, one on the left and one on the right. Participants heard one of four types of experimental conditions, as shown in Table 1. Conditions 1 and 2 were the critical conditions described above, and conditions 3 and 4 were control conditions designed to eliminate low-level, perceptual explanations of any effects we might observe. If intonation speeds up the pragmatic process of deriving the implicature, we would expect a larger effect of intonation in conditions 1 and 2 than in conditions 3 and 4.

Method

Twenty six undergraduate students in the School of Psychology at Cardiff University participated in this experiment for either course credit or a 3 pound Sterling reimbursement. The experiment took roughly 15 minutes to complete. All participants were debriefed upon completion.
Stimuli The same auditory stimuli were used for both experiments (except for the addition of prepositional phrases in Experiment 2). An utterance had the stem "Mark has a" and either had one referent (A)or two referents (AB) (see Table 1). Roughly half of the stimuli (24 items) were adapted from Dahan, Tannenhaus, & Chambers (2002) and the other half (26 items) were created in order to increase the number of items. Of these items, half of the sentence and

picture combinations were phonological competitors, e.g. candle vs. camel and the other half were semantic competitors, e.g. pencil vs. eraser. This was done to help disguise the purpose of the experiment. For each item combination, black and white clip art pictures of each referent were constructed. Each item had either a picture of just one of the objects (candle) or both (candle and a camel). Objects were sized equally so that the picture of the object was the same size as when the object was in the two-object picture. This was done to control the salience of a one-object picture versus a two-object picture. The utterance-picture combinations are also shown in Table 1.

A male speaker of British English with no noticeable regional variety was used to record the sentences. Sentences were recorded in a sound attenuated booth using a uni-directional microphone and digitized with USB sound capture device. All utterances were first recorded in sentence form and then the individual referents were recorded in isolation in both stressed and unstressed forms. A trained phonetician inspected these recordings and made sure that utterances with focus intonation had H*L-L% patterns and non-focus intonation utterances had L*L-L% patterns. Acoustic measurements were conducted so that this and mean F0 were the only significant different between the two versions. Next, objects in isolation were spliced into the sentence frames. In the two referent utterances, the pause between "and" and the second referent "a camel" was reduced to 100ms so that listeners could not reliably use the stress to detect speaker continuation.

Table 1: Utterance-picture combinations Exp. 1

Utterance (Pitch accent)	Picture(s)
Target conditions	
(1) Mark has an A (L*)	A vs. AB
(2) Mark has an A (H*)	A vs. AB
(3) Mark has an A (L*)	A vs. B
(4) Mark has an A (H*)	A vs. B
Filler conditions	
(5)Mark has an A (L*) and a B (L*)	AB vs. A
(6)Mark has an A (H*) and a B (H*)	AB vs. A
(7) Mark has an A (H*) and a B (L*)	C|B vs. A|B
(8) Mark has an A (L*) and a B (H*)	A|C vs. A|B

Design & Procedure In both experiments, participants were were presented with an audio file and clicked on the picture that corresponded to the mentioned referent in the sentence. In the instructions, they were told that they were overhearing a speaker describing to another person which objects Mark has. Response boxes were equally sized and placed at the top left and right and corners of the screen. To begin each trial, participants clicked on START at the bottom center of the screen and then saw the response options for 2000ms before the audio file was played. Participants could move their mouse and make their response at the onset of the word "has".

Participants were exposed to all conditions. Four experimental lists were generated so that a given participant had only one of the four target conditions for a given item. Filler conditions were added that had both related one-object pictures as well as non-related one-object pictures. Filler conditions were kept the same across all lists. As mentioned in the stimuli section, all versions of filler picture conditions had utterances with both H*L-L% and L*L-L% accent patterns on initial referents so that listeners would be as likely to hear focus intonation in both one and two-referent utterance.

The experiment was run with *Runner* program in the Mousetracker suite (Freeman & Ambady, 2010). The *Analyser* program exported responses into 101 normalized time steps. The dependent measure used was the *Area under the Curve* (AUC), which amounts to the total geometrical area for a mouse trajectory relative to a straight line from the start button to correct target.

Results

The average mouse-paths for the target conditions are shown in Figure 1. Figure 1 shows the raw x- and y-coordinates for the mouse-paths for the various conditions, showing that utterances with unstressed referents in the two-object competitor condition have delayed mouse-paths towards the response target. Utterances with stressed referents in the two-object competitor condition do not look to be substantially delayed relative to the control conditions.

A mixed model with two predictor variables (focus intonation and competitor type) was used to test the directness of participants mouse paths (AUCs) towards the correct response. Intonation (H* vs. L* pitch accents) and competitor type (weaker interpretation or phonological/semantic cohort) were used as fixed effects (along with an interaction term) and used subjects and items as random effects. In all conditions, accuracy rates were over 97%. Participants had more direct mouse paths to control condition (Conditions 3 & 4) than when the weaker alternative was used as a competitor (Conditions 1 & 2), $t = 3.94$, $p < .01$. Across competitor type, focus intonation yielded more direct responses toward the correct target, $t = 3.31$, $p < .03$. Critically, the interaction between focus and competitor type was significant, $t = 2.91$, $p < .05$, suggesting that the main effects were driven by the relative difference of focus intonation between Conditions 1 and 2.
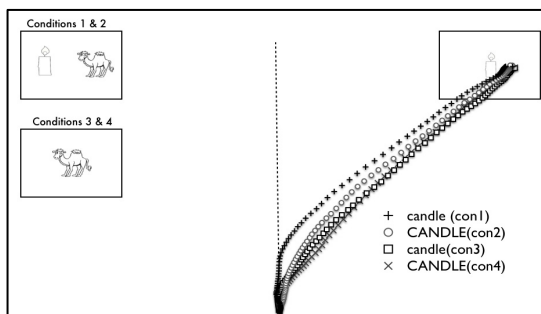

Figure 1: Raw x- on y-coordinates for Experiment 1.

Discussion

In the presence of having a picture of the weaker interpretation as a competing target, listeners had more direct responses to the target picture of the stronger interpretation for utterances with a stressed referent than an unstressed referent. This suggests that the pitch accent made the weaker interpretation less accessible. Mouse-paths in Condition 2 were more direct towards the target and quite close to the control conditions. This means that focus seems to have substantially reduced the interference of the weaker interpretation competitor found in Condition 1 almost to the extent that is wasn't present (as in Conditions 3 and 4). These findings suggest that the implicatures have been processed more quickly in the focus condition.

An alternative explanation of our findings is that listeners could be interpreting the focus intonation as a discourse signal that the speaker has finished speaking. This would explain why participants mouse movements were more direct to the signal referent because listeners would be less likely to expect more upcoming speech from the listener. In our second experiment, we seek to eliminate this explanation of our findings.

Experiment 2

Gricean maxims explain not only how speakers imply meanings beyond literal sentence meaning, but also provide allow listeners to infer whether a speaker has finished his/her turn. Moreover, research on intonation has shown that listeners interpret falling intonation at the end of the phrase to indicate that a speaker has finished his or her turn (Deruiter, Mitterer, & Enfeld, 2006). In contrast, phrase final rising intonation can indicate both speaker continuation or uncertainty and this along with durational information can alter listeners' attention to upcoming speech (Tomlinson & Fox Tree, 2011). Regarding our items in Experiment 1, it is possible that the falling intonation on the referent in phrase final position might have yielded more direct mouse paths to the correct target because listeners inferred that the speaker had finished speaking. To control for this possibility, prepositional phrases were added to each phrase, e.g. "Mark has a candle on the table". Because of this, two more competitor pictures were added to the display, increasing the possible targets from two to four.

Stimuli The same experimental items from Experiment 1 were used. However, a prepositional phrase was added (either "on the table" or "on the shelf") to the existing auditory files. Because of this, two more picture targets were added to each trial. In Conditions 1 & 2, participants were now forced to choose between a picture of a candle and a camel on the table, a candle on the table, along with two distractor pictures (a picture of an apple and a pear on the shelf as well as a picture of an apple on the shelf). Conditions 3&4 made use of table/shelf distinction by having participants choose between the single referent on either the table or the shelf along with the distractor pictures. Last, a third experimental condition testing the availability of weaker interpretations in our paradigm. In

this condition, items such as "Mark has a candle on the shelf" would be heard in the context of a picture of only a candle on a table and a picture of both a candle and a camel on a shelf along with the distractor pictures. In this case, participants would need to click on the picture of the weaker interpretation, as the prepositional phrase on the single referent would make the stronger interpretation incompatible with item.

Results & Discussion

The average mouse-paths for the target in conditions 1-2, 3-4, & 5-6 are shown in Figures 2-4. Conditions 1 & 2 show the same pattern as in Experiment 1, in that the focus intonation helped listeners choose the single referent target in the presence of a two-referent target. However focus did not have a yield a more direct mouse path to the target in the control condition.
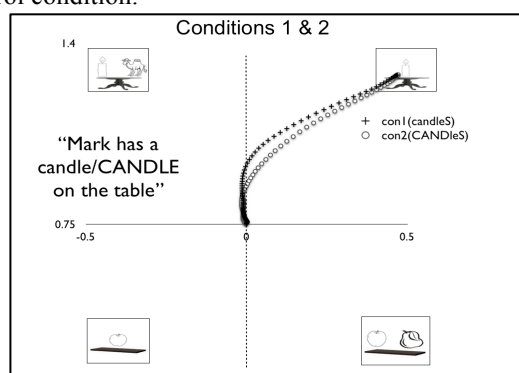

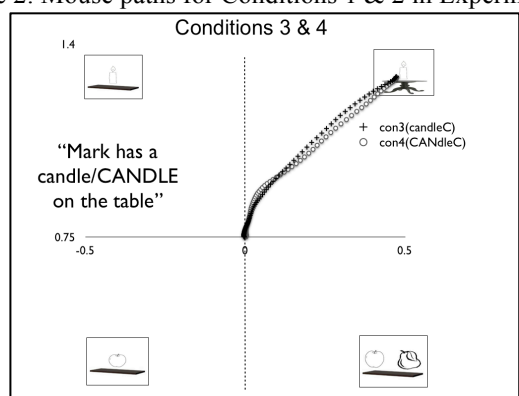Figure 2: Mouse paths for Conditions 1 & 2 in Experiment 2.

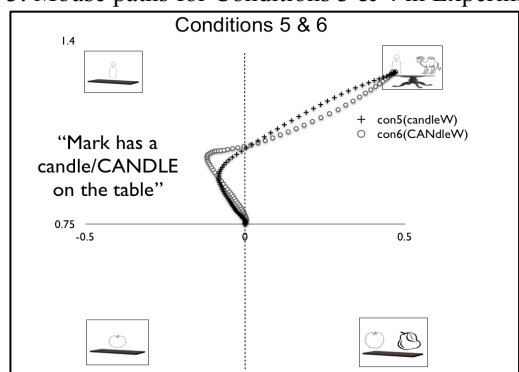Figure 3: Mouse paths for Conditions 3 & 4 in Experiment 2.

Figure 4: Mouse paths for Conditions 5 & 6 in Experiment 2.

A mixed-effect model was used to test AUC values with focus intonation (H* L-L% vs. L* L-L% patterns) and implicature type (stronger interpretation, control, weaker interpretation) as fixed effects (along with an interaction term) and with subjects and items as random effects. Accuracy rates were over 97% for Conditions 1-4. However accuracy was only 90% for Conditions 5-6. Overall, participants' responses to correct targets for control items (Conditions 3&4) were more direct than both stronger interpretations (conditions 1 &2), $t = 4.07$, $p < .03$, and weaker interpretations (conditions 5 & 6), $t = 7.44$, $p < .01$. Across all conditions, focus intonation was not a significant predictor of AUCs, $t = 1.29$, $= .31$. Critically, focus intonation yielded more direct mouse paths towards the correct target for stronger interpretations than for control conditions, $t = 2.79$, $p = 04$. The opposite pattern was found for weaker interpretations: focus intonation yielded less direct mouse paths to correct targets compared to the control condition, $t = 2.03$, $p < .05$.

In sum, Experiment 2 replicated our findings from Experiment 1: focus intonation helps listeners exclude competition from weaker alternatives when selecting strong interpretations of an utterance. The added prepositional phrase and visual context suggests that the focus intonation is integrated incrementally. This also suggests that the finding from Experiment 1 did not result from listeners exclusively interpreting the focus intonation as a signal that the speaker has finished his or her turn. In addition, focus intonation made it more difficult for participants to choose weaker interpretations upon hearing an item with a single referent. This further suggests that the focus intonation is helping reinforce the "only" operator in such utterances.

Conclusion

In two experiments, we sought to better understand how prosody, pitch accents, affects the interpretive processes of pragmatic inference. In our first experiment, focus intonation reduced the processing cost of understanding a stronger interpretation (Mark has *only* a candle) in the presence of a weak interpretation competitor. The second experiment replicated the findings from Experiment 1 in that focus intonation helped listeners exclude weaker interpretations when clicking on the correct target. Also, focus intonation introduced more competition for single referent pictures when choosing weaker interpretations.

We now discuss our findings as they relate to how and when prosody is integrated incrementally into utterance meanings. At first glance, our findings might suggest that focus intonation acted as an explicit *only*. This effect could arise by the focus intonation being initially decoded into at a phonological level and then fed forward into a focus operator into pragmatics via information theoretic relationships (Pierrehumbert & Hirschberg, 1990; Büring 2007). Semantic accounts of focus might also explain our results (Krifka, 1999; van Rooij & Schulz, 2004; Rooth, 1993). Such accounts hold that focus marking is integrated into utterance interpretations by triggering a search for

lexically available alternatives. As a result of the information structure, the constituent can take on additional meanings due to its elevated status relative to alternatives.

However, our findings only partly support this idea of intonation working at the level of information structure by ruling out contextually available alternatives. Because both stronger and weaker alternatives were visually available, listeners could not use the intonation to create or search out alternatives based on linguistic information. This suggests that listeners were integrating non-linguistic information into these interpretations e.g., visual information and/or speaker specific information, and that focus intonation sped up this integration. In other words, a more plausible explanation might be that focus intonation allowed listeners to start deriving the inference earlier on in the sentence.

Future work is needed to better tease apart these possibilities. One way forward would be to dovetail on a recent investigation by Breheny, Ferguson, & Katsos (2013), which examined the rapid integration of speakers' perspectives when processing ad hoc, conversational implicatures. In their study, listeners' eye movements were sensitive to speaker information when generating the "nothing else" implication, suggesting that information structure is necessary, but not sufficient for rapidly inferring "nothing else" implications: initial early biases toward the "nothing else" interpretation disappeared when listeners believed that the speaker's viewpoint of the objects was obscured. Although their confederate speakers in the look and listen experiment did not reliably use pitch accents when communicating the "nothing else" implication, an open question is whether focus intonation on the referents in their study would have reduced the delay in the speaker ignorance condition. We are conducting ongoing research to test this possibility, which can better adjudicate at what level intonation affects pragmatic inference.

Acknowledgments

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