Emotional Priming of Sentence Comprehension: Effects of a Speaker's Static Emotional Expression and Listener Age

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Abstract

We report two visual-world eye-tracking experiments that investigated how and with which time course emotional information from a speaker's face affects younger (N = 32, Mean age = 23) and older (N = 32, Mean age = 64) listeners' visual attention and language comprehension as they processed emotional sentences in a visual context. The age manipulation was aimed at testing predictions by socio-emotional selectivity theory of a positivity effect in older adults. After viewing the emotional face of a speaker (happy or sad) on a computer display, participants were presented simultaneously with two pictures depicting opposite-valence events (positive and negative; IAPS database) while they listened to a sentence referring to one of the events. Participants' eye fixations on the pictures while processing the sentence were enhanced when the speaker's face was emotionally congruent with the sentence/picture compared to when it was not. The enhancement occurred from the early stages of sentence-reference disambiguation; importantly, it was modulated by age, in that for the older adults it was more pronounced with positive faces, and for the younger ones with negative faces. These findings demonstrate for the first time that emotional facial expressions, similarly to previously studied speaker cues such as eye gaze and gestures, are rapidly integrated into sentence processing. They also provide new evidence for positivity effects in older adults in online incremental situated sentence processing.

Keywords: sentence processing; visual-world paradigm; emotional processing; speaker cues; positivity effect; facial expressions

Visual Context Effects on Language Processing

The study of context effects on language processing has been a major topic of investigation in psycholinguistic research, and since the development of the visual world paradigm in the mid-nineties, psycholinguists have had at their disposal a powerful tool to investigate a potentially rich source of context effects on language processing, that of the visual context**.** Among other things, findings from this research have demonstrated how information such as an object's size, color, or shape, depicted clipart events, real-world action events, action affordances, and the spatial location of objects are all rapidly integrated during sentence comprehension and can affect a listener's visual attention while processing sentences (for a recent review, see Huettig, Rommers, & Meyer, 2011**)**.

In recent years the scope of research on the language-vision interaction has been extended to more complex and subtle aspects of naturalistic, visually-situated language events, such as dialogue interactions. One topic has been how visually-perceivable speaker-based cues, for example, speaker gaze and gestures, affect language processing. Results suggest that a speaker's gaze is incrementally integrated into language processing by listeners (e.g., Hanna & Brennan, 2007).

Another potentially powerful cue that could be used by a listener is a speaker's emotional facial expression. The question of how such a cue is used in language processing is particularly relevant to current psychological research, especially in light of the recent surge in interest in embodied and situated cognition, and the increasingly available evidence supporting a close interaction between emotions and language (e.g., Havas, Glenberg, & Rinck, 2007). However, to the best of our knowledge there is todate no study that has examined effects of a speaker's facial expression on spoken sentence comprehension. Additionally, evidence for visual context effects in sentence processing comes almost exclusively from studies with young adults (ca. 19-31 years). By contrast, the extent to which visual context affects sentence comprehension in older adults is less clear. The present research addresses these two open issues in two eye-tracking experiments that examined (a) the time course with which a speaker's emotional facial expressions can influence a comprehender's visual attention to target pictures during spoken sentence comprehension; and (b) the nature of this influence in young versus older adults.

Emotion Processing and Emotional Priming

Ekman's (1972) proposal of a set of six basic universal emotions associated with distinct facial emotional expression configurations (happiness, sadness, fear, anger, disgust, and surprise) has been widely tested over the years and assumed by many scholars in the field of emotion research (e.g., Lundqvist, Flykt, & Öhman, 1998). Within this view, the basic facial expressions are associated with a

distinctive meaning, so they could, in principle, be used by a speaker to strengthen the meaning of her utterances. There is evidence that emotional faces such as happy or angry ones, are attended to faster and are processed more deeply than neutral ones (Palermo & Rhodes, 2007). Generally, the same attention advantage enjoyed by emotional *faces* (compared to nonemotional, neutral ones) is found for emotional stimuli in different modalities, for example, emotional words, pictures and sounds (e.g., Hermans, De Houwer, & Eelen, 2001).

Not only do emotional stimuli attract more attention and are remembered better than corresponding neutral ones, they can also influence how other stimuli (e.g., words, pictures) are processed. This influence has been demonstrated in emotional priming studies (Fazio, 2001), where responses to a target stimulus are facilitated (i.e., faster) when prime and target have the same emotional valence (e.g., positive-positive, negative-negative), compared to when they have opposite valence. Interestingly, priming occurs not only when prime and target belong to same modality and category (e.g., when they are both faces, pictures or words) but also across modalities. e.g., from a picture to a face (Carroll & Young, 2005, Expt 2), or from a picture or facial expression to a word (Carroll & Young 2005, Expt 1 and 4).

Emotional Priming of Sentences: Current Study

With regard to the issue of whether a speaker's emotional facial expression can influence not just lexical but also sentence processing, the just-mentioned findings on emotional priming from faces to words suggest that it should: Just as the perception of a happy face (the prime) produces a faster response to a positive (vs. negative) target word, so a smile on a speaker's face might facilitate a listener's processing of a positive (vs. negative) sentence. To our knowledge, no research has so far investigated the emotional priming of *whole* sentences (as opposed to *isolated* words) using emotional facial expressions. In the current study, we used the visual world paradigm to examine the time course of emotional priming in sentence processing. We employed a design typical of many visual-world experiments on sentence comprehension: Participants listened to sentences relating to visual material displayed on a computer screen (see Fig.1, for the sequence of events in an experimental trial). Before hearing the sentences, our participants saw either a smiling or a sad face (see Fig. 1, Display 1). They were told that this was the face of the speaker of the ensuing sentence (thus simulating a speaker-hearer scenario). Then two emotional pictures from the International Affective Picture System database (IAPS, Lang, Bradley, & Cuthbert, 1999), one positive and one negative, were displayed side by side on the screen. After 1500 ms the sentence was played and referenced either one or the other picture; accordingly, the sentence also had a positive or negative emotional content (see Fig. 1, Display 2). Thus, the speaker's facial expression could be emotionally congruent or incongruent with the sentence. Participants' eye movements to the display on the monitor while they listened to the sentence were recorded. In line with the usual findings from the visual world paradigm, when participants begin processing the sentence, we expect them to look at the target (the IAPS picture described in the sentence) from the time it becomes clear which picture the sentence is about (i.e., a sentence effect).

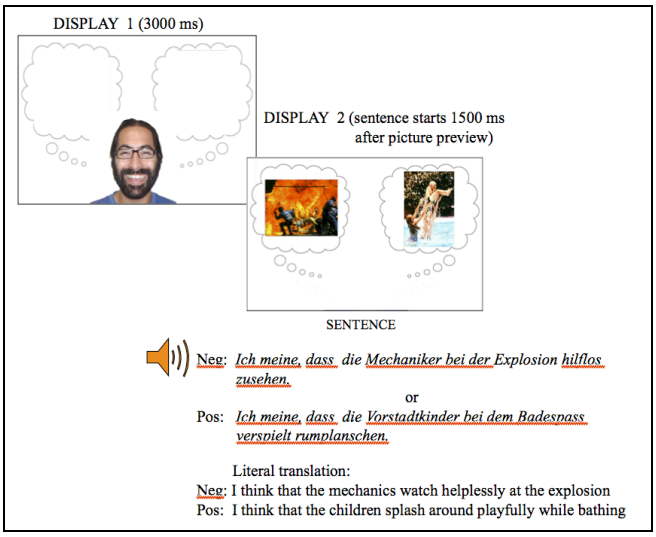

Figure 1: Sequence of events in an experimental trial

However, for us the more interesting question is whether and how the facial prime affects (i.e., primes) the processing of the sentence, in other words, the face x sentence interaction. In line with findings from emotional priming research, we expect facilitation when the prime (i.e., the face) is emotionally congruent with the target (i.e., the sentence/picture) compared to when prime and target are incongruent. In our experiment the dependent variable is fixations on the pictures while incrementally processing the sentence; so we expect that looks to the target picture should be facilitated when the emotional face is valence-congruent (vs. incongruent) with the sentence. This facilitation should be reflected in more and longer fixations to the target picture in congruent than in incongruent conditions (cf. Arai, Van Gompel, & Scheepers, 2007).

Furthermore, the timing of this facilitation is of particular interest to us, as it would reveal details about the time course of integrating emotion information into language processing. Earlier findings (see above) suggest that emotional information enjoys privileged attention, so this would predict that facilitation effects should occur from the early stages of processing the sentence. Alternatively, considering the specifics of our experimental task, facilitatory effects may not surface until later or not occur at all *during* the processing of the sentence. This is because for facilitation to take place perceivers need to integrate cues from the visual, linguistic and emotional modalities and this may be a complex task to perform on the fly. In addition to facilitating the processing of the sentence itself (face x sentence interaction), the face may affect the fixations that listeners make on the pictures *independently* of the sentence

valence. This would be reflected in a preference to look at the picture which is emotionally congruent with the face, i.e., a face-picture congruence effect. To be triggered, this face-picture congruence effect does not require linguistic input from the sentence (but only information from the face and the pictures), so it could occur earlier, before sentence disambiguation, as well as later, after disambiguation. Note that a face x sentence interaction, which is the effect of primary interest to us, *cannot* be reduced to a face-picture congruence effect, as it requires the additional input from the sentence to occur.

Emotion Processing in Younger and Older Adults

The age group manipulation in our study was inspired by research showing that emotion processing changes across the life span (for a review, see Ruffman et al., 2008). According to socio-emotional selectivity theory (Mather & Carstensen, 2003), as people grow older, they realize that their time is limited and focus more on emotionally-satisfying experiences in the present moment. This change arguably leads to the so-called 'positivity effect', observed in studies where young and older adults were compared on emotional processing. For example, when presented with pairs of pictures (a neutral face, and a positive or negative face), older people spent less time inspecting the negative than positive face; i.e., they displayed an attentional bias away from the negative and towards the happy expression. Younger people, by contrast, showed no preference (Mather & Carstensen, 2003), or preferred negative faces (Isaacowitz et al., 2006). Positivity effects have also been found in the recall of pictures and facial expressions (e.g., Mather & Carstensen, 2003), or of long-term life events (Kennedy, Mather, & Carstensen, 2004). In recent years, researchers have discussed the proper characterization of the positivity effect and the experimental conditions under which it can be observed. This has led to a broadening of the definition of the effect, which now includes, not only an increased focus on positive compared to negative information in older versus younger adults, but also a reduced focus on negative information in older adults (see especially Langeslad & van Strien, 2009; Scheibe & Carstensen, 2010).

In light of this, given that our study involves the processing of emotional faces and emotional pictures and sentences, we should see differences in the way younger and older adults integrate the information from a negative or positive face with the processing of a negative or positive target sentence and corresponding picture (i.e., a face x sentence x age interaction). A prediction is that older people should find it easier to integrate a positive face with a positive sentence than a negative face with a negative sentence (i.e., facilitation only for positive sentences, or greater facilitation for positive than negative sentences). For younger people, on the other hand, one may expect equal facilitation for positive and negative sentences, only facilitation for negative, or greater facilitation for negative than positive sentences. Similar modulations by age are predicted for the face-picture congruence effect.

Methods

Participants

Thirty-two older (60-72 years, $M = 64.37$, $SD = 3.57$) and 32 younger (19-29 years, $M = 22.90$, $SD = 2.73$) adults took part in the experiment in return for a monetary reward; all gave informed consent.

Materials

Materials consisted of photographs of emotional facial expressions, emotional pictures and auditorily presented sentences. There were 28 experimental and 56 filler items. Each experimental item consisted of a facial expression (happy/sad), a display showing a positive and a negative picture taken from the IAPS database (Lang et al., 1999) and a sentence describing either the positive or negative picture. The emotional faces were selected from 15 sets of Bielefeld-University student portraits, each set depicting a neutral, a sad and a happy expression. From these sets we selected the 4 best sets (2 male, 2 female) based on the results of a valence-rating study (N=18).

The positive and negative images were selected on the basis of the valence ratings in Lang et al., 2008, (negative images: range 2.42 - 5.07, $M = 3.46$, $SD = 1.69$; positive images: range 5.51 - 8.22, $M = 7.19$, $SD = 1.55$). Arousal scores of negative and positive images were similar (paired t-test $t(27) = -.84$, $p = .41$).

The sentences for each of the two images of the 28 experimental item-picture pairs fulfilled constraints specific to length, structure and content. All started with an introductory main clause containing a verb of opinion in the first person singular (e.g., I think/believe/am of the opinion that…). This was followed by a subordinate clause about the event depicted in one of the two IAPS images of an item. The subordinate clause contained a subject noun phrase (N1), followed by an object noun phrase (N2), an adverb (Adv) and a final finite verb (Verb). Examples of the positive and negative sentence for an item are given in Figure 1. Care was also taken to match the sentences, so far as possible, by lemma frequency of nouns and adverbs, using frequency counts from the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995).

The sentences were recorded by 4 native speakers of German, two female and two male, and the speakers assigned to the faces, with 1 male being used for half of the experimental items (14) and 1 female for the other half (14). The sound files of the two experimental sentences associated with an experimental picture pair were edited using professional sound editing software, to ensure that the onsets of the critical words (N1, N2, Adverb) occurred exactly at the same point in time from sentence start in the positive and corresponding negative sentence (to achieve this, pauses were shortened or between-word breaks were lengthened slightly as necessary). The combination of the experimental faces, pictures and sentences yielded a 2 (Face: positive vs. negative) x 2 (Picture: positive vs. negative) x 2 (Sentence: positive vs. negative) design.

For the 56 distractor item picture-pairs, we constructed a sentence that matched one of the two IAPS pictures. The content of half of the distractor sentences (28) was neutral, while 14 contained at least one positive word (e.g., The talented artist is drawing the nice portrait) and the remaining half one negative word (e.g., It is obvious that today the weather will be unbearable). The 56 filler items further differed from the experimental items as follows: the facial expression was either neutral (28 items), positive (14 items) or negative (14 items); both IAPS images had mid-range valence (3.5 - 6.5); there was only 1 sentence per filler item.

Procedure

The experimental session started with the collection of demographic details from the participants, and with the administration of some cognitive tests and of a mood questionnaire. Eye movements were recorded using an SR Research Eyelink 1000 Desktop head-stabilised eye tracker (SR Research, Mississauga, Ontario, Canada). Participants were told that the study investigated language comprehension in relation to a visual display: They would first see the face of a person who was thinking about something and was about to speak, and after that they would hear him/her utter a sentence which described one of the two pictures shown on the screen. The task was to look, listen and understand the sentence, and decide whether the valence of the face matched the valence of the sentence ("Does the face match the sentence?") by pressing one of two buttons. The sequence of events in an experimental trial is illustrated in Fig. 1.

Analyses and Results

The data of interest were the participants' fixations on the pictures during sentence processing, i.e., during the time listeners inspect Display 2 (see Fig. 1). Because the initial part of the sentence (cf. Fig. 1, "Ich meine dass") was neutral between the negative and positive sentence, disambiguation towards the positive or negative picture occurred from the initial NP (N1) of the embedded sentence onwards (cf. Fig. 1, "die Mechaniker/die Vorstadtkinder"). Therefore any possible facilitation in the processing of the sentence (face x sentence interaction) due to having seen a congruent face can only be expected to occur after N1 onset.

By contrast, a face-picture congruence effect (i.e., looks to the pictures as a function of prime face) can occur both before and after sentence disambiguation. We thus defined two time periods: the Post-N1 (onset) region (from the onset of N1 until sentence end (average duration 4016 ms, *SD* = 456) and the Pre-N1 (onset) region (including, in addition to the initial, neutral part of the sentence, the last 1200 ms of the 1500-ms picture preview period, for a total duration of 3000 ms). Because our main focus is the face x sentence interaction (and its possible modulation by age), we will first present the findings for the post-N1 onset region.

The measure we used to analyze fixations on the pictures is the mean log gaze probability ratio, i.e., the log of the ratio of the probability of looking at the negative picture divided by the probability of looking at the positive picture (*ln*(*p*(neg picture)/*p*(pos picture)). This measure expresses the strength of the visual bias towards the negative versus positive picture. It is particularly suited for eye tracking data analyses with parametric tests (such as ANOVAs) because it violates neither independence nor homogeneity of variance assumptions (cf. Arai et al., 2007). The log ratio is symmetrical around zero: A positive log ratio indicates more looks to the negative than the positive picture; a negative log ratio indicates more looks to the positive than the negative picture; and a value of zero means the two pictures get an equal number of looks.

Fig. 2 (a)-(b) plots the time course of fixations for the Post-N1 onset region for the two age groups. These graphs are based on log gaze probability ratios (henceforth 'log ratios') computed on successive 20-ms time slices.

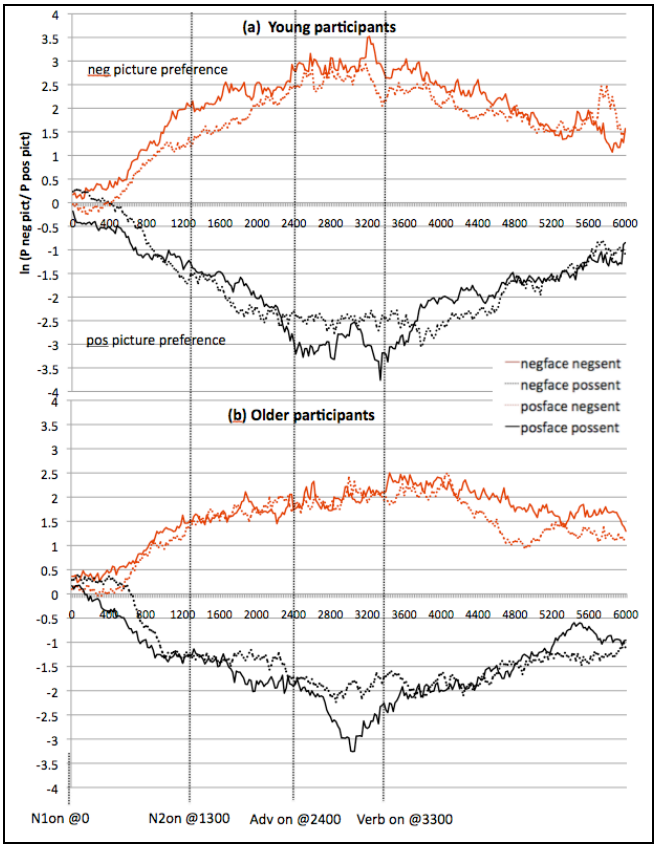

Figure 2: Mean log gaze probability ratios for young and older participants in the Post-N1 onset region, from the onset of N1.

In Fig. 2 the sentence effect can clearly be seen in the two sets of lines moving apart from about 500 ms after the onset of N1: The red lines (for the two negative sentence conditions) rise steadily above zero, indicating an increasing preference for the negative picture, while the black lines (for the positive sentence conditions) go in the opposite direction, indicating an increasing preference for the positive picture in these conditions.

A face-priming effect on the processing of the sentence (i.e., the facilitatory effect occurring from having seen a sentence-congruent emotional face) emerges in the relative distance between the solid and the dotted line of each sentence condition: If having seen a face of the same valence as the sentence facilitates sentence processing, the congruent condition (solid line) should be associated with a greater absolute value than the incongruent condition (dotted line).

The log-ratio means for the post-N1 region were submitted to 2 x 2 x 2 (Face x Sentence x Age) repeated-measures ANOVAs with participants and items as random effects. The ANOVAs revealed a significant effect of face-picture congruence (ps < .001), with a negative picture preference when the face was negative (M= .15) and a positive picture preference when the face was positive (M = -.11). This effect was not modulated by age (both F's < 1).

As expected, there was a highly significant sentence effect (ps < .001): When the sentence was negative, there was a preference for looking at the negative picture and the opposite was true when the sentence was positive (Ms = 1.65 vs. - 1.61). Importantly, the sentence effect was significantly modulated by age (ps < .002). This Sentence x Age interaction is due to the fact that older adults, when hearing a negative sentence, look less at the negative picture (vs. the positive one) than the younger adults; in other words, they are less "responsive" to the negative sentence than the younger group.

Crucially for our experimental hypotheses, the 3-way Face x Sentence x Age interaction was fully significant by participants ($p1$ = .025, $p2$ = .13). For our hypotheses, this interaction reflects the facilitating effect of the face on the processing of the sentence and the modulation of this effect by age. Post-hoc pairwise comparisons on participants and items means of the individual groups (i.e., for each age group) compared the two negative sentence conditions and the two positive sentence conditions (Bonferroni correction for 4 comparisons, p = 05/4 = .0125). These comparisons can tell us if younger and older participants show different sensitivities to the negative or positive prime face during the processing of the sentence. In the comparisons for the younger participants, only the difference between the two negative sentence conditions was significant (ps < .02), while the corresponding comparisons for the older adults yielded only a significant difference between the two positive sentence conditions (ps < .02).

Thus, for younger participants a negative prime face (vs. a positive one) significantly enhanced looks to the negative picture during the processing of a negative sentence. By contrast, a positive face had no enhancing effect on younger adults' processing of a positive sentence. For the older group however, the opposite pattern emerged: A negative face had no effect on the processing of a negative sentence, but a positive (vs. negative) face elicited more looks to the positive picture when the positive sentence was processed.

To assess the time course of this facilitation, we performed pairwise comparisons (similar to the ones reported above for the whole Post-N1 region) on mean log ratios for the individual word regions, i.e., N1, N2, Adverb and Verb (see Fig. 2). For the N1 region, these comparisons yielded a similar pattern of results as in the previous analyses, i.e., older participants showed a facilitation from the positive prime face in the positive sentence conditions (ps < .01), but not in the negative sentence conditions. By contrast, young participants showed significant facilitation in the negative sentence condition (ps < .002), while in the positive sentence condition facilitation was fully significant only in the item analysis ($p1$ = .06; $p2$ = .02). The only other (nearly) significant comparison occurred for the positive sentences in the adverb region (ps < .05): For older adults a positive (vs. negative) face, facilitated the processing of a positive sentence, but a negative face was of no advantage in processing a negative sentence. The fact that results were significant in the early, N1 region for both age groups suggests that the integration of the visual context with facial and linguistic information occurs early and that the time course of this integration does not substantially differ between the two age groups.

In the pre-N1 onset region, the ANOVA analyses on the log ratios revealed a face-picture congruence effect (ps > .02), not modulated by age: The negative picture was fixated longer when the face was negative and the positive picture, when the face was positive. There was also a significant picture effect, with the negative picture attracting overall more looks than the positive one (ps < .02). However, this general bias for the negative picture was weaker for the older participants (the interaction with age was marginally significant in the participants' analysis ($p1$= .069; $p2$= .18).

Discussion and Conclusion

These eye-tracking results are important for the following reasons. First, they demonstrate for the first time that priming from an emotional face occurs during sentence comprehension in a visually-situated task (i.e., when language is about objects and actions in the visual context). Moreover, priming effects were found from the early stages of sentence-reference and valence disambiguation (i.e., N1), showing that the seemingly complex integration of visual information from an emotional face, a picture and a sentence happens rapidly and without particular effort. Previous research in visually-situated comprehension tasks has demonstrated that speaker-based information such as gaze is rapidly integrated into sentence processing (e.g., Hanna & Brennan, 2007; Knoeferle & Kreysa, 2012). Importantly, our results provide evidence that a speaker's emotional facial expression also has a rapid influence on sentence interpretation.

Crucially also, our results provide new evidence for age differences in the processing of emotional information. All of the age-based modulations that we observed are compatible with a positivity effect, i.e., either an increased focus on positive compared to negative information by older versus younger adults, or a reduced focus on negative information by older adults (Langeslad & van Strien, 2009;

Scheibe & Carstensen, 2010). The fact that positivity effects were found in the early stages of sentence processing using a highly time-sensitive methodology such as eye tracking has also implications for the question of the mechanisms underlying the positivity effect, and the level(s) of processing at which these mechanisms operate.

A central tenet of socioemotional selectivity theory is that emotion regulation improves with age and that the positivity effect occurs because older people are capable (consciously or unconsciously) to selectively regulate their emotions in order to enhance positivity and well-being. According to this view, the positivity effect should be strongest in tasks and situations that require controlled processing with associated exertion of cognitive effort, and less so in tasks that measure automatic or initial processing (Scheibe & Carstensen 2010). Although evidence from several studies suggests that positivity effects require deliberate use of mood regulation strategies to occur (e.g., Isaacowitz, Toner, & Neupert, 2009), recent evidence has shown that controlled processing and cognitive effort are not necessary to trigger positivity effects in older adults (e.g., Allard, Wadlinger & Isaacowitz, 2010). We suggest that the positivity effects found in early processing in the eye tracking measures of our experiment are also more likely to be a result of an early and non-strategic emotion processing mechanism.

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