Empathy influences how listeners interpret intonation and meaning when words are ambiguous

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Abstract

This study examines how individual pragmatic skills, and more specifically empathy, influences language processing when a temporary lexical ambiguity can be resolved via intonation. We designed a visual-world eye-tracking experiment in which participants could anticipate a referent before disambiguating lexical information became available, by inferring either a contrast meaning or a confirmatory meaning from the intonation contour alone. Our results show that individual empathy skills determine how listeners deal with the meaning alternatives of an ambiguous referent, and the way they use intonational meaning to disambiguate the referent. Listeners with better pragmatic skills (higher empathy) were sensitive to intonation cues when forming sound-meaning associations during the unfolding of an ambiguous referent, and showed higher sensitivity to all the alternative interpretations of that ambiguous referent. Less pragmatically-skilled listeners showed weaker processing of intonational meaning since they needed subsequent disambiguating material to select a referent, and showed less sensitivity to the set of alternative interpretations. Overall our results call for taking into account individual pragmatic differences in the study of intonational meaning processing and sentence comprehension in general.

Keywords: intonation processing, individual differences, empathy, eye-tracking, intonational meaning, French, homophone

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Introduction

An important aspect of language comprehension is that in the presence of the same linguistic elements, listeners can arrive at different interpretations of the message (eg. Cain, Lemmon, & Oakhill, 2004; Gandour, Wong, & Hutchins, 1998; Swets, Desmet, Hambrick, & Ferreira, 2007). Individual differences in language processing are widely documented in previous research (see reviews by Kidd, Donnelly, & Christiansen, 2018 and Münster & Knoeferle, 2018), and yet what causes this variation is still to be understood. We know that cognitive capacities like working memory and executive functions are linked to individual variation in language processing tasks (eg. Friedman et al 2008; Just & Carpenter, 1992; Swets et al., 2007). Here we explore another potential source of individual differences in utterance interpretation: pragmatic abilities, and more specifically, empathy, as it relates to listeners' ability to respond to intonational disambiguation of lexical ambiguity.

From a comprehender's viewpoint, empathy is an essential tool for language processing because it allows one to understand the intentions of others, predict their behavior, and experience an emotion triggered by others' emotions (Bahron-Cohen & Wheelwright, 2004). Empathy is part of the set of pragmatic abilities that is generally known as Theory of Mind (ToM), mindreading, mentalizing, or perspective-taking (Carruthers, 2009; Baron-Cohen, 2011; Frith & Frith, 2003). Researchers have traditionally categorized two dimensions of empathy that in practice are tightly related and sometimes difficult to distinguish: affective empathy (to be emotionally aligned with the interlocutor) and cognitive empathy (to recognise and understand what an interlocutor feels or thinks) (Baron-Cohen & Wheelwright, 2004; Shamay-Tsoory, Aharon-Peretz, Perry, 2009; Zaki & Ochsner, 2012). Empathy is needed to comprehend others' motives behind their actions, including understanding verbal interactions that convey literal as well as nonliteral meaning (Li, Jian, Yu, & Zhou, 2004; Rockwell, 2003; Van den Brink et al 2012). Individual empathy is thus a potential source of variability in language comprehension, especially when linguistic meaning is nonliteral.

Speakers' expression of feelings and thoughts is not limited to lexical-semantic cues. Speakers also use intonational cues of speech, i.e. the melodic variation at the utterance level, to express pragmatic meaning, mental states, and commitment towards the content of an utterance, and to structure information in speech (Ladd 1996/2008, Pierrehumbert & Hirschberg, 1990, for English; Chen, Gussenhoven, & Rietveld, 2004, for Dutch; see Prieto, 2015 for a review). In a language like English or French, intonation contours are formed by combinations of pitch accents (i.e. tonal movements associated with prominent words in the sentence) and edge tones (i.e. melodic targets associated with the edges of intonational domains) that together transmit the speaker's intended meaning.

The speaker's choice of pitch accents and edge tones in each utterance is a key contributor to its pragmatic value. In the last decades an effort has been made to describe the intonational phonology of many languages and its contribution to pragmatic meaning (Jun, 2005; Frota & Prieto, 2015; Pierrehumbert & Hirschberg, 1990). For instance, in many languages high tones at the end of the phrase signal a yes-no question, and a final high tone preceded by a rising pitch accent supports a counter-expectational interpretation in languages like French or Spanish (Delais-Roussaire et al., 2015; Estebas-Vilaplana & Prieto, 2010). Similarly, in English new contrastive referents in the discourse are produced with a combination of a rising pitch accent and a low edge tone, and listeners reliably use this intonational information to process and even to anticipate the referent of the utterance (eg. Braun & Tagliapietra, 2010; Cutler, Dahan & Van Donselaar, 1997; Dahan, Tanenhaus, & Chambers, 2002; Ito & Speer, 2008).

Importantly, individuals vary in how they process intonational cues and how they use them to infer pragmatic meaning (Diehl et al., 2008; Jun & Bishop, 2014; Bishop, Chong, & Jun, 2015; Katz & Selkirk, 2011; Portes, Beyssade, Michelas, Marandin, Champagne-Lavau, 2014; Ward & Hirschberg, 1988). Portes et al. (2014) found that listeners can have different interpretations for the very same tonal configuration in French, and Bishop (2016) and Bishop & Kuo (2016) found that listeners rely on distinct cues (pitch accent, edge tones, or duration cues) to interpret the syntactic structure of a relative clause.

Only recently, researchers have started investigating the reasons behind individual variability in intonation processing. One factor could be key: individual pragmatic skills. Jun & Bishop (2014) assessed the autistic traits of normal adults and found they correlated with their use of intonational cues to syntactic processing. Specifically, Bishop (2016) observed that pragmatically-skilled individuals use prosodic prominence and pitch accent type to interpret whether a relative clause has high or low attachment, while less pragmatically-skilled individuals tend to rely mainly on subsequent boundary tone and durational information.

Previous results in the semantics/pragmatics literature had already reported individual variability in the interpretation of the quantifier *some*. Some listeners prefer a literal/semantic interpretation of *some* (as ‘at least some and possibly all’) while others choose a pragmatically-enriched interpretation (as ‘only some but not all’) (Bott & Noveck, 2004; Degen & Tanenhaus, 2015; Nieuwland, Ditman, & Kuperberg, 2010; Zhao, Liu, Chen, & Chen, 2015). Nieuwland et al. (2010) found that this difference was correlated with their individual pragmatic skills. In a series of visual-world eye-tracking experiments, Degen and Tanenhaus (2015) observed that ‘semantic’ listeners did not resolve the ambiguity immediately but waited for subsequent disambiguating material, and once their interpretational choice was made they committed to it and did not reconsider possible alternatives; instead, ‘pragmatic’ listeners started constructing the enriched meaning immediately after the presentation of the ambiguous expression, while showing delayed looks at the target due to lack of commitment to one of the possible alternative meanings.

All together, previous studies suggest that individuals that are more pragmatically skilled can be expected to be more sensitive to a cue (e.g. intonation) that conveys pragmatic meaning, and that they will more likely activate and consider all the potential interpretations of an utterance. The goal of the present study is in fact to investigate individual variability in processing the intonation-meaning mapping, testing listener's empathy as a relevant factor in this variation. We ask two main research questions: (1) Does individual empathy affect how listeners use intonation cues to resolve temporary meaning ambiguities? (2) Does individual empathy influence the selection of alternatives in lexically ambiguous words?

Based on previous evidence, we formulated two main hypotheses. First, individuals with higher empathy (better pragmatic skills) will be more sensitive to intonational cues that can be used to infer the meaning of an ambiguous referent, as opposed to less empathically-skilled individuals. Second, compared to less empathically-skilled individuals, listeners with higher empathy will be more likely to activate and maintain all the potential alternative interpretations of temporary ambiguous referents.

To test these hypotheses we designed a visual-world eye-tracking task in which Speaker A uttered a suggestion about a referent and Speaker B either confirmed or rejected that guess. We recorded the listeners' looking patterns towards a target referent during Speaker B's response, and correlated them with the listeners' empathy level.

For convenience, we preview here key aspects of our design and the comparisons in our analysis. Three critical conditions were manipulated: two in which Speaker B's response was lexically ambiguous but intonation could be used to infer either a rejection (contrast-test) or a confirmation (confirmation-test) meaning, and one condition in which the response was non-ambiguous at the intonational and lexical levels (contrast-control). Additionally, two additional filler conditions were created with unambiguous referents in both Speaker A's guess and Speaker B's response (confirmation-filler; contrast-filler).

To assess listeners' use of intonation to resolve meaning ambiguities we will first compare the contrast-test and confirmation-test conditions because they were lexically identical but differed in the intonation contour that was used, and distinct eye fixation patterns would indicate the listeners' use of intonation to infer meaning. Second, we will compare the contrast-test to contrast-control condition to assess the listeners' patterns when intonation is accompanied by disambiguating lexical cues, given that the control condition was lexically unambiguous. Finally, additional comparisons between the critical and the filler conditions will be used to inspect the effect of the overall presence of ambiguity in our stimuli and to contextualize the findings from the critical conditions.

Method

Participants

Sixty native speakers of French (14 males, age ranging from 19 to 48) were recruited in the Paris area from the French RISC database (http://www.risc.cnrs.fr). From these, 6 participants were excluded due to technical errors (N = 2) or because they only looked at the center of the screen during the experimental trials (N = 4). The final sample included 54 participants (12 males; mean age 26 years old, age ranging from 19 to 48). They all received 10€ for their participation in the study, gave informed consent, and reported no history of speech or hearing issues.

Experimental Task

Using the Visual World eye-tracking paradigm (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), listeners were tested in an experiment evoking a card-guessing game in which homophones were used. In this game, player A made suggestions about an image on player B's cards (e.g. 'I think you have a female duck'), and player B responded either confirming or contradicting player's A suggestions by indicating the right referent (e.g. 'I have a female duck, indeed, the animal' / 'I have a stick, instead, to walk'). Three features were crucial in this design. First, the target referent was a homophone and thus semantically ambiguous (in French, both female duck and walking stick are equally pronounced as /kan/, though the orthography is different, i.e. *cane* vs. *canne*). Second, player A's suggestions provided a discourse context that could constrain the possible meaning interpretations, as they were accompanied by A showing B a picture of one of the alternative interpretations of the homophone (in the previous example, for instance, a picture of a female duck). Third, player B's responses were segmentally identical in the critical test conditions before the unfolding of a disambiguating sequence (i.e. either *bien sûr* 'of course/indeed' + additional disambiguating material or *plûtot* 'instead/actually' + additional disambiguating material). Crucially, though, despite the presence of lexical ambiguity, the intonation contour indicated whether contradiction or confirmation was intended.

Materials

Critical trials

Eighteen sets of critical sentences, each composed of a suggestion followed by a response, were created to simulate a dialogue that might occur while playing a simple card game (see Table 1 for a summary and exemplification of the composition of critical sentences).

Auditory stimuli. Auditory stimuli of player A's suggestions had the form of *Je pense que tu as un/e* 'I think you have a/an [critical word]', with a homophone as the critical word in phrase-final position. For instance, player A would say *Je pense que tu as une [cane]* 'I think you have a [female duck]', *cane* ('female duck') being homophonous in French with *canne* ('walking stick'), both being pronounced as /kan/. All homophonous words had two possible meaning alternatives. Each suggestion utterance was followed by a response utterance. The response stimuli had the form of *J'ai un/e* 'I have a/an' + ambiguous homophonous critical word + disambiguating sentence context'. For instance, after the previous player A's suggestion, player B would respond either *J'ai une cane, bien sûr, l'animal* 'I have a female duck, indeed, the animal' or *J'ai une canne, plutôt, pour marcher* 'I have a walking stick, instead, to walk'. Crucially, the 'I have a/an + [critical word]' portion of the response was uttered with one of two possible intonation contours: (1) a falling pitch movement (labeled as LHiL* L-L% in French-ToBI), characterized by an accentual fall preceded by an initial phrasal rise, which is generally associated with a confirmation meaning, or (2) a rising-falling pitch movement (labeled as LH* L-L%) which has been mostly associated with a *contrast of beliefs* between interlocutors (Delattre, 1966; Jun & Fougeron, 2000; Portes, 2004; Portes & Reyle, 2014). The first intonation condition (called 'confirmation-test condition') was intended to trigger a confirmation interpretation, and thus listeners were expected to fixate the figure depicting the homophone suggested in the previous scene. The second intonation condition (called 'contrast-test condition') was intended to trigger a contrast interpretation, thus we anticipated that listeners would show increased fixations to the alternative meaning of the homophone. A third type of response was also created to serve as control utterances, in which the critical word in the response was not a homophone and therefore not semantically ambiguous. In this condition, called ‘contrast-control condition’, responses were produced with the same rising-falling pitch movement as in the contrast-test condition, signaling a contrast with respect to the suggestion scene. A total of 18 critical trials were created (6 in the confirmation-test, 6 in the contrast-test, and 6 in the contrast-control condition).

Table 1 summarizes and exemplifies each condition, and Figure 1 shows pitch curves for the three possible critical responses. Crucially, confirmation-test and contrast-test responses were lexically identical before the disambiguating sentence context was presented, and so only intonation could indicate whether the homophone referred to the suggested or the alternative meaning (prior to the end of the critical word).

Type		*Condition*	*Speaker’s A suggestion*	*Speaker’s B response*
Critical trials	Test	Confirmation-test	Je pense que tu as un/e [CW_{HOM}] *Je pense que tu as une cane* ‘I think you have a female duck’	J’ai un/e [$CW_{HOM\text{-}SAME}$] *J’ai une cane* $_{\text{LHiL* L-L\%}}$*, bien sûr, xxx* ‘I have a female duck, indeed, xxx’
Critical trials	Test	Contrast-test	Je pense que tu as un/e [CW_{HOM}] *Je pense que tu as une cane* ‘I think you have a female duck’	J’ai un/e [$CW_{HOM\text{-}DIFFERENT}$] *J’ai une canne* $_{\text{LH* L-L\%}}$*, plutôt, xxx* ‘I have a stick, instead, xxx’
Critical trials	Control	Contrast-control	Je pense que tu as un/e [CW_{HOM}] *Je pense que tu as une cane* ‘I think you have a female duck’	J’ai un/e [CW_{NONHOM}] *J’ai une poupée* $_{\text{LH* L-L\%}}$*, plutôt, xxx* ‘I have a doll, instead, xxx’
Filler trials		Confirmation-filler	Je pense que tu as un/e [CW_{NONHOM}] *Je pense que tu as une bouteille* ‘I think you have a bottle’	J’ai un/e [$CW_{NONHOM\text{-}SAME}$] *J’ai une bouteille* $_{\text{LHiL* L-L\%}}$*, bien sûr, xxx* ‘I have a bottle, indeed, xxx’
Filler trials		Contrast-filler	Je pense que tu as un/e [CW_{NONHOM}] *Je pense que tu as une fleur* ‘I think you have a flower’	J’ai un/e [$CW_{NONHOM\text{-}DIFFERENT}$] *J’ai une figue* $_{\text{LH* L-L\%}}$*, plutôt, xxx* ‘I have a fig, instead, xxx’

Table 1. Summary and examples of all test and filler trial conditions. CW states for ‘Critical Word’

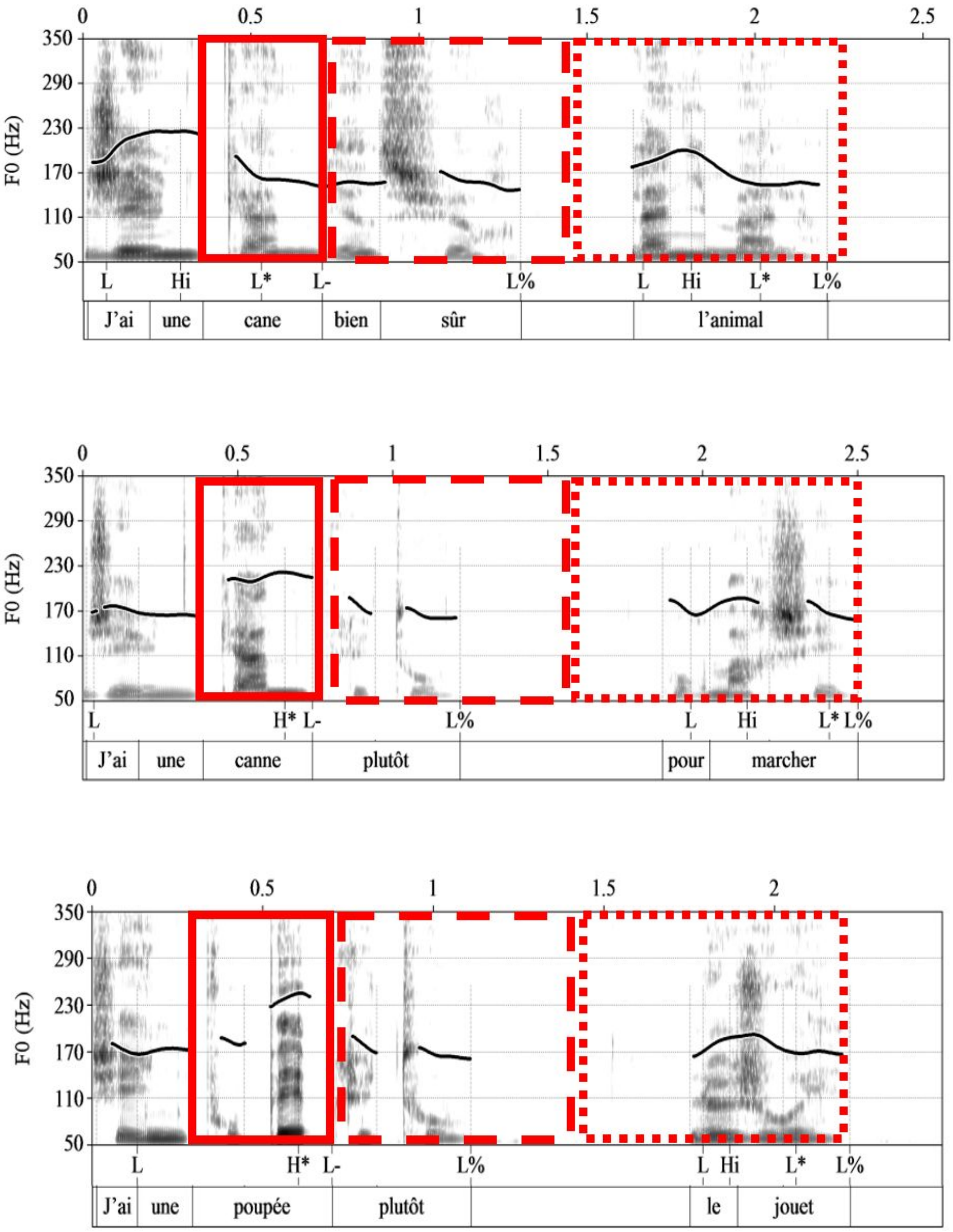

Figure 1. Spectrograms and pitch curves of Player B's responses in each critical condition. The top panel displays the confirmation-test condition (*J'ai une cane, bien sûr, l'animal* 'I have a female duck, indeed, the animal'). The middle panel displays the contrast-test condition (*J'ai une canne, plutôt, pour marcher* 'I have a walking stick, instead, for walking'). The lower panel displays the contrast-control condition (*J'ai une poupée, plutôt, le jouet* 'I have a doll, instead, the toy'). The solid rectangle indicates the temporal limits of the critical word; the dashed

rectangle indicates the temporal limits of the first half of the disambiguation phase; the dotted rectangle indicates the temporal limits of the second half of the disambiguation phase.

Stimuli were recorded in a soundproof chamber by two prosodically trained female speakers. One female speaker produced suggestions using the same intonation contour in all sentences. The other female speaker first produced all sentences with the confirmatory contour, and then repeated the set with the contrast contour. Using Praat (Boersma & Weenick, 2012), all stimuli were annotated for duration (in milliseconds) and mean F0 values (in Hz) in the region preceding the critical word, the critical word, and the clarification phrase, and the overall mean duration and mean F0 values were then calculated per critical condition. The results of one-way ANOVAs on durations and mean F0 values for the critical responses (Table 2) revealed that there were indeed robust phonetic differences between the two tunes. More specifically: (1) the region preceding the critical word was significantly longer and had higher F0 values in the confirmation-test than in the contrast-test and contrast-control conditions (with no differences between the latter two); (2) the critical word in the confirmation-test condition was equally long but with lower pitch than in the contrast-test and contrast-control conditions (the latter two differing in both duration and pitch); and (3) the clarification phrase was shorter and with lower pitch in the confirmation-test than in the contrast-test condition, the two contrast conditions not differing between each other in any parameter.

	J'ai un/e		CW		Clarification phrase	
Condition	Dur in ms	F0 in Hz	Dur in ms	F0 in Hz	Dur in ms	F0 in Hz
confirmation-test	348 (6.93)	208 (1.35)	364 (15.96)	169 (1.56)	1970 (32.86)	165 (0.55)
contrast-test	323 (8.42)	169 (1.15)	350 (15.12)	227 (3.29)	2137 (52.57)	172 (0.89)
contrast-control	304 (8.89)	167 (0.82)	413 (20.11)	212 (2.67)	2113 (39.23)	171 (0.96)
conf-test vs. contr-test						
F value (df = 35):	5.09*	480.81***	.44	250.38***	8.59**	53.87***
conf-test vs. contr-cont						
F value (df = 35):	14.61**	669.02***	3.62	193.53***	3.44	33.61***
contr-test vs. contr-cont						
F value (df = 35):	2.28	2.103	6.36*	11.976**	1.75	.87

***$p < .001$, **$p < .01$, *$p < .05$.

Table 2. Mean duration and pitch values (SD in parentheses) for each critical condition during the critical word (CW), before it ('J'ai un/e'), and after it (during the clarification phrase).

Visual stimuli. The visual display accompanying the suggestion auditory stimulus depicted the subordinate meaning of that homophone (Figure 2, left panel), thus providing disambiguating contextual cues by which a less frequent interpretation of the homophone was asserted. Frequency scores were determined through the *Lexique* database (New, Pallier, Brysbaert, & Ferrand, 2004) (see Appendix A for a complete list of the homophone pairs). Given that previous research testing homophones in visual world experiments has found that listeners activate the dominant interpretation even in subordinate-biased contexts (Chen & Boland, 2008; Huettig & Altmann, 2007), displaying the subordinate interpretation of the homophone allowed us to ensure that our participants would activate both alternative interpretations[1].

The visual display for the auditory response stimulus presented four objects, one of which always matched the target referent of the response (Figure 2, right panel). There were four areas of interest in each display, corresponding to the division of the screen into four quadrants. The bottom left position always depicted the previous suggestion, and so always matched the previously suggested meaning (the target homophone for the confirmatory responses but the competitor in contrast responses). The other three positions presented the image depicting the alternative meaning of the homophone pair (the target image for the contrast-test condition) and

[1] The other possibilities would have been to use both the subordinate and the dominant meanings as primes, or to always prime participants with the dominant interpretation. These two options would have more strongly biased participants' responses towards a dominant alternative: in the first case, we would not have been able to control that in all trials both interpretations would be activated to the same extent; in the latter case, we would not have been able to ensure that participants would also activate the subordinate interpretation.

two images depicting a non-homophone referent (one of which was the target in the contrast-control condition).

Note that in the scene configuration the subordinate interpretation of the homophone was always located in the bottom left position, used for all suggested images. This display was chosen for several reasons. First, it allowed to better test the influence of sentence context, as participants could more easily anticipate the image depicting the interpretation primed by this sentence context without the need to first explore the entire visual display. Second, it allowed participants to anticipate the position of the suggested referent and therefore we could more easily test if the information from the intonation contour caused a rapid switch from the suggested interpretation to the alternative one. The assignment of images to the other three positions was counterbalanced.

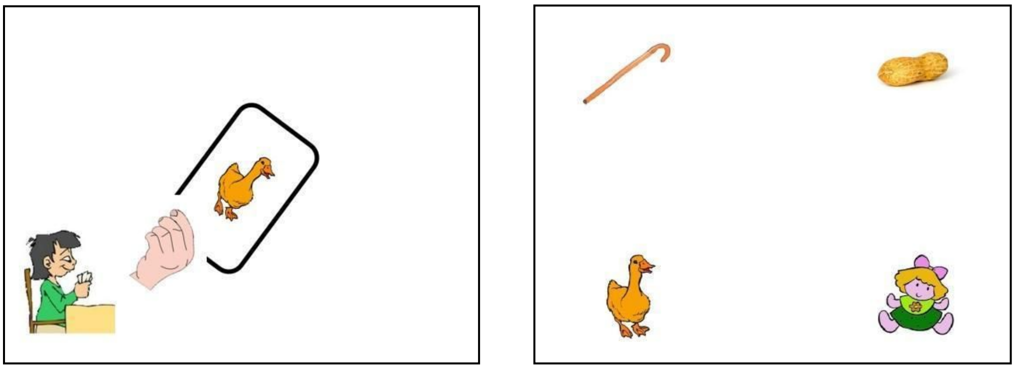

Figure 2. Example of a visual display accompanying suggestions (left) and responses (right). In the right panel, the bottom left image is the suggested meaning of the homophone, the top left image is the alternative meaning of the homophone, and the other two images are unrelated distractors.

Filler trials

Thirty-six filler suggestion-response pairs were also created. Filler pairs had the same form as critical pairs (*Je pense que tu as un/e X* 'I think you have a/an X' – *J'ai un/e X* 'I have a/an X') but included non-homophone words in the critical positions of the suggestion and response parts.

Auditory stimuli. There were two types of fillers: *confirmation-filler* pairs ($N = 21$), with a non-homophone word in the suggestion and the same non-homophone as the critical word in the response, produced with a LHiL* L-L% falling confirmation intonation; and *contrast-filler* pairs ($N = 15$), with a non-homophone in the suggestion and a different non-homophone as the critical word in the response, produced with a LH* L-L% rising-falling contrast intonation. There were fewer filler-contrast pairs than filler-confirmation pairs to balance confirmation and contrast responses across the experiment. Thus, in total, 27 response trials in the experiment used confirmation intonation for correct card guesses (6 in the critical responses and 21 in the filler responses), and 27 response trials used contrast intonation for incorrect guesses (12 in the critical responses and 15 in the filler responses).

Visual stimuli. The visual display in filler trials was the same as in critical trials, except for the fact that while the bottom-left position depicted the previous suggestion (like in critical trials), the other three positions now depicted three non-homophone referents (one of which was the target in the contrast-filler condition). Like in critical trials, there were four areas of interest in each display, corresponding to the division of the screen into four quadrants.

Procedure

Prior to the eye-tracking task, all participants completed a self-reported Empathy Quotient (EQ) questionnaire (Baron-Cohen & Wheelwright, 2004) to tap into their individual empathy skills, and their individual scores were used as a predictor in the subsequent analyses. There exist various tools to tap into individual empathy and pragmatic skills, such as false-belief tasks in children (Baron-Cohen, Leslie, & Frith, 1985; Wimmer & Perner, 1983) or self-reported questionnaires in adults (Autism Quotient questionnaire, Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; EQ questionnaire, Baron-Cohen & Wheelwright, 2004; Interpersonal Reaction Index questionnaire, Davis, 1980). The EQ questionnaire is a tool designed to be used with adults of normal intelligence and has been successfully validated with individuals with high-functioning autism and Asperger syndrome. It contains 60 forced-choice questions (40 test items and 20 fillers) in which responders score 1 point if reporting an empathic behavior mildly or 2 points if reporting the behavior strongly. Test items tap into both the affective and the cognitive component of empathy, and, as the authors state, no distinction is made between categories because both components co-occur and cannot be disentangled. The EQ questionnaire has been successfully used in previous studies on language production and processing (Chu, Meyer, Foulkes & Kita, 2014; Foucart et al., 2015; Van den Brink et al., 2012).

Also before the experiment we determined the subject's dominant eye by applying the Miles-test (Miles, 1929). Only eye-movements from the dominant eye were registered. Participants were seated in front of an Eyelink II eye-tracking system (distance between participants and screen: ca. 80 cm), connected to two loudspeakers, before game instructions were given to them. In the instructions, they were told that they would see a scene in which one player would try to guess the other player’s cards, and that they would hear the first player’s suggestion and then the other player’s response, either confirming or contradicting the suggestion. Participants first saw the suggestion display where player A showed a card with an object to player B and then the response display. A drift correction with a fixation point at the middle of the screen was performed between the suggestion display and the response display to make sure that participants always started from the same position. The visual displays were presented for 3.5 sec in suggestion scenes and for 4.5 sec in response scenes. Their corresponding auditory stimuli were synchronized with the onset of the visual displays. The interval between the suggestion and the response display was self-paced by participants and depended on the time it took them to fixate the drift-correcting fixation point.

To ensure participants' attention to the eye-tracking task, after listening to the entire response participants were asked to press one of four keys on the number pad corresponding to the position of the image on the screen (1 = top left; 2 = top right; 3 = bottom left; 4 = bottom right) corresponding to their response. No time pressure was put on the picture choice to prevent the participants looking at the keys before the trial ended.

Three practice trials preceded a five-point calibration and the subsequent experiment. Each participant was presented with a total of 54 (18 critical and 36 filler) trials. Critical and filler trials appeared in randomized order during the experiment. Test conditions were counterbalanced across participants in a Latin Square design and resulted in three different lists so that each trial condition changed according to the list. Participants were randomly assigned to the lists.

Analysis of the Eye-tracking Data

We used the R environment and the RStudio interface for the analysis. We specifically used the following packages: EyetrackingR (Dink & Ferguson, 2015), lme4 (Bates, Maechler, Bolker, & Walker, 2014), ggplot2 (Wickham, 2016), lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017), and optimx (Nash & Varadhan, 2011). Growth curve analyses (Mirman, Dixon & Magnuson, 2008; Mirman, 2014) were run. These analyses are especially suitable when including time as a continuous predictor and when changes over time are predicted (as is the case in our study, where looks to the images were expected to change during the unfolding of the utterance). All data and analysis code used for this paper are available on the Open Science Framework (https://osf.io/nwe7s).

The dependent variable was the empirical logit of looks to the image depicting the suggested word versus looks to the other three areas of interest in the visual scene[2]. Looks to the suggested image are not independent of looks to the other images at a given time point, because only one image can be fixated at a time in a given trial. Given that there can be visual biases to particular images or locations in the visual scene, we follow common practice in the visual-world paradigm literature and use a dependent measure based on the ratio of looks to the suggested image versus looks elsewhere. Trials with over 25% trackloss were excluded. The independent variables were Time, Condition (5 levels: confirmation-test, contrast-test, contrast-control, confirmation-filler, and contrast-filler), Empathy (as a continuous variable), and Time Window (3 levels: 0-675 ms, 675-1400 ms, 1400-1900 ms). The 0-675 ms Time Window corresponds to the processing of the critical word; the 675-1400 ms Time Window corresponds to the first portion of subsequent sentence disambiguation; the 1400-1900 ms Time Window corresponds to the second portion of the disambiguating sentence. We applied mean centred coding for all independent variables. When applicable, random variables included a by-item random slope and a by-participant random slope for the interaction of Condition and Time Window (Barr, Levy, Scheepers, & Tily, 2013). We enforced zero correlations between random effects in order to avoid overparameterization or false convergence (Bates, Kliegl, Vasishth, & Baayen, 2015).

Two primary comparisons were applied. *Comparison 1* (confirmation-test vs. contrast-test) tested the listeners' use of intonation to process meaning, and *comparison 2* (contrast-test vs. contrast-control) tested the listeners' processing of disambiguating lexical cues next to intonation, versus intonation alone. To supplement these, two additional comparisons were applied: *comparison 3* (contrast-control vs. contrast-filler) and *comparison 4* (confirmation-test

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[2] Empirical logits were calculated via the EyetrackingR package using the following function: "make_time_sequence_data(data, time_bin_size = 50, predictor_columns = c("Conditions", "Empathy", "Time_windows"), aois = c("suggested"))

vs. confirmation-filler) served as a test of the overall effect of ambiguity in the suggestion and response stimuli.

The procedure was the same for each comparison. First, we determined the model with the best-fit orthogonal polynomial function of time, following Mirman (2014). We only included orthogonal polynomial functions that statistically improved model fit (linear time for comparisons 1, 2, and 4; quadratic time for comparison 3). We then kept the same polynomial orthogonal function of time for the subsequent analyses (results of all the time models are available in Appendix B). Second, we ran an inclusive model with all the independent variables (Time, Condition, Empathy, and Time Windows). If the variable Time Windows interacted with Empathy and/or Condition, we then looked at main effects and interactions within those relevant Time Windows. In these subsequent analyses within the relevant Time Windows, the independent variables were Time, Condition and Empathy. The p-values of the initial inclusive model and of the four comparisons were corrected using the Holm-Bonferroni approach. Only significant results are reported here; complete results of the eye-tracking data are available in Appendix C).

Results

Picture choice

Participants pressed the correct key representing the position of the target image in 97.9% of the trials (98.8% of the filler trials and 96.4% of the critical trials). A logistic regression model indicated that the accuracy of picture choice was not significantly affected by condition (intercept: $\beta = .98$, $t = 92.39$, $p < .001$; confirmation-test: $\beta = -.01$, $t = -.11$, $p = .911$; contrast-test: $\beta = -.02$, $t = -.09$, $p = .923$; contrast-control: $\beta = .01$, $t = .53$, $p = .59$; confirmation-filler: $\beta = -.01$, $t = -.05$, $p = .962$) nor by participants' empathy score ($\beta = .01$, $t = .37$, $p = .714$), neither did the interaction between these two factors reach significance (confirmation-test:empathy: $\beta = -.01$, $t = -.21$, $p = .837$; contrast-test: $\beta = .01$, $t = .24$, $p = .814$; contrast-control: $\beta = -.01$, $t = -.19$, $p = .84$; confirmation-filler: $\beta = -.01$, $t = -.46$, $p = .648$). These results indicate that participants were attentive to the task, irrespective of empathy skills, trial type, and intonation condition.

Eye-movements

Figure 3 shows raw fixation proportions every 50 ms to the image depicting the suggested word (the target in the confirmation conditions) out of looks to all areas of interest (AoIs) in the five filler and test conditions included in the study. Two panels are displayed: one for participants with higher empathy and one for participants with lower empathy (see footnote 3). Fixation proportions are aligned to the onset of the critical word. We assume that it takes about 225 ms for the eyes to program a saccade in reaction to a linguistic stimulus (Allopenna, Magnuson, Tanenhaus, 1998; Altmann & Kamide, 2004; Matin, Shao, & Boff, 1993; Salverda, Kleinschmidt, & Tanenhaus, 2014), hence the region depicting eye fixations in response to the material in the critical word starts (conservatively) at 0 ms (onset of the critical word) and continues until 675 ms (the average duration of critical words across all five conditions was 450 ms).

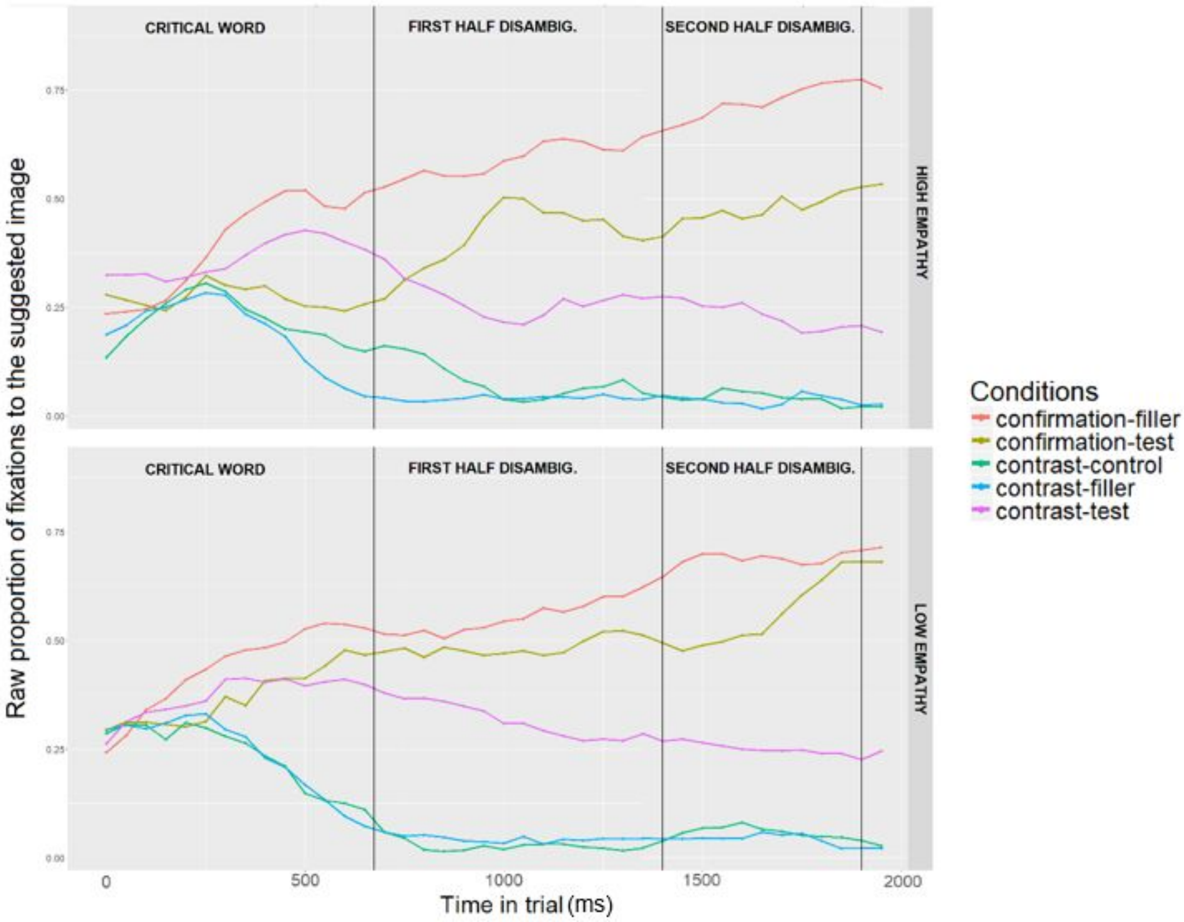

Figure 3. Raw proportion of fixations to the suggested image across critical conditions and time (ms), averaged across items and aligned to the onset of the critical word. Upper panel, proportion of fixations for high-empathy participants; lower panel, proportion of fixations for low-empathy participants[3]. The 'Critical word' Time Window corresponds to the listeners' gaze patterns during the processing of the referent in the response (solid rectangle in Figure 1). The 'First half of disambiguation' and 'Second half of disambiguation' Time Windows correspond to the listeners' gaze patterns during the first and second portions of subsequent disambiguating material, respectively (dashed and dotted rectangles in Figure 1).

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[3] While Empathy is a continuous variable in the analyses, two groups are displayed in Figure 3 (median split) to better illustrate participants' patterns. Listeners in the high-empathy group had a score in the EQ-questionnaire that was higher than the aggregated mean (M_{score} = 51, range from 45 to 72; N = 27, 26 females and 1 male) and low-empathy listeners had a score lower than the mean (M_{score} = 37, range from 21 to 44; N = 27, 16 females and 11 males).

The two panels in Figure 3 reveal that before processing the critical word, the suggested image received around 25% of the total looks in all conditions and empathy values. During critical word processing, we observe that the presence of lexical ambiguity influenced the listeners' gaze patterns: as soon as a non-ambiguous word was processed, listeners looked at the target AoI (the suggested image in confirmation-filler, and the other AoI in contrast-filler and contrast-control conditions); instead, when an ambiguous response was processed, listeners' patterns varied across empathy groups (less empathic individuals looked at the suggested image around 40% of the time in the confirmation-test and contrast-test conditions, but highly empathic individuals looked at the suggested image around 25% of the time in the confirmation-test condition but 40% of the time in the contrast-test condition).

Once the ambiguous target referent started being segmentally disambiguated (first portion of the disambiguation), all participants looked at the suggested image more in the confirmation-test condition than in the contrast-test condition (as expected), with finer differences across empathy groups: gaze shifts to the target image are sharper in the high-empathy group but milder in the low-empathy group. This time period also reveals an influence of empathy when the critical word had been ambiguous in the suggestion scene but unambiguous in the response (contrast-control condition): low empathy individuals barely looked at the suggested image (the expected behavior) but high empathy individuals still direct some looks at it.

Looking patterns during the second portion of the disambiguation region are very similar across empathy groups, but still a slight difference can be observed: individuals with lower empathy scores reached the target gaze behavior more accurately (the suggested image received around 75% of total looks in the confirmation-test condition), while individuals with higher empathy still seem to fixate the alternative AoI (the suggested image received only around 50% of total looks in the confirmation-test condition). This is interesting since at this point listeners had already perceived enough segmental material to undoubtedly disambiguate the target. These observed patterns were then subjected to statistical analyses, which are presented below.

Primary comparisons

Confirmation-test vs. contrast-test (comparison 1). The first inclusive model revealed a Time Window x Empathy x Condition interaction (β = -2.617, *t* = -2.947, *p.adj*<.05), a Time Window x Condition x Time interaction (β = -2.419, *t* = -5.675, *p.adj*<.001), and a Time Window x Empathy x Time interaction (β = 1.794, *t* = 3.848, *p.adj*<.001). In all three interactions the significant differences were found between the 0-675 ms and the 675-1400 ms windows. The inspection within the relevant Time Windows shows that Empathy, Condition, and Time interacted in the 0-675 ms window (β =0.267, *t* = 3.802, *p.adj*<.001), while in the 675-1400 ms time window Time only interacted either with Empathy (β =2.353, *t* = 3.515, *p.adj*<.001) or with Condition (β =-4.527, *t* = -7.398, *p.adj*<.001). These results reveal that during the unfolding of the ambiguous word listeners directed their gaze patterns at distinct images depending on the intonation contour they were exposed to and as a function of their empathy level. Then, during the subsequent disambiguation portion, Condition and Empathy influenced listeners' fixations.

Contrast-test vs. contrast-control (comparison 2). The first inclusive model revealed an interaction of Time Windows x Condition x Empathy x Time (β = -1.414, *t* = -3.524, *p.adj*<.001 for the 0-675 ms vs. 675-1400 ms comparison), an interaction of Time Window x Empathy x Time (β = -1.477, *t* = -3.257, *p.adj*<.01, for the 0-675 ms vs. 1400-1900 ms comparison) and an interaction of Time Window x Condition x Time (β = 2.399, *t* = 6.515, *p.adj*<.001, for the 0-675 ms vs. 675-1400 ms comparison; β = 2.711, *t* = 6.515, *p.adj*<.001, for the 0-675 ms vs. 1400-1900 ms comparison). A closer inspection within the relevant Time Windows revealed a Condition x Time interaction (β = 5.164, *t* = 8.35, *p.adj*<.001) as well as an Empathy x Time interaction (β = 0.22, t = 3.285, $p.adj$<.01) in the 0-675 ms window, while in the subsequent 675-1400 ms time window we found an Empathy x Condition x Time interaction (β = 1.948, t = 3.562, $p.adj$<.001). These results reveal that during the critical word listeners fixated different images depending both on the condition, and on their empathy level. Then, during the first portion of the disambiguation, the distinct fixations across conditions were modulated by the listeners' empathy level.

Additional comparisons

Contrast-control and contrast-filler (comparison 3). The first inclusive model revealed an interaction of Time Window x Empathy x Time (β = 4.236, t = 2.971, $p.adj$<.05 for the 0-675 ms vs. 675-1400 ms comparison). An inspection of the relevant time windows shows an interaction of Empathy x Time in the 0-675 ms time window (β = -4.768, t = -3.038, $p.adj$<.05). These results indicate that empathy modulates listeners' fixations during the critical word processing, independently of whether the previous context was lexically ambiguous or not.

Confirmation-test vs. confirmation-filler (comparison 4). The first inclusive model revealed an interaction of Time Window x Condition x Empathy x Time (β = -1.272, t = -3.757, $p.adj$<.001 for the 0-675 ms vs. 675-1400 ms comparison), and an interaction of Time Window x Condition x Time (β = -1.649, t = -5.310, $p.adj$<.001 for the 0-675 ms vs. 675-1400 ms comparison; β = -2.488, t = -7.118, $p.adj$<.001 for the 0-675 ms vs. 1400-1900 ms comparison). The inspection to the relevant windows shows an interaction of Condition x Empathy x Time in the 0-675 ms time window (β = 2.333, t = 4.500, $p.adj$<.001), while Condition was a main effect in the subsequent time windows (β = 4.328, t = 3.250, $p.adj$<.01 in the 0-675 ms window; β = 9.407, t = 1.340, $p.adj$<.001 in the 675-1400 ms window). This comparison shows that fixations towards the target varied in these two conditions as a function of the listeners' empathy score, but that once the disambiguating material was presented these two conditions elicited distinct fixations towards the target independently of the listeners' empathy level.

Summary of the eye-tracking results

Comparison 1 showed that the listeners' empathy level impacted the processing of an ambiguous word, when intonation was the only cue that could be used to disambiguate the target. Figure 3 shows that while less empathic listeners looked at the suggested image equally in the two conditions during the 0-675 ms window, highly empathic listeners' looking patterns differed across conditions, since they looked at the suggested image less often in the confirmation-test condition. Given that this pattern goes against our expectations, we designed a post-hoc behavioral task to explore the intonation-meaning associations across empathy scores (see next section). In subsequent time windows, once the referent was overtly (lexically) disambiguated, all participants looked at the relevant AoI in each condition. Comparison 2 further supports the claim that empathy matters to the processing of intonation by showing an empathy effect even if the response contains a non-ambiguous critical word. The interaction between Empathy and Time during the unfolding of the critical word shows that highly empathic listeners looked more at the suggested image in both conditions, and did so even if there were unambiguous segmental cues indicating that it was the incorrect referent.

Additional comparisons showed that empathy modulates listeners' fixations during the critical word processing independently of the nature of previous sentence context (comparison 3), and that confirmed that the effect of empathy is stronger when there is linguistic ambiguity (comparison 4), as listeners with higher empathy looked less at the target when the critical word was ambiguous, but that this influence disappears in subsequent disambiguating portions.

Post-hoc behavioral task

Comparison 1 in the eye-tracking data showed that empathy impacted on how listeners processed intonation, and Figure 3 illustrates that less empathic individuals did not vary their looking behavior as a function of intonation cues, while highly empathic individuals did. Importantly, the direction of the looking behavior in the highly empathic individuals was intriguing: confirmation intonation was expected to imply confirmation meaning and thus to elicit more looks at the suggested image, while contrast intonation was expected to trigger a contrast meaning and thus to elicit more looks at other AoIs. And yet eye fixations suggested the reverse intonation-meaning mapping in highly empathic listeners.

These results could have two explanations: it could be that highly empathic listeners map intonation contours to less plausible meaning interpretations, or instead it could be that highly empathic listeners were considering all the possible alternative meanings while still mapping intonation to the most plausible interpretation. We designed an offline task to investigate these possibilities. Participants listened only to the ambiguous portion of the same test sentences as in the eye-tracking task (we cut sentences at the beginning of the segmental disambiguation), and had to match them to either a confirmatory or a contrast meaning. If the first explanation is true, we would expect higher-empathy listeners to choose the contrast meaning after hearing the confirmatory LHiL* L% falling intonation, and vice-versa. If the second explanation is true, we expect all listeners to prefer contrast meaning for contrast intonation, and confirmatory meanings upon being exposed to confirmation intonation.

A matching task was presented online to 21 French-speaking participants using the Surveygizmo online application. The task consisted of 36 trials (18 critical trials and 18 filler trials), with materials adapted from the visual-world eye-tracking experiment. As in the eye-tracking task, in each trial participants were first presented with a Player A's guess accompanied by the left image in Figure 2, and afterwards they were presented with Player B's audio response now accompanied by two pictures depicting each possible interpretation of the homophone pair. All guesses and responses were equal to the eye-tracking task, but now the responses did not contain the disambiguation phrase and thus ended at the end of the critical word, as in (1).

(1) Speaker's A suggestion: *Je pense que tu as une* <u>*cane*</u>
'I think you have a female duck'

Speaker's B response: *J'ai un/e* <u>*canne*</u>$_{LH*\ L\text{-}L\%}$
'I have a stick'

In total, participants were presented with 18 confirmation trials (12 confirmation-fillers + 6 confirmation-test) and 18 contrast trials (6 contrast-fillers + 6 contrast-control + 6 contrast-test). Listeners had to click on the interpretation they found more plausible. Before completing the intonation-meaning matching task, participants filled in the French version of the Empathy-Quotient Questionnaire (Baron-Cohen & Wheelwright, 2004), as in the eye-tracking task.

A mixed-effects logistic regression model (with participants and items as random effects to accommodate by-participant and by-item variation, Baayen, 2008; Barr et al., 2013; Jaeger, 2008) was applied to the participants' responses in the critical trials using the *lmer* package in the R platform. The dependent variable was Appropriate Response (1 if participants chose the expected response in each condition, and 0 if they did not), while fixed factors were Empathy (continuous) and Test Condition (2 levels: confirmation-test, contrast-test)[4]. Results showed a main effect of Empathy (β = 0.02397, z = 2.240, p < .05), a marginal effect of condition (β = 0.6265, z = -1.782, p = .07), and no interaction between empathy and condition (β = -0.03586, z = 1.386, p = .16). These findings show that empathy impacted both conditions: the higher the listeners' empathy the more they preferred the appropriate response. Interestingly, an inspection

[4]glmer(Appropriate Response ~ empathy*condition + (empathy|item) + (condition|participant), data).

to Figure 4 shows that less empathic individuals preferred a contrast interpretation independently of the intonation contour: they appropriately chose contrast meaning for contrast intonation 60% of the time, and *inappropriately* chose the contrast meaning for confirmation intonation also 60% of the time. Because Speaker A's guesses were always accompanied by an image of the non-dominant interpretation of the homophonous word, preferring a contrast interpretation for Speaker B's response could indicate a bias for the dominant (most frequent) interpretation of the homophonous word. We therefore propose that less empathic individuals ignored intonation cues and based their answers on frequency effects.

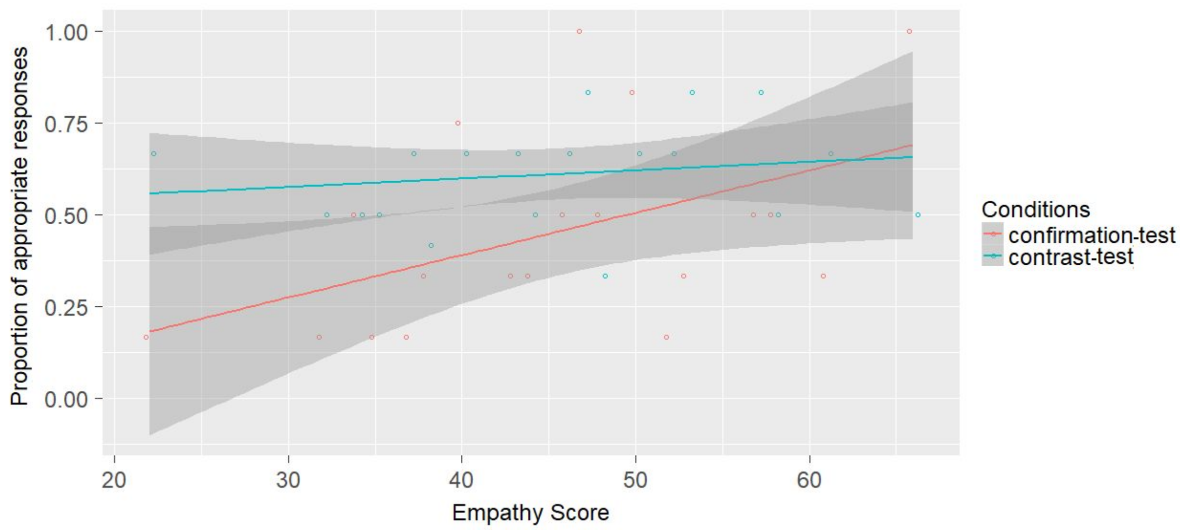

Figure 4. Accuracy in selecting the appropriate response in each test condition as a function of the listeners' empathy score.

The offline task confirmed that highly empathic listeners appear to map intonation cues to the most plausible meaning. In the eye-tracking data we also observed that highly empathic individuals looked more at the inappropriate AoI during the processing of each critical intonation contour, we therefore suggest that these listeners map intonation to the most plausible meaning yet still consider the set of all possible alternatives.

Discussion

By means of a visual-world eye-tracking task, this study aimed at investigating how individual empathy skills impact the online processing of sentence meaning, when lexical cues are temporarily ambiguous and accompanying cues like intonation can be used to disambiguate a speaker's intentions. We hypothesized that individuals with higher empathy (greater pragmatic skills) would use intonation to form hypotheses about the most plausible interpretation of ambiguous lexical cues, and that individuals with higher empathy would be more likely to activate and maintain all the potential alternative interpretations of temporary ambiguous words.

Our main result is that individual empathy influenced the processing of intonation-meaning associations: less empathic individuals did not disambiguate an ambiguous referent on the basis of the intonation they perceived, while individuals with higher empathy skills formed distinct associations depending on the intonation cues accompanying the ambiguous critical word. Previous studies have reported an effect of individual pragmatic skills on intonation processing and on the type of prosodic events that are relevant for sentence processing (Diehl et al., 2008; Bishop, 2016; Bishop & Kuo, 2016; Jun & Bishop, 2015, Bishop et al. 2014). Our results are in line with this proposal, and we further showed that listeners with better pragmatic abilities process tonal information to form intonation-meaning associations in the presence of lexical ambiguity, while less empathic individuals wait for lexical disambiguation to be presented.

The specificity of French prosodic structure might have highlighted the effect of empathy. Hexagonal French is a language with fixed stress, in which nuclear tonal information generally occurs during the last full syllable of the phrase (Jun & Fougeron, 2000, 2002). In other languages, such as English or Spanish, the position of the stressed syllable is not fixed and can occur at pre-final positions, hence allowing segmental material to occur between the pitch accent and right-edge boundary tone (Jun, 2005). Hence, if listeners used intonation cues to disambiguate meaning in our eye-tracking task, they had to do it very quickly before subsequent lexical disambiguating material was presented, and maybe only pragmatically-skilled individuals are able to do so.

Interestingly, highly empathic listeners used tonal events in the non-expected direction, i.e. looking at the suggested image when intonation was contrastive but not looking at it when intonation was confirmatory. One possibility, which we argued is not supported by the results of the post-hoc task, was that individuals with higher empathy stopped looking at the image that was suggested upon hearing confirmation intonation simply because they interpreted the falling contour as signaling contrast of beliefs instead of confirmation. This account would be in line with previous results reporting that in French (as in many other languages) there is no absolute one-to-one intonation-meaning mapping (Portes et al., 2014; Katz & Selkirk, 2011; Ward & Hirschberg, 1988). Results of the post-hoc task did not show that highly empathic individuals favor an unexpected mapping between intonation and meaning, and therefore we propose that the lack of one-to-one intonation-meaning mapping reported in the literature for other intonation contours does not explain our results.

Another possibility, however, was that highly empathic individuals mapped tunes to meanings as expected, but that they were more sensitive to all the meaning alternatives of a given referent and therefore fixated them when the critical word was presented. We propose that the post-hoc behavioral task confirmed this second prediction: highly empathic listeners associated contrast intonation with an appropriate contrastive interpretation (and the reverse for the confirmation intonation). Listeners with higher empathy skills consider the set of all possible alternatives while still mapping intonation to the most plausible meaning. Previous eye-tracking research has shown that listeners activate the set of alternatives when processing a contrastively focused element (e.g. Braun & Tagliapietra 2010; see Gotzner 2015 for an overview), and that they can look at the negated referent when computing negation (Orenes, Beltrán, & Santamaría, 2014; Shuval & Hemforth, 2008). Additionally, we know that individuals with higher perspective-taking abilities are more sensitive to all possible alternative interpretations of an implicature, and more eager to interpret them in a pragmatically-enriched way (Bott & Noveck, 2004; Degen & Tanenhaus, 2015; Li et al., 2014).

The present study evaluated empathy as a source of individual variability in the processing of intonation to resolve sentence ambiguity. Empathy is part of the set of pragmatic abilities that enable listeners to understand the communicative intentions and feelings behind the interlocutor's words (Baron-Cohen & Wheelwright, 2004). Our study provides evidence that listeners make use of these abilities when processing linguistic information, especially when this information is ambiguous or non-literal. We show that empathy influences how we evaluate the alternatives of ambiguous information, and how we use features accompanying lexical-semantic material, like intonation, to infer pragmatic meaning. Due to the task constraints, and because of the nature of the questionnaire, we cannot distinguish whether it is the affective or the cognitive component of empathy that triggers our findings (Zaki & Ochsner, 2012). Although both components are intertwined and co-occur (Baron-Cohen & Wheelwright, 2004), future studies could use more precise measures to find out whether they equally influence the processing of intonational and linguistic information.

Communicative exchanges require listeners to understand the pragmatic intentions behind the interlocutor's speech acts, and our skills in inferring others' social and pragmatic states seem to affect this linguistic understanding. Individual pragmatic and social skills are also a good indicator of language and cognitive impairments (e.g. Baron-Cohen, 1989; Perner, Frith, Leslie,

& Leekam, 1989), and their specific training results in improvement of the socially-related behavior (Peters & Thompson, 2018). Our study shows that individual variability in terms of social and pragmatic skills needs to be considered when investigating the online processing of intonation and meaning in typical populations as well. Only then will we have a more complete picture of how listeners are able to infer communicative intentions and utterance meaning from intonational speech cues.

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Open Practices Statement

Neither of the experiments reported in this article was formally preregistered. Neither the data nor the materials have been made available on a permanent third-party archive; requests for the data or materials can be sent via email to the lead author at nesteveg@uoc.edu.

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Appendix A

Critical trials

Suggestion sentence	Response sentence	Condition
Je pense que tu as un [pin]	*J'ai un [pin], bien sûr, l'arbre*	confirmation-test
‘I think you have a [pine tree]’	‘I have a [pine tree], indeed, the tree	
	J'ai un [pain] plutôt, de la boulangerie	contrast-test
	‘I have a [bread], instead, from the bakery’	
	J'ai un [raisin], plutôt, le fruit	contrast-control
	‘I have a [grape], instead, the piece of fruit	
Je pense que tu as un [choeur]	*J'ai un [choeur], bien sûr, de chanteurs*	confirmation-test
‘I think you have a [choir]’	‘I have a [choir], indeed, with singers’	
	J'ai un [coeur], plutôt, l'organe	contrast-test
	‘I have a [heart], instead, the organ’	
	J'ai un [marteau], plutôt, l'outil	contrast-control
	‘I have a [hammer], instead, the tool’	
Je pense que tu as un [ver]	*J'ai un [ver], bien sûr, l'animal*	confirmation-test
‘I think you have a [worm]’	‘I have a [worm], indeed, the animal’	
	J'ai un [verre], plutôt, pour boire	contrast-test
	‘I have a [glass], instead, for drinking’	
	J'ai un [chien], plutôt, un fox terrier	contrast-control
	‘I have a [dog], instead, a fox terrier’	
Je pense que tu as une [cane]		confirmation-test
‘I think you have a [female duck]’	*J'ai une [cane], bien sûr, l'animal*	
	‘I have a [female duck], indeed, the animal’	
	J'ai une [canne] plutôt, pour marcher	contrast-test
	‘I have a [walking stick], instead, for walking’	
	J'ai une [poupée], plutôt, le jouet	contrast-control
	‘I have a [doll], instead, the toy’	
Je pense que tu as une [datte]	*J'ai une [datte], bien sûr, le fruit*	confirmation-test
‘I think you have a [date]’	‘I have a [date], indeed, the fruit’	
	J'ai une [date], plutôt, du calendrier	contrast-test
	‘I have a [date], instead, from the calendar’	
	J'ai une [tomate], plutôt, le légume	contrast-control
	‘I have a [tomatoe], instead, the vegetable’	
Je pense que tu as une [amende]	*J'ai une [amende], bien sûr, de la police*	confirmation-test
‘I think you have a [fine]’	‘I have a [fine], indeed, from the police’	
	J'ai une [amande], plutôt, le fruit sec	contrast-test
	‘I have an [almond], instead, the nut’	
	J'ai une [bicyclette], plutôt, pour pédaler	contrast-control
	‘I have a [bicycle], instead, for pedaling’	
Je pense que tu as un [cygne]	*J'ai un [cygne], bien sûr, l'oiseau*	confirmation-test
‘I think you have a [swan]’	‘I have a [swan], indeed, the bird’	
	J'ai un [signe], plutôt, de victoire	contrast-test
	‘I have a [sign], instead, of victory’	
	J'ai un [cactus], plutôt, la plante	contrast-control
	‘I have a [cactus], instead, the plant’	
Je pense que tu as un [philtre]	*J'ai un [philtre], bien sûr, d'amour*	confirmation-test
‘I think you have a [potion]’	‘I have a [potion], indeed, of love’	
	J'ai un [filtre], plutôt, à cafe	contrast-test
	‘I have a [filter], instead, for the coffee’	
	J'ai un [piano] plutôt, l'instrument	contrast-control
	‘I have a [piano], instead, the instrument’	
Je pense que tu as un [autel]	*J'ai un [autel], bien sûr, d'église*	confirmation-test
‘I think you have an [altar]’	‘I have an [altar], indeed, from the church’	

	J'ai un [hôtel], plutôt, le bâtiment 'I have a [hotel], instead, the building'	contrast-test
	J'ai un [crayon], plutôt, pour dessiner 'I have a [pencil], instead, for drawing'	contrast-control
Je pense que tu as un [comte] 'I think you have an [earl]'	*J'ai un [comte], bien sûr, un noble* 'I have an [earl], indeed, a noble'	confirmation-test
	J'ai un [conte], plutôt, à raconter 'I have a [tale], instead, to be explained'	contrast-test
	J'ai un [briquet], plutôt, en bleu 'I have a [lighter], instead, a blue one'	contrast-control
Je pense que tu as un [poing] 'I think you have a [fist]'	*J'ai un [poing], bien sûr, la main fermée* 'I have a [fist], indeed, the closed hand'	confirmation-test
	J'ai un [point], plutôt, rond 'I have a [point], instead, round'	contrast-test
	J'ai un [robot], plutôt, la machine 'I have a [robot], instead, the machine'	contrast-control
Je pense que tu as une [voie] 'I think you have [rails]'	*J'ai une [voie], bien sûr, pour les trains* 'I have [rails], indeed, for the trains'	confirmation-test
	J'ai une [voix], plutôt, pour parler 'I have a [voice], instead, for speaking'	contrast-test
	J'ai un [livre], plutôt, de poésie 'I have a [book], instead, of poetry'	contrast-control
Je pense que tu as un [serf] 'I think you have a [serf]'	*J'ai un [serf], bien sûr, la personne* 'I have a [serf], indeed, the person'	confirmation-test
	J'ai un [cerf], plutôt, l'animal 'I have a [deer], instead, the animal'	contrast-test
	J'ai un [coco], plutôt, le fruit 'I have a [coconut], instead, the fruit'	contrast-control
Je pense que tu as un [sein] 'I think you have a [breast]'	*J'ai un [sein], bien sûr, la glande mammaire* 'I have a [breast], indeed, the mammary gland'	confirmation-test
	J'ai un [saint], plutôt, religieux 'I have a [saint], instead, religious'	contrast-test
	J'ai un [dé] plutôt, pour les jeux 'I have a [dice], instead, for the games'	contrast-control
Je pense que tu as un [port] 'I think you have a [harbour]'	*J'ai un [port], bien sûr, pour les bateaux* 'I have a [harbour], indeed, for the boats'	confirmation-test
	J'ai un [porc], plutôt, l'animal 'I have a [pig], instead, the animal'	contrast-test
	J'ai un [canapé] plutôt, pour s'asseoir 'I have a [sofa], instead, to sit on'	contrast-control
Je pense que tu as un [python] 'I think you have a [python]'	*J'ai un [python], bien sûr, le serpent* 'I have a [python], indeed, the snake'	confirmation-test
	J'ai une [piton], plutôt, rocheaux 'I have a [peak], instead, rocky'	contrast-test
	J'ai une [raquette], plutôt, de tennis 'I have a [racket], instead, for tennis'	contrast-control
Je pense que tu as un [fard] 'I think you have [make-up]'	*J'ai un [fard], bien sûr, à paupière* 'I have [make-up], indeed, for the eyeshadow'	confirmation-test
	J'ai un [phare], plutôt, pour la navigation 'I have a [lighthouse], instead, for the navigation'	contrast-test
	J'ai un [crabe], plutôt, le crustacé 'I have a [crab], instead, the crustacean'	contrast-control
Je pense que tu as un [sceau] 'I think you have a [seal]'	*J'ai un sceau, bien sûr, à cacheter* 'I have a [seal], indeed, to seal'	confirmation-test
	J'ai un [saut], plutôt, le mouvement du corps 'I have a [jump], instead, the body movement'	contrast-test
	J'ai un [papillon], plutôt, l'insecte 'I have a [butterfly], instead, the insect'	contrast-control

Appendix B

Comparison 1. Confirmation-test vs. contrast-test

```
m: Elog ~ Condition * Empathy * (ot1) * (coding variable Time windows 1-3
 + coding variable Time windows 1-2)) + (1 +Condition * (coding variable Time windows 1-3 + coding
variable Time windows 1-2) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable
Time windows 1-2) || Participant)
m.1: Elog ~ Condition * Empathy * (ot1 + ot2) * (coding variable Time windows 1-3 + coding variable Time
windows 1-2) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) ||
Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) ||
Participant)
m.2: Elog ~ Condition * Empathy * (ot1 + ot2 + ot3) * (coding variable Time windows 1-3 + coding variable
Time windows 1-2)) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows
1-2) || Trial) + (1 +  Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) ||
Participant)

    Df AIC    BIC    logLik deviance Chisq Chi Df Pr(>Chisq)
m   37 115249 115545 -57588 115175
m.1 49 115231 115624 -57567 115133 41.775     12 3.634e-05 ***
m.2 61 115244 115733 -57561 115122 11.180     12 0.5135
```

Comparison 2. Contrast-test vs. Contrast-control

```
m: Elog ~ Condition * Empathy * (ot1) * (coding variable Time windows 1-3
 + coding variable Time windows 1-2)) + (1 +Condition * (coding variable Time windows 1-3 + coding
variable Time windows 1-2)) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding
variable Time windows 1-2)) || Participant)
m.1: Elog ~ Condition * Empathy * (ot1 + ot2) * (coding variable Time windows 1-3 + coding variable Time
windows 1-2)) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2))
|| Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2)) ||
Participant)
m.2: Elog ~ Condition * Empathy * (ot1 + ot2 + ot3) * (coding variable Time windows 1-3 + coding variable
Time windows 1-2)) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows
1-2) || Trial) + (1 +  Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2)) ||
Participant)

    Df AIC    BIC    logLik deviance Chisq Chi Df Pr(>Chisq)
m   37 103888 104183 -51907 103814
m.1 49 103849 104240 -51876 103751 63.241     12 5.754e-09 ***
m.2 61 103850 104337 -51864 103728 22.727     12 0.03014 *
```

Comparison 3. Contrast-control vs. Contrast-filler

m: Elog ~ Condition * Empathy * (ot1) * (coding variable Time windows 1-3 + coding variable Time windows 1-2) + (1+ (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Participant)
m.1: Elog ~ Condition * Empathy * (ot1 + ot2) * (coding variable Time windows 1-3 + coding variable Time windows 1-2) + (1 + (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Participant)
m.2: Elog ~ Condition * Empathy * (ot1 + ot2 + ot3) * (coding variable Time windows 1-3 + coding variable Time windows 1-2) + (1 + (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Participant)

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
m	34	121311	121591	-60621	121243			
m.1	46	121151	121531	-60529	121059	184.042	12	< 2.2e-16 ***
m.2	58	121118	121597	-60501	121002	56.402	12	1.013e-07 ***

Comparison 4. Confirmation-filler vs. confirmation-test

m: Elog ~ Condition * Empathy * (ot1) * (coding variable Time windows 1-3 + coding variable Time windows 1-2)) + (1+ (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Participant)
m.1: Elog ~ Condition * Empathy * (ot1 + ot2) * (coding variable Time windows 1-3 + coding variable Time windows 1-2) + (1 + (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Participant)
m.2: Elog ~ Condition * Empathy * (ot1 + ot2 + ot3) * (coding variable Time windows 1-3 + coding variable Time windows 1-2) + (1 + (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Trial) + (1 + Condition * (coding variable Time windows 1-3 + coding variable Time windows 1-2) || Participant)

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
m	34	218181	218475	-109056	218113			
m.1	46	218141	218539	-109024	218049	63.844	12	4.455e-09 ***
m.2	58	218136	218638	-109010	218020	29.029	12	0.003901 **

Appendix C

Comparison 1. Confirmation-test vs. contrast-test

A. First inclusive model

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	-1.07E-01	1.13E-01	1.12E+02	-0.947	0.345462	1
Empathy	-2.68E-02	1.60E-02	7.91E+01	-1.673	0.098189	0.785512
Time ot1	2.62E+00	3.95E-01	2.19E+04	6.628	3.48E-11	< .0001
Time windows 1-3	-4.95E-01	1.45E-01	1.16E+02	-3.412	0.000889	0.007112
Time windows 1-2	-3.54E-01	1.16E-01	6.64E+01	-3.039	0.003393	0.027144
Condition:Empathy	1.91E-02	1.08E-02	1.43E+02	1.765	0.079783	0.638264
Condition:Time ot1	-3.09E+00	3.95E-01	2.19E+04	-7.839	4.73E-15	< .0001
Empathy:Time ot1	-1.87E-02	4.33E-02	2.19E+04	-0.432	0.665503	1
Condition:Time Windows 1-3	-1.40E-01	1.27E-01	2.13E+02	-1.099	0.273127	1
Condition:Time Windows 1-2	-3.45E-01	8.81E-02	1.43E+02	-3.918	0.000138	0.001104
Empathy:Time Windows 1-3	3.16E-02	1.33E-02	2.45E+02	2.372	0.018444	0.147552
Empathy:Time Windows 1-2	1.30E-02	9.93E-03	1.37E+02	1.308	0.193163	1.545304
Time ot1:Time Windows 1-3	-1.43E+00	4.81E-01	2.19E+04	-2.978	0.002904	0.023232
Time ot1:Time Windows 1-2	-2.48E+00	4.26E-01	2.19E+04	-5.816	6.09E-09	< .0001
Condition:Empathy:Time ot1	1.41E-01	4.33E-02	2.19E+04	3.246	0.001172	0.009376
Condition:Empathy:Time Windows 1-3	-1.48E-02	1.30E-02	2.92E+02	-1.137	0.256634	1
Condition:Empathy:Time Windows 1-2	-2.62E-02	8.88E-03	1.97E+02	-2.947	0.003598	0.028784
Condition:Time ot1:Time windows 1-3	-2.72E+00	4.81E-01	2.19E+04	-5.66	1.53E-08	< .0001
Condition:Time ot1:Time windows 1-2	-2.42E+00	4.26E-01	2.19E+04	-5.675	1.40E-08	< .0001

Empathy:Time ot1:Time windows 1-3	-2.30E-02	5.29E-02	2.19E+04	-0.434	0.664516	1
Empathy:Time ot1:Time windows 1-2	1.79E-01	4.66E-02	2.19E+04	3.848	0.00012	0.00096
Condition:Empathy:Time ot1:Time Windows 1-3	-1.13E-01	5.29E-02	2.19E+04	-2.125	0.033606	0.268848
Condition:Empathy:Time ot1:Time windows 1-2	-7.45E-02	4.66E-02	2.19E+04	-1.598	0.110063	0.880504

B. Within Time Window 1 (0ms-675ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	2.42E-01	1.57E-01	2.34E+02	1.54E+00	1.25E-01	1
Empathy	-5.68E-02	2.40E-02	1.00E+02	-2.37E+00	0.019761	0.237132
Time ot1	5.38E+00	6.45E-01	7.48E+03	8.34E+00	<2E-016	< .0001
Condition:Empathy	4.81E-02	1.63E-02	2.95E+02	2.96E+00	0.003345	0.04014
Condition:Time ot1	4.81E-01	6.44E-01	7.49E+03	7.47E-01	4.55E-01	1
Empathy:Time ot1	-1.41E-01	7.05E-02	7.48E+03	-2.00E+00	0.045876	0.550512
Condition:Empathy:Time ot1	2.68E-01	7.05E-02	7.49E+03	3.80E+00	1.45E-04	0.00174

C. Within Time Window 2 (675ms-1400ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	-4.72E-01	1.29E-01	4.65E+01	-3.65E+00	6.59E-04	7.91E-03
Empathy	-2.96E-02	1.48E-02	5.21E+01	-2.00E+00	5.06E-02	6.07E-01
Time ot1	2.72E-01	6.12E-01	7.98E+03	4.44E-01	0.657027	1
Condition:Empathy	-6.35E-03	1.09E-02	5.45E+01	-5.82E-01	0.563039	1
Condition:Time ot1	-4.53E+00	6.12E-01	7.98E+03	-7.40E+00	1.53E-13	< .0001
Empathy:Time ot1	2.35E-01	6.70E-02	7.98E+03	3.52E+00	4.42E-04	5.30E-03
Condition:Empathy:Time ot1	1.15E-01	6.70E-02	7.98E+03	1.72E+00	0.085602	1

D. Within Time Window 3 (1400ms-1900ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	-6.20E-02	2.28E-01	1.95E+02	-2.72E-01	7.86E-01	1
Empathy	1.26E-02	2.38E-02	2.18E+02	5.27E-01	0.5986	1
Time ot1	2.28E+00	8.06E-01	6.44E+03	2.82E+00	4.79E-03	0.05748
Condition:Empathy	1.58E-02	2.31E-02	2.62E+02	6.84E-01	0.49428	1
Condition:Time ot1	-5.47E+00	8.06E-01	6.44E+03	-6.78E+00	1.30E-11	< .0001
Empathy:Time ot1	-1.91E-01	8.91E-02	6.44E+03	-2.14E+00	0.03248	0.38976
Condition:Empathy:Time ot1	2.35E-02	8.91E-02	6.44E+03	2.64E-01	7.92E-01	1

Comparison 2. Contrast-test vs. contrast-control

A. First inclusive model

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	-1.08E+00	9.57E-02	9.59E+01	-11.329	<2E-016	< .0001
Empathy	6.96E-03	1.14E-02	9.74E+01	0.611	0.542764	1
Time ot1	-1.91E+00	3.42E-01	2.11E+04	-5.588	2.32E-08	< .0001
Time windows 1-3	-3.93E-01	1.34E-01	1.29E+02	-2.94	0.003894	0.0312
Time windows 1-2	-4.58E-01	1.09E-01	8.70E+01	-4.197	6.50E-05	0.0005
Condition:Empathy	1.54E-02	8.67E-03	1.68E+02	1.777	0.077313	0.6185
Condition:Time ot1	-1.62E+00	3.42E-01	2.11E+04	-4.73	2.26E-06	< .0001
Empathy:Time ot1	1.08E-01	3.73E-02	2.11E+04	2.883	0.003945	0.0316
Condition: Time windows 1-3	2.43E-01	1.02E-01	2.68E+02	2.376	0.018187	0.1455
Condition:Time windows 1-2	2.57E-01	7.90E-02	8.39E+01	3.258	0.001622	0.0130
Empathy: Time windows 1-3	4.96E-04	1.29E-02	1.65E+02	0.038	0.969374	1

Empathy: Time windows 1-2	-1.51E-02	1.02E-02	9.85E+01	-1.481	0.141861	1
Time ot1: Time windows 1-3	-1.49E+00	4.16E-01	2.11E+04	-3.581	3.43E-04	0.0027
Time ot1: Time windows 1-2	-2.61E+00	3.69E-01	2.11E+04	-7.085	1.44E-12	< .0001
Condition:Empathy:Time ot1	-2.09E-02	3.73E-02	2.11E+04	-0.559	0.57645	1
Condition:Empathy: Time windows 1-3	-1.70E-02	1.04E-02	4.52E+02	-1.631	0.103632	0.8291
Condition:Empathy: Time windows 1-2	-2.27E-03	7.01E-03	2.62E+02	-0.323	0.746796	1
Condition:Time ot1: Time windows 1-3	2.71E+00	4.16E-01	2.11E+04	6.515	7.42E-11	< .0001
Condition:Time ot1: Time windows 1-2	2.40E+00	3.68E-01	2.11E+04	6.515	7.41E-11	< .0001
Empathy:Time ot1: Time windows 1-3	-1.48E-01	4.54E-02	2.11E+04	-3.257	0.001127	0.0090
Empathy:Time ot1: Time windows 1-2	-2.91E-02	4.02E-02	2.11E+04	-0.724	0.469187	1
Condition:Empathy:Time ot1: Time windows 1-3	-1.51E-02	4.54E-02	2.11E+04	-0.334	0.738729	1
Condition:Empathy:Time ot1: Time windows 1-2	-1.41E-01	4.01E-02	2.11E+04	-3.524	0.000427	0.0034

B. Within Time Window 1 (0ms-675ms)

Fixed effects	**Estimate**	**Std. Error**	**df**	**t value**	**p value**	**p adjusted**
Condition	1.43E+00	1.47E-01	1.90E+02	9.74E+00	< 2e-16	< .0001
Empathy	1.86E-02	2.31E-02	9.88E+01	8.04E-01	0.42336	1
Time ot1	1.02E+00	6.20E-01	7.37E+03	1.65E+00	0.09988	1
Condition:Empathy	-2.76E-02	1.43E-02	4.99E+02	-1.93E+00	0.05369	0.6443
Condition:Time ot1	5.16E+00	6.18E-01	7.38E+03	8.35E+00	< 2e-16	< .0001
Empathy:Time ot1	2.20E-01	6.71E-02	7.36E+03	3.29E+00	0.00102	0.0122
Condition:Empathy:Time ot1	-9.76E-02	6.69E-02	7.37E+03	-1.46E+00	1.45E-01	1

C. Within Time Window 2 (675ms-1400ms)

Fixed effects	**Estimate**	**Std. Error**	**df**	**t value**	**p value**	**p adjusted**
Condition	9.00E-01	1.14E-01	4.28E+01	7.90E+00	6.71E-10	< .0001

Empathy	-1.27E-02	8.96E-03	5.46E+01	-1.42E+00	1.61E-01	1
Time ot1	-4.36E+00	4.98E-01	7.89E+03	-8.76E+00	< 2e-16	< .0001
Condition:Empathy	-2.33E-02	8.94E-03	5.22E+01	-2.60E+00	0.011962	0.1435
Condition:Time ot1	1.76E-01	4.98E-01	7.90E+03	3.53E-01	0.724163	1
Empathy:Time ot1	1.64E-01	5.46E-02	7.90E+03	3.00E+00	2.74E-03	0.0329
Condition:Empathy:Time ot1	1.95E-01	5.47E-02	7.90E+03	3.56E+00	0.000371	0.0045

D. Within Time Window 3 (1400ms-1900ms)

Fixed effects	**Estimate**	**Std. Error**	**df**	**t value**	**p value**	**p adjusted**
Condition	8.88E-01	1.80E-01	2.09E+02	4.93E+00	1.66E-06	< .0001
Empathy	1.91E-02	1.77E-02	3.62E+02	1.08E+00	0.281268	1
Time ot1	-2.29E+00	6.62E-01	5.86E+03	-3.46E+00	5.53E-04	0.0066
Condition:Empathy	1.03E-02	1.80E-02	3.38E+02	5.74E-01	0.566119	1
Condition:Time ot1	-8.97E-01	6.64E-01	5.86E+03	-1.35E+00	1.77E-01	1
Empathy:Time ot1	-1.07E-01	7.25E-02	5.85E+03	-1.47E+00	0.141454	1
Condition:Empathy:Time ot1	-6.32E-02	7.26E-02	5.85E+03	-8.69E-01	3.85E-01	1

Comparison 3. Contrast-control and contrast-filler

A. First inclusive model

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	3.20E-01	2.43E-01	1.62E+04	1.321	1.87E-01	1
Empathy	-5.37E-02	2.68E-02	1.08E+04	-2.002	0.045337	0.3627
Time ot1	-1.24E+01	1.52E+00	2.81E+04	-8.157	3.59E-16	< .0001
Time ot2	-2.48E+00	6.62E-01	2.81E+04	-3.753	0.000175	0.0014

Time windows 1-3	1.44E+00	3.62E-01	1.72E+04	3.98	6.93E-05	0.0006
Time windows 1-2	2.43E+00	2.22E-01	3.29E+03	10.954	< 2e-16	< .0001
Condition:Empathy	-3.03E-02	2.61E-02	2.51E+04	-1.159	0.246355	1
Condition:Time ot1	2.31E+00	1.51E+00	2.81E+04	1.528	0.126551	1
Condition:Time ot2	8.02E-01	6.62E-01	2.81E+04	1.212	0.225575	1
Empathy:Time ot1	-2.93E-01	1.66E-01	2.81E+04	-1.768	0.077088	0.6167
Empathy:Time ot2	-2.11E-01	7.25E-02	2.81E+04	-2.904	0.003683	0.0295
Condition: Time windows 1-3	-5.75E-01	3.58E-01	2.39E+04	-1.606	0.108378	0.8670
Condition: Time windows 1-2	-2.80E-01	2.14E-01	6.94E+03	-1.309	0.190578	1
Empathy: Time windows 1-3	6.20E-02	3.93E-02	2.03E+04	1.577	0.114881	0.9190
Empathy: Time windows 1-2	6.55E-02	2.36E-02	5.82E+03	2.77	0.005619	0.0450
Time ot1: Time windows 1-3	1.75E+01	2.29E+00	2.81E+04	7.646	2.14E-14	< .0001
Time ot1: Time windows 1-2	1.52E+01	1.30E+00	2.81E+04	11.643	< 2e-16	< .0001
Time ot2: Time windows 1-3	3.95E+00	8.58E-01	2.81E+04	4.602	4.2E-06	< .0001
Time ot2: Time windows 1-2	8.21E+00	6.66E-01	2.81E+04	12.336	< 2e-16	< .0001
Condition:Empathy:Time ot1	9.88E-03	1.65E-01	2.81E+04	0.06	0.952182	1
Condition:Empathy:Time ot2	-1.00E-01	7.21E-02	2.81E+04	-1.393	0.163555	1
Condition:Empathy: Time windows 1-3	-1.53E-02	3.88E-02	2.69E+04	-0.395	0.693083	1
Condition:Empathy: Time windows 1-2	1.18E-02	2.27E-02	1.90E+04	0.523	0.6012	1
Condition:Time ot1: Time windows 1-3	-1.03E+00	2.29E+00	2.81E+04	-0.448	6.54E-01	1
Condition:Time ot1: Time windows 1-2	-3.26E+00	1.30E+00	2.81E+04	-2.514	1.20E-02	0.0957
Condition:Time ot2: Time windows 1-3	-1.23E+00	8.57E-01	2.81E+04	-1.436	1.51E-01	1
Condition:Time ot2: Time windows 1-2	-8.59E-02	6.64E-01	2.81E+04	-0.129	8.97E-01	1
Empathy:Time ot1: Time windows 1-3	4.05E-01	2.51E-01	2.81E+04	1.618	0.105777	0.8462
Empathy:Time ot1: Time windows 1-2	4.24E-01	1.43E-01	2.81E+04	2.971	0.002971	0.0238

Empathy:Time ot2: Time windows 1-3	2.02E-01	9.38E-02	2.81E+04	2.158	0.030955	0.2476
Empathy:Time ot2: Time windows 1-2	1.86E-01	7.31E-02	2.81E+04	2.543	0.01101	0.0881
Condition:Empathy:Time ot1: Time windows 1-3	2.87E-01	2.49E-01	2.81E+04	1.152	0.249387	1
Condition:Empathy:Time ot1: Time windows 1-2	1.10E-01	1.41E-01	2.81E+04	0.779	0.435876	1
Condition:Empathy:Time ot2: Time windows 1-3	-2.83E-02	9.32E-02	2.81E+04	-0.303	0.761737	1
Condition:Empathy:Time ot2: Time windows 1-2	1.73E-02	7.25E-02	2.81E+04	0.238	0.811542	1

B. Within Time Window 1 (0ms-675ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	8.87E-01	5.55E-01	8.31E+03	1.60E+00	1.10E-01	1
Empathy	-1.42E-01	6.16E-02	6.95E+03	-2.30E+00	0.0213	0.2556
Time ot1	-3.47E+01	3.62E+00	1.00E+04	-9.60E+00	< 2e-16	< .0001
Time ot2	-1.13E+01	1.43E+00	1.00E+04	-7.88E+00	3.73E-15	< .0001
Condition:Empathy	-3.02E-02	5.96E-02	9.85E+03	-5.07E-01	0.61231	1
Condition:Time ot1	5.51E+00	3.60E+00	1.00E+04	1.53E+00	1.26E-01	1
Condition:Time ot2	1.62E+00	1.42E+00	1.00E+04	1.14E+00	2.56E-01	1
Empathy:Time ot1	-8.67E-01	3.96E-01	1.00E+04	-2.19E+00	0.02868	0.3442
Empathy:Time ot2	-4.77E-01	1.57E-01	1.00E+04	-3.04E+00	0.00238	0.0286
Condition:Empathy:Time ot1	-2.47E-01	3.91E-01	1.00E+04	-6.31E-01	0.52775	1
Condition:Empathy:Time ot2	-9.66E-02	1.55E-01	1.00E+04	-6.25E-01	5.32E-01	1

C. Within Time Window 2 (675ms-1400ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	3.09E-01	1.16E-01	1.09E+03	2.67E+00	7.70E-03	0.0924

Empathy	-7.30E-03	1.28E-02	1.01E+03	-5.72E-01	0.5675	1
Time ot1	-3.51E+00	2.56E-01	1.08E+04	-1.37E+01	< 2e-16	< .0001
Time ot2	5.63E+00	6.69E-01	1.07E+04	8.42E+00	< 2e-16	< .0001
Condition:Empathy	-5.96E-03	1.20E-02	3.16E+03	-4.99E-01	0.6181	1
Condition:Time ot1	-1.22E+00	2.57E-01	1.08E+04	-4.75E+00	2.09E-06	< .0001
Condition:Time ot2	1.44E+00	6.71E-01	1.08E+04	2.15E+00	3.15E-02	0.3780
Empathy:Time ot1	5.17E-03	2.82E-02	1.08E+04	1.84E-01	0.8544	1
Empathy:Time ot2	-9.50E-02	7.36E-02	1.07E+04	-1.29E+00	1.97E-01	1
Condition:Empathy:Time ot1	-2.12E-02	2.82E-02	1.08E+04	-7.51E-01	0.4525	1
Condition:Empathy:Time ot2	-6.21E-02	7.37E-02	1.08E+04	-8.43E-01	3.99E-01	1

D. Within Time Window 3 (1400ms-1900ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	-4.21E-01	4.75E-01	7.32E+03	-8.85E-01	3.76E-01	1
Empathy	-1.72E-03	5.17E-02	7.36E+03	-3.30E-02	0.9735	1
Time ot1	5.01E+00	3.01E+00	7.37E+03	1.66E+00	9.63E-02	1
Time ot2	-2.30E+00	1.10E+00	7.37E+03	-2.08E+00	3.74E-02	0.4488
Condition:Empathy	-6.58E-02	5.16E-02	7.38E+03	-1.28E+00	0.2022	1
Condition:Time ot1	3.13E+00	3.02E+00	7.37E+03	1.04E+00	3.00E-01	1
Condition:Time ot2	-1.18E+00	1.11E+00	7.37E+03	-1.07E+00	2.86E-01	1
Empathy:Time ot1	5.20E-02	3.30E-01	7.37E+03	1.58E-01	0.8746	1
Empathy:Time ot2	-1.70E-02	1.21E-01	7.37E+03	-1.41E-01	0.8882	1
Condition:Empathy:Time ot1	4.08E-01	3.29E-01	7.37E+03	1.24E+00	0.215	1
Condition:Empathy:Time ot2	-1.62E-01	1.20E-01	7.37E+03	-1.35E+00	1.77E-01	1

Comparison 4. Confirmation-test and confirmation-filler

A. First inclusive model

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	7.57E-01	1.09E-01	1.11E+02	6.964	2.46E-10	< .0001
Empathy	-2.44E-02	1.87E-02	6.21E+01	-1.308	0.195752	1
Time ot1	7.01E+00	2.88E-01	4.18E+04	24.316	< 2e-16	< .0001
Time windows 1-3	-3.64E-01	1.27E-01	1.45E+02	-2.871	0.004704	0.0376
Time windows 1-2	-4.23E-01	1.05E-01	1.08E+02	-4.051	9.61E-05	0.0008
Condition:Empathy	1.35E-02	9.06E-03	1.05E+02	1.494	0.138239	1
Condition:Time ot1	7.46E-01	2.88E-01	4.19E+04	2.589	0.009633	0.0771
Empathy:Time ot1	2.15E-02	3.13E-02	4.18E+04	0.687	0.492167	1
Condition: Time windows 1-3	-1.73E-03	1.04E-01	2.00E+02	-0.017	0.986707	1
Condition: Time windows 1-2	-2.44E-01	7.48E-02	1.33E+02	-3.259	0.001418	0.0113
Empathy: Time windows 1-3	2.08E-03	1.13E-02	1.48E+02	0.184	0.854081	1
Empathy: Time windows 1-2	5.43E-03	9.59E-03	8.63E+01	0.566	0.572841	1
Time ot1: Time windows 1-3	-2.87E+00	3.51E-01	4.18E+04	-8.184	2.83E-16	< .0001
Time ot1: Time windows 1-2	-2.86E+00	3.10E-01	4.18E+04	-9.208	< 2e-16	< .0001
Condition:Empathy:Time ot1	1.09E-01	3.15E-02	4.18E+04	3.447	0.000568	0.0045
Condition:Empathy: Time windows 1-3	-2.56E-02	9.41E-03	2.91E+02	-2.722	0.006873	0.0550
Condition:Empathy: Time windows 1-2	-1.92E-02	6.59E-03	1.63E+02	-2.921	0.003986	0.0319
Condition:Time ot1: Time windows 1-3	-2.49E+00	3.50E-01	4.19E+04	-7.118	1.11E-12	< .0001
Condition:Time ot1: Time windows 1-2	-1.65E+00	3.11E-01	4.19E+04	-5.31	1.10E-07	< .0001
Empathy:Time ot1: Time windows 1-3	1.41E-02	3.81E-02	4.18E+04	0.371	0.710605	1
Empathy:Time ot1: Time windows 1-2	4.10E-02	3.36E-02	4.18E+04	1.22	0.222378	1

Condition:Empathy:Time ot1: Time windows 1-3	-4.55E-02	3.82E-02	4.19E+04	-1.189	0.234252	1
Condition:Empathy:Time ot1: Time windows 1-2	-1.27E-01	3.39E-02	4.19E+04	-3.757	0.000172	0.001376

B. Within Time Window 1 (0ms-675ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	9.47E-01	1.37E-01	1.79E+02	6.92E+00	7.75E-11	< .0001
Empathy	-2.96E-02	2.23E-02	7.77E+01	-1.33E+00	0.186787	1
Time ot1	1.10E+01	4.76E-01	1.45E+04	2.31E+01	< 2e-16	< .0001
Condition:Empathy	4.49E-02	1.21E-02	2.95E+02	3.72E+00	0.000239	0.0029
Condition:Time ot1	3.59E+00	4.75E-01	1.46E+04	7.55E+00	4.66E-14	< .0001
Empathy:Time ot1	-1.64E-02	5.13E-02	1.45E+04	-3.20E-01	0.748747	1
Condition:Empathy:Time ot1	2.33E-01	5.19E-02	1.46E+04	4.50E+00	6.85E-06	< .0001

C. Within Time Window 2 (675ms-1400ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	4.33E-01	1.33E-01	7.08E+01	3.25E+00	1.77E-03	2.12E-02
Empathy	-1.87E-02	2.04E-02	5.40E+01	-9.14E-01	3.65E-01	1
Time ot1	5.05E+00	4.49E-01	1.51E+04	1.12E+01	< 2e-16	< .0001
Condition:Empathy	4.00E-03	1.01E-02	5.18E+01	3.96E-01	0.69354	1
Condition:Time ot1	1.43E-01	4.51E-01	1.52E+04	3.17E-01	0.75113	1
Empathy:Time ot1	6.65E-02	4.88E-02	1.51E+04	1.36E+00	1.73E-01	1
Condition:Empathy:Time ot1	-3.20E-02	4.91E-02	1.52E+04	-6.51E-01	0.51474	1

D. Within Time Window 3 (1400ms-1900ms)

Fixed effects	Estimate	Std. Error	df	t value	p value	p adjusted
Condition	9.37E-01	1.91E-01	1.81E+02	4.90E+00	2.09E-06	< .0001
Empathy	-2.54E-02	2.40E-02	9.75E+01	-1.06E+00	0.2923	1
Time ot1	4.69E+00	5.80E-01	1.22E+04	8.08E+00	7.00E-16	< .0001
Condition:Empathy	-1.22E-02	1.78E-02	1.84E+02	-6.86E-01	0.49332	1
Condition:Time ot1	-1.89E+00	5.78E-01	1.22E+04	-3.27E+00	1.06E-03	0.0127
Empathy:Time ot1	1.24E-02	6.34E-02	1.22E+04	1.95E-01	0.84524	1
Condition:Empathy:Time ot1	1.34E-01	6.33E-02	1.22E+04	2.12E+00	3.44E-02	0.4128