Linguistic inferences from pro-speech music

Musical gestures generate scalar implicatures, presuppositions, supplements, and homogeneity inferences

May 2021

Abstract

Language has a rich typology of inferential types. It was recently shown that subjects are able to divide the informational content of new visual stimuli among the various slots of the inferential typology: when gestures or visual animations are used in lieu of specific words in a sentence, they can trigger the very same inferential types as language alone (Tieu *et al.*, 2019). How general is the algorithm that divides at-issue from non-at-issue content? We show that it extends to the auditory modality and to music cognition. We tested whether pro-speech musical gestures, i.e. musical excerpts that replace words in sentences, can give rise to the same inferences. We show that it is possible to replicate the same typology of inferences using pro-speech music. Minimal and complex musical excerpts can behave just like language, gestures, and visual animations with respect to the logical behavior of their content when embedded in sentences. Specifically, we found that pro-speech music can generate scalar implicatures, presuppositions, supplements, and homogeneity inferences.

Contents

1 Introduction

Natural language semantics has long evidenced the existence of a rich typology of content, showing that the meaning of sentences can be split up into different content types (Tonhauser *et al.*, 2013; Schlenker, 2018b). Projection, i.e. the preservation of inferences in the scope of various logical operators, has been one of the main tools used to individuate these various components of meaning (Schlenker, 2018a; Heim, 2002). Question formation, for instance, impacts different types of content in different ways. Consider the classical example of presuppositions and scalar implicatures. Sentence (1)a conveys two kinds of information: the speaker asserts that John does not smoke now, while taking for granted that John used to smoke. Such inferences, presuppositions, survive in different logical environments. When turning the sentence into a question in (1)b, the assertion that John stopped smoking is now questioned, but the presupposition that he used to smoke remains.

(1) a. John stopped smoking.
⤳ John used to smoke.

b. Did John stop smoking?
⤳ John used to smoke.

By contrast, consider the pattern of scalar implicatures in (2). Sentence (2)a conveys that John graded some but not all of the homeworks. Conversely, in (2)b, this implicature disappears.

(2) a. John graded some of the homeworks.
⤳ John graded some, but not all of the homeworks.

b. Did John grade some of the homeworks?
⤴ John graded some, but not all of the homeworks.

Where do these different patterns of projection originate? For some inferential types, and typically for presuppositions, it has been argued that the observed projection patterns are linked to the grammar of language (Levinson, 2000). On this view, the distinction between at-issue content, i.e. relevant for the truth conditions of a sentence, and non-at-issue content, is lexically encoded, i.e. determined on the basis of word meaning. The meaning of "stop" would for instance be divided as in (3).

(3) *x* stops *Q*-ing.
- At-issue: *x* does not *Q*.
- Presupposed: *x* *Q*-ed before.

For some other inferential types, such as scalar implicatures, and although similar theories of lexical encoding have sometimes been proposed, it has rather been argued that domain-general algorithms allow speakers to productively derive the observed typology of inferences from linguistically undifferentiated meanings. On this view, humans can divide at-issue content from non-at-issue content on the fly. Two predictions follow directly. First, if such general procedures exist, we expect to see their footprints in other aspects of our cognitive lives, i.e. the same mechanisms should not be restricted to intimately linguistic issues. Second, upon novel exposure, people should be able to arrange the content of a non-language-specific stimulus in the same way as they do for known, language-specific stimuli. Zero-shot learning is in a way a radical version of the poverty of the stimulus (Chomsky, 1980, 1988). Contextual conditions such as knowledge of specific words of a given language cannot be responsible for a systematic behavior in presence of novel stimuli. Consequently, there is no real alternative to the conclusion that humans already have an algorithm available to adequately arrange content in at-issue and non-at-issue before experience with a given linguistic item.

Both theoretical and experimental research on pro-speech gestures and pro-speech visual animations (i.e. gestures or visual animations replacing words in sentences) have corroborated these predictions. Schlenker (2019a) developed a typology of embedded gestural depictions replacing, following, or co-occurring with words, showing that, in particular, the content of pro-speech gestures can be divided among familiar slots of the inferential typology. Tieu *et al.* showed this experimentally. Consider (4) from Tieu *et al.* (2019):

(4) a. The student REMOVE_GLASSES.
⤳ The student currently has glasses on.

b. Will the student REMOVE_GLASSES?
⤳ The student currently has glasses on.

Here, REMOVE_GLASSES stands for the gesture mimicking someone removing their glasses. Sentence (4)a presupposes that, at the time of the utterance, the student has glasses on. Similarly, the question in (4)b still presupposes that the student has glasses on, just like the presupposition that John used to smoke was preserved under question in (1). Subjects were shown to be able to access this presuppositional content significantly more than control inferences. In general, Tieu *et al.* found that embedded visual stimuli can give rise to the same inferential types as purely linguistic ones. This suggests that the algorithm humans apply to divide at-issue content from non-at-issue content must be productive, and, because the stimuli were visual, it cannot be limited to language narrowly intended.

How general is the algorithm that divides at-issue content from non-at-issue content? Here we ask whether it extends to the auditory modality and to music cognition. We used pro-speech music, i.e. musical excerpts that replace words in sentences, henceforth *musical gestures*.[1] Building our paradigm after Tieu *et al.* (2019), we tested whether musical gestures can give rise to the same inferential typology as language, pro-speech gestures and pro-speech visual animations. For example, given a context where a person is hiking, sentence (5) behaved just like a change-of-state verb like "stop", and triggered the presupposition that the hiker is down a mountain both when embedded in a declarative sentence as in (5)a, and when it is embedded in an interrogative sentence as in (5)b.[2]

(5) a. The hiker will UPWARD_SCALE.[3]
⤳ The hiker is at the foot of a mountain.

b. Will the hiker UPWARD_SCALE?
⤳ The hiker is at the foot of a mountain.

UPWARD_SCALE stands for a minimal musical stimulus of a classical major scale played by a harp. In general, because of the intuitive mapping between gesture and meaning (Schlenker, 2019a), the informational content of iconic gestures can be grasped even in absence of previous exposure (Schlenker, 2017). The reader has plausibly never been exposed to (5)a or (5)b, but the content of the musical gesture UPWARD_SCALE can still be productively divided between at-issue content, *viz.* the hiker is going up, and presuppositional content, *viz.* at the time of utterance, the hiker is located at a low point in space. Crucially, the inference goes through even though (5)b is a question, which is a classical test for presupposition projection.

Here we are merely interested in the logical behavior of the informational content of musical sounds. This paper is not about how this content relates to the actual musical properties of the stimuli, i.e. about musical meaning and how it is derived. Still, we provide first insights into how this meaning can interact with the logical structures of language, which suggests the existence of a non-trivial informational content in music.[4]

Before we move on, let us address a potential worry concerning the methodology used here and in Tieu *et al.* (2019). There is the possibility that pro-speech music is systematically translated into words. In this case, there would be the possibility that the relevant inferences arise because they are lexically encoded in the words of the translation. Consequently, our results would be uninformative about the generality of the algorithm dividing content in at-issue and non-at-issue. Two reasons militate against this hypothesis. First, just as in Tieu *et al.* (2019), subjects of our experiment were able to interpret fine-grained gestural iconic information that was absent from the words of the closest verbal translation. Second, such verbal translations would make iconic dimensions at-issue

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[1]Alhtough 'musical gestures' are a specific kind of pro-speech music that refer to the iconic musical motives or excerpts we used in lieu of words here, as was done with actual gestures in Tieu *et al.* (2019), we use 'pro-speech music' and 'musical gestures' interchangeably throughout this paper.

[2]Except for the paradigm testing supplements in section 3.3, we mainly used basic scales, drum sounds or isolated tones. Our definition of these as music could be contested because of their simple nature. However, even if these stimuli did not count as music, our claims on the generality of the algorithm that divides content in at-issue and non-at-issue would remain unaltered.

[3]All musical gestures can be directly accessed by clicking on the hyperlinks.

[4]Recent work has suggested that music could in fact be said to have a semantics of its own (Schlenker, 2017, 2019b), but understanding the extent to which such a music semantics could play a role in the results we present here is a fascinating question that lies beyond the scope of the present work.

when not encoded in a verbal translation that lexically makes them non-at-issue, a behavior that seems to be excluded by the logical tests we provide in section 4.

This paper is structured as follows. In section 2, we detail the experimental setup. In section 3.1 we present the paradigm we used to test for scalar implicatures. Two stimuli involving respectively one and three repetitions of a drum sound competed and gave rise to scalar implicatures. In section 3.2, we present the paradigm we used to test for presupposition projection, already introduced in (5). While the presupposition was preserved under question formation, participants did not behave as expected in the classical test under "none". We discuss in detail possible explanations of the difference between our results and Tieu *et al.*'s. We then move on to other linguistic inferences and introduce a paradigm testing for supplements in section 3.3. Pro-speech music did indeed behave like a supplement, yielding the typical conditional projection. In section 3.4, we test homogeneity inferences from pro-speech music. There are different theoretical accounts of such inferences: some attribute the existence of homogeneity inferences to the noun phrase, others to the predicate. We prove "by case" that pro-speech music gives rise to homogeneity inferences both when it replaces the noun phrase and when it replaces the predicate. Finally, in section 4, we discuss in detail why it is unlikely that pro-speech music is systematically translated in words.

2   Methods

Stimuli were recordings of French sentences with musical gestures (either specifically generated for our purposes or pre-existing) either artificially generated through GarageBand (version 10.3.5) or taken from real music replacing one or some words.

We collected data on 68 participants. We excluded non-native French speakers, participants who had already taken one of our pilot experiment and participants who had failed the two attention checks, which left us with 53 subjects. Participants were recruited through the French platform Crowdpanel, and online informed consent was obtained for each of them. After a short training on three examples of hybrid sentences containing music, and for each stimulus, each participant had to assess to what extent the presented inference followed from the auditory stimulus (i.e. the spoken sentences with embedded music), using a slider bar ranging from 0, labeled *totally disagree* (in French: *pas du tout d'accord*), to 100, labeled *totally agree* (in French: tout à fait d'accord) (cf. Figure 1). Stimuli played automatically for each trial, but participants could listen to the stimulus as many times as needed. The experiment was set up on Qualtrics. All stimuli were fully randomized. In each section, we report comparisons of linear regression models using R (version 3.6.2.) to assess the significance of the contrasts in endorsement found between inferences (R core Team (2016); Barr *et al.* (2013)). The details of the stimuli are given in the next sections, for each type of inference.[5]

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Le prochain randonneur est au pied d'un rocher.

Pas du tout d'accord   Tout à fait d'accord

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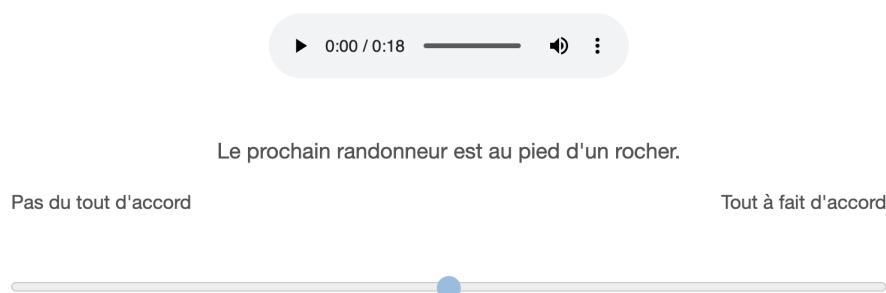
Figure 1: An example of a stimulus discussed in 3.2

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3 Replication of the typology of inferences

3.1 Scalar implicatures

3.1.1 In language and from visual stimuli

Scalar implicatures convey an implicit, strengthened meaning beyond the explicit or literal meaning of an utterance. Traditionally, they have been viewed as arising from pragmatic reasoning on the speaker's communicative intentions (Grice, 1975). According to Gricean approaches (Horn, 1972; Chierchia *et al.*, 2012), when a speaker utters a sentence, the listener evaluates it against a set of relevant alternatives, some of which are logically stronger than the utterance. Grice's maxime of quantity demands that speakers make their contribution (i) as informative as required, (ii) not more informative than required. Thus, the Gricean reasoning goes, if the speaker had meant a logically stronger alternative they would have uttered it. Because they did not, they believe it is false. For instance, in (6)a the speaker chose to utter "some" instead of the logically stronger "all", and is therefore inferred to mean *some but not all*. More recently, some theorists have argued that the mechanism responsible for scalar implicatures is a grammatical one (Chierchia *et al.*, 2012). On this view, a silent operator with a meaning very similar to *only* is applied to scalar sentences: the inference in (6)b is the result of interpreting "some" in (6)a as *only some*.

(6) a. He read some of the books.
    ⤳ b. He read some, but not all of the books.

(Tieu *et al.*, 2019) showed that scalar implicatures arise from gestures and visual animations. For instance, in the positive environment in (7) where TURN_WHEEL stands for the gesture mimicking a driver turning a wheel, we understand that TURN_WHEEL does not only mean *to turn* but *to turn somewhat, but not a lot*. TURN_WHEEL competes with the more informative gesture TURN_WHEEL_COMPLETELY, which is not used, thus taken to be false.

(7) a. He will TURN_WHEEL_COMPLETELY.
    ⤳ He will turn the wheel completely.

    b. He will TURN_WHEEL.
    ⤳ He will turn the wheel, but not completely.

The inference in (7)b. could be explained by the fact that TURN_WHEEL semantically means *to turn somewhat, but not completely*. In this case, however, we would expect *not*-TURN_WHEEL to mean *to not turn somewhat*.

(8) a. He will not TURN_WHEEL_COMPLETELY.
    ⤳ He will turn the wheel, but not completely.

    b. He will not TURN_WHEEL.
    ⤳ He will not turn the wheel at all.

We rather understand from (8)b that the wheel was not turned at all. The informativity pattern gets reversed under negation, just like in language. *not*-TURN_WHEEL is now logically stronger than not-TURN_WHEEL_COMPLETELY. The inferences in (8) thus derive from a competition between both gestures. It is a typical scalar implicature.

3.1.2 From music

We reasoned that realizations with different numbers of repetitions of a sound could be represented by speakers as a logical scale (Horn, 1972). We generated two different realizations of the timpani sound DRUM (from GarageBand instruments library): the weaker DRUM×1 and the stronger DRUM×3. We first set up a context introducing the stronger alternative:

(9) **Context (positive environment):** Jean boxes regularly at the gym. During last week's workout, he had a lot of energy, and was able to DRUM×3.

In the target premise (10), DRUM×1 competes with the more informative alternative DRUM×3:

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(10) **Target premise**
This week, Jean will DRUM×1.

Original stimulus

Cette semaine, Jean va DRUM×*1.*
This week, Jean will DRUM×1.

If DRUM×1 forms a scale with DRUM×3, the stronger alternative DRUM×3 should be taken to be false if not realized. We expect speakers to draw the inference that John will punch somewhat, but not a lot:

(11) **Target inference**
This week, John is going to punch somewhat, but not a lot.

In the control stimulus in (12), we did not vary the number of repetitions:

(12) **Control premise**
This week, Jean will DRUM×3

Original stimulus

Cette semaine, Jean va DRUM×*3.*
This week, Jean will DRUM×3.

Because in (12) the informativity of the stimulus is not manipulated, we expect speakers to stick with the context and endorse the baseline inference in (13) when given the control premise.

(13) **Baseline inference**
This week, Jean will punch a lot.

Just like for linguistic stimuli, the critical test is negation. The expected pattern for the positive environment may otherwise be explained as follows: DRUM×3 conveys that Jean will punch a lot because DRUM×3 means *to punch exactly three times*, i.e. two or less or four or more. To rule out this alternative explanation, we set up a context in which both alternatives were introduced:

(14) **Context (negative environment):** Jeanne is boxing at the gym. At last week's session, she had a lot of energy, and was able to DRUM×3. But during the second week of training, she did not DRUM×1.

If the two realizations form a scale, under negation, informativity should be reversed: *not-*DRUM×1 constitutes a more informative alternative with respect to *not-*DRUM×3:

(15) **Target premise**
This week, Jeanne will not DRUM×3.

Original stimulus

Cette semaine, Jeanne ne va pas DRUM×*3.*
This week, Jeanne NEG will not DRUM×3.

If DRUM×3 means *to punch exactly three times*, we expect its negation to mean *not punch exactly three times*, i.e. two or less, or four or more. If on the other hand the two realizations form a scale, as we argue, we expect *not-*DRUM×3 to convey that although not a lot, some punching still occurred, as in (16) below.

(16) **Target inference**
This week, Jeanne will punch somewhat, but not a lot.

And similarly for the weaker realization: if DRUM×1 means *to punch exactly once*, then *not-*DRUM×1 should mean *not punching exactly once*. This yields an inference pattern different from what is expected under our hypothesis that *not-*DRUM×3 forms a scale with *not-*DRUM×1. In this case, *not-*DRUM×1 should convey that there was no punching at all.

(17) **Control premise**

This week, Jeanne will not DRUM×1.

Original stimulus

Cette semaine, Jeanne ne   va   pas DRUM×1.
This   week,   Jeanne NEG will not DRUM×1.

We thus expect *not*-DRUM×1 to be interpreted as *did not punch at all* rather than *did not punch exactly once*, which would allow for punching more than once:

(18) **Baseline inference**

This week, Jeanne will not punch at all.

3.1.3 Results

We expected a higher endorsement of the target inference for the target premise in both the positive and the negative environment. In the positive environment, we found a significant effect of inference type, i.e. a higher endorsement of the target inference compared to the baseline inference ($\chi^2 = 170$, $p < 0.001$). In the negative environment, participants endorsed the baseline inference significantly more than the target inference ($\chi^2 = 21$, $p < 0.001$).
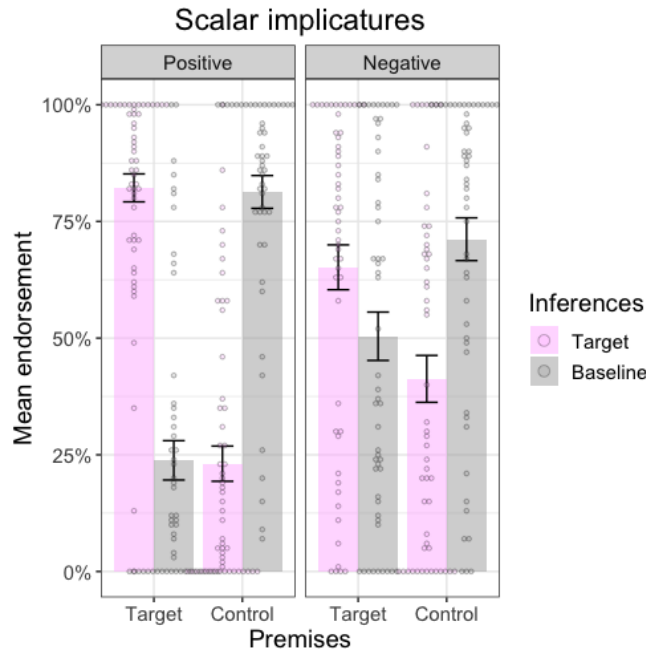

Figure 2: Mean endorsement rate for scalar implicatures

3.1.4 Discussion

In the positive environment, as expected, DRUM×1 competes with the more informative alternative DRUM×3 so that DRUM×1 is understood as *to punch somewhat but not a lot.* In the negative environment, *not*-DRUM×3 competes with *not*-DRUM×1. Thus *not*-DRUM×3 was interpreted as *punch somewhat, but not a lot.* This shows that subjects computed scalar implicatures.

What do our results say about the grammatical and the productive perspectives on implicatures mentioned in 3.1.1? Consider a first scenario in which one single mechanism can yield all scalar implicatures. Given our results,

this mechanism must be applicable to musical gestures. As mentioned, if the algorithm is a pragmatic, general-purpose one, this is not particularly surprising. On the other hand, at least *prima facie* our results are slightly more surprising if the mechanism is grammatical: musical gestures fall outside the traditional definitions of grammar. However, the mere fact that pro-speech gestures (gestures, animations, music) can be interpreted may call for an extension of these definitions. To wit, the fact that a pro-speech gesture can replace a verb and be interpreted as such shows that the syntax has access to it.

In general, our results call for further investigation. One promising avenue for future research is to test whether musical scalar implicatures can be embedded. If the embedding of implicatures is evidence for the grammatical approach in language, then the same should hold for pro-speech music.

Now consider a second scenario, in which more than one mechanism yields scalar implicatures. In this case, a grammatical mechanism may be responsible for purely linguistic scalar implicatures while a general-purpose, pragmatic one allows speakers to draw inferences from different realizations of musical gestures. It is enough for speakers to be able to arrange such realizations on scales; Gricean reasoning on logical strength will do the rest. Independently of whether clause-level implicatures are grammatical or not, there is good evidence that quantity implicatures can arise at the discourse-level, thus as a result of Gricean reasoning (Geurts, 2010).[6] In this case, a general-purpose mechanism would arrange the realizations on a scale, while Gricean reasoning would yield the strengthening responsible for the scalar implicature.[7]

3.2 Presuppositions

3.2.1 In language and from visual stimuli

A presupposition is a meaning component that is taken for granted that must follow from the local context of an expression, and which sentences inherit across different logical operators, such as negation (Stalnaker, 1974; Heim & Kratzer, 1998). In language, some particular expressions are associated with the triggering of presuppositions. For instance, in (19), the presupposition that John used to smoke is triggered by "stop". In general, change-of-state verbs (e.g. "start", "become", "stop") all presuppose their initial state. For John to be able to stop smoking, John must have been smoking to begin with.

Presuppositional content is untouched by logical operations that change the meaning of a sentence, such as negation, modality, and questions (Abusch, 2010; Abrusán, 2011; Chemla, 2009). For instance, the question in (19)b still presupposes that John used to smoke.

(19) a. John stopped smoking.
⤳ John used to smoke.

  b. Did John stop smoking?
⤳ John used to smoke.

Interestingly, embedding under "none" gives rise to a universal inference, as shown in (20).

(20) None of the students stopped smoking.
⤳ Each student used to smoke.

Tieu *et al.* (2019) found that presuppositions could also be generated by means of pro-speech gestures and visual animations, and that they were preserved both under question formation and under "none". Consider (21):

(21) **Context** Aliens are green. But when they are in a meditative state, their antennae are blue. There is a meditation session in progress on the first floor of an architecture firm. Jane is watching the union representatives and says:

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[6]Cf. Grice's famous example of a letter of recommendation, conveying that a student is bad without asserting it explicitly: "Mr. Smith's command of English is excellent, and his attendance at tutorials has been regular."

[7]Note that embedding is crucial here as well: if pro-speech musical gestures can trigger embeddable implicatures, then either the grammatical approach to implicatures must be extendable to pro-speech music, or inherently pragmatic processes must be able to trigger such inferences.

(22) "Will the union representatives' antennae GREEN_TO_BLUE?" [8]
    (animation content: *bar is green at first, then slowly whole bar goes blue*)

    ⤳ The union representative is currently not in a meditative state.
    ⇸ The union representative is currently in a meditative state.

(23) "None of the union representatives' antennae will GREEN_TO_BLUE"

    ⤳ None of the union representatives are currently in a meditative state.
    ⇸ Some of the union representatives are currently in a meditative state.

The context used in (21) introduces the two states between which the transition denoted by the visual animation GREEN_TO_BLUE can be made. When turning from green to blue, the embedded visual animation triggers the presupposition that the initial state denoted by the green color is true, i.e. the individual is not in a meditative state. This inference arises both in an interrogative environment, as shown in (22), and under "none", as shown in (23).

3.2.2 From music

We tested whether pro-speech music could generate presuppositions. Consider the context below:

(24) ***Context***: Some hikers are hiking in the mountains, where there can be significant drops and peaks in elevation. They alternate between reaching the top and the foot of steep rocks. Two of them, who finished first, are talking while waiting for the others.

We used an upward scale played by a harp to evoke a hiker going up a mountain, as in (25).

(25) **Target premise (question)**
    One asks the other: "Will the next hiker UPWARD_SCALE?"

    Original stimulus:

    L' un demande à l' autre : "Est ce que le prochain randonneur va UPWARD_SCALE?"
    The one asks   to the other : "Is   it that the next   hiker   will UPWARD_SCALE?"

Question formation is a classical test for presupposition (Chemla, 2009; Tieu *et al.*, 2019). In (25), if the initial state of the musical scale is presupposed rather than at-issue, the sentence should presuppose that the hiker is at the bottom of a rock. We thus expect the target inference in (26) to be more endorsed than its negation, the baseline inference in (27).

(26) **Target inference**
    The next hiker is at the foot of a rock.

(27) **Baseline inference**
    The next hiker is not at the foot of a rock.

Following Tieu *et al.* (2019)'s paradigm on pro-speech gestures and visual animations, we also performed a test under "none" instead of simple negation, as shown in (28).

(28) **Target premise under 'None'**
    One tells the other: "None of the hikers will UPWARD_SCALE".

    Original stimulus

    L' un dit à l' autre : "Aucun des randonneurs ne   va UPWARD_SCALE.
    The one tells to the other : "None the hikers   NEG will UPWARD_SCALE.

Presuppositions project universally out of "none". For instance, the sentence "None of my friends stopped smoking" presupposes that *all of my friends used to smoke*. We thus expected the universal inference in (29) to be more endorsed than its negation, the baseline inference in (30).

(29) **Target inference**
     Each of the hikers is at the foot of a rock.

(30) **Baseline inference**.
     Not all of the hikers are at the foot of a rock.

3.2.3 Results

We expected both target inferences to be more endorsed than the control inferences. Under question formation, as expected, we found a significant effect of inference type ($\chi^2 = 6$, $p < 0.05$), i.e. the target premise was significantly more endorsed than the baseline inference. However, although significant ($\chi^2 = 22$, $p < 0.001$), the contrast under "none" displayed the exact inverse pattern.
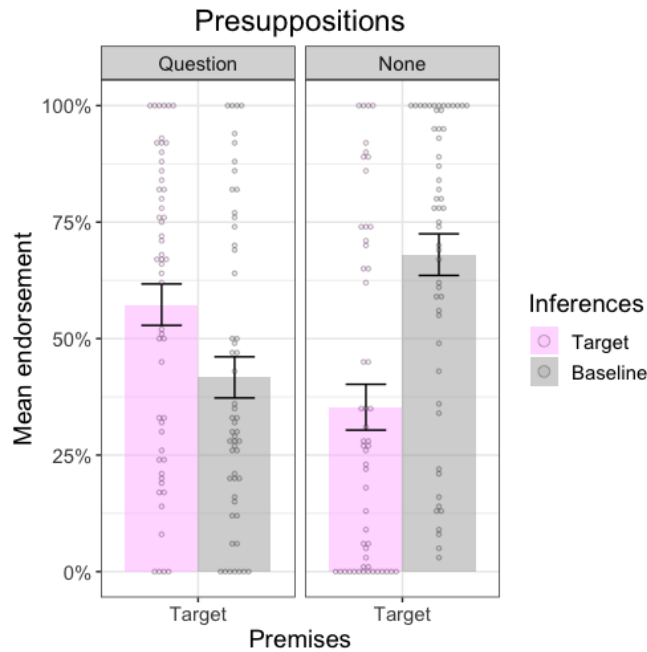

Figure 3: Mean endorsement rate for presuppositions

3.2.4 Discussion

In the interrogative environment, as expected, participants judged the initial state of UPWARD_SCALE to be true at the time of the utterance. Participants computed the initial state as non-at-issue, a behavior that matches the inferential pattern of change-of-state verbs. To wit, if the initial state had been at-issue, the question would have targeted the information that the hiker is at the bottom, amounting to something like "Is the hiker at the bottom and will he go up?". Instead, the question only targeted the change of state, asking something like "Will the hiker go up?". They did so by relying on a productive algorithm, as they had probably never been exposed to such a sentence.

On the other hand, UPWARD_SCALE embedded under "none" did not give rise to the expected universal inference that "Each of the hikers was at the foot of a rock". One conceivable explanation for this unexpected behavior touches upon a specific feature of our context (in (24), reported below):

(24) Some hikers are hiking in the mountains, where there can be significant drops and peaks in elevation. They alternate between reaching the top and the foot of steep rocks. Two of them, who finished first, are talking while waiting for the others.

It is possible that participants inferred that not all of the hikers were at the bottom of a rock because the two characters discussing were at the top of a rock already, given that the context states that *they have already finished*. Let us again look at sentence (20), reported below.

(20) **Target premise (question)** One tells the other: "None of the hikers will UPWARD_SCALE?"

If there is a domain restriction of the noun phrase "the hikers" that excludes the two hikers at the top, i.e. if "the hikers" is understood as referring to all hikers except the two who have finished and discuss, the inference in (29), reported below, should be true.

(29) **Target inference**
Each of the hikers is at the foot of a rock.

This is, however, not what we observed: the inference that some of them are at the bottom was more endorsed. It is possible that the domain of "the hikers" in the target inference in (29) *includes* the two hikers discussing. In this case, if the hikers are interpreted to be at the top of the hill while discussing, this makes the target inference in (29) false.

One further possible explanation for the difference in inferential pattern with respect to Tieu *et al.* (2019) is that it might be easier to convey absolute initial states in the visual modality than in the auditory modality. In Tieu *et al.* (2019), the visual animation of a green bar becoming blue (GREEN_TO_BLUE) was used to refer to the color change in the antennae of aliens introduced in the context. In our own paradigm, the first note of the musical scale was used to refer to the level at which the hiker was located in space. While in our context any point on the rock can be denoted by the first note of the scale, the initial state "green" in Tieu et al.'s stimulus can only be interpreted as absolute, i.e. no other point on the color spectrum is compatible with this initial state. Then, some of the hikers may fail to climb up while (i) being in a position to climb up, i.e. not at the top, and (ii) not being at the foot of the rock (but higher). This would explain why subjects thought that not all of the hikers were at the foot of a rock.

Finally, it is worth noting that different patterns of presupposition projection have been evidenced in language. For instance, Zehr *et al.* (2016) and Sudo *et al.* (2012) have shown the availability of existential readings of sentences under "none". These would be compatible with the inference endorsed by the subjects of our experiment, "Not all of the hikers are at the foot of the rock". However, before concluding that pro-speech music does not project universally under "none", the concerns we raise here should be addressed by experimental work using (i) a context with a clearer domain of predication and (ii) stimuli with an absolute initial state. It is worth noting, too, that the effect size in Tieu *et al.* was itself not big, although the contrast went in the expected direction. Still, the difference we observed with respect to their results is a puzzling problem for future research.

3.3 Supplements

3.3.1 In language and from visual stimuli

Supplements are inferences triggered by non-restrictive relative clauses that behave like independent sentences (Potts, 2004; Schlenker, 2019a). For instance, sentence (31)a below is understood as (31)b and not as (31)c.

(31) a. It is unlikely that Robin lifts weights, which is harmful.
    b. It is unlikely that Robin lifts weights. This is harmful.
    c. It is unlikely that Robin lifts weights and that this is harmful.

Tieu *et al.* (2019) found that both gestures and visual animations used in lieu of a non-restrictive relative clause gave rise to the conditional presupposition characteristic of supplements. For instance, in (32), the gesture HIT replaces a non-restrictive relative clause similar to "which involves hitting". The informational content of the gesture is not at-issue here, i.e. it is not target by "if", hence the inference that if the event under question happens, it will involve some hitting.

(32) If June bugs a classmate today - HIT, she will get a detention.
   ⤳ If June bugs a classmate today, it will involve hitting her.

By contrast, in (33), the content of the gesture is made at-issue by the use of "and does so *like this*". The way in which the bugging happens, i.e. by hitting, is now made at-issue and thus targeted by the conditional, hence the weaker inference that hitting will not necessarily be involved.

(33) If June bugs a classmate today and does so like this - HIT, she will get a detention.
   ⤳ If June bugs a classmate today, it will not necessarily involve hitting her.

3.3.2   From music

We used an excerpt of real film music by American composer Bernard Herrmann from the soundtrack of the movie *Psycho* to denote a scary dog coming closer to the character in the context shown in (34).[9] We reasoned that a rich musical gesture with a non-ambiguous emotional content could be informative about the scene while being interpreted as a non-restrictive relative clause.

(34) **Context:** Marie is walking back home. She spots a dog on the other side of the street. She sometimes worries about dogs, because some of them can be vicious - PSYCHO.

In the target premise in (35), PSYCHO behaves like a non-restrictive relative clause. It conveys that if the dog comes closer, it will look somewhat dangerous or scary.

(35) **Target premise**
   If the dog comes to her - PSYCHO, Marie will cross the street.

   Original stimulus

   Si le chien s' approche d' elle - PSYCHO, Marie changera de trottoir.
   If the dog self approaches to her - PSYCHO, Marie changes of sidewalk.

If the musical gesture PSYCHO logically behaves like a non-restrictive relative clause, we expect the target sentence in (35) to give rise to the target inference in (36), in which the behavior of the dog is not at-issue, thus not targeted by the conditional.

(36) **Target inference**
   If the dog comes to Mary, it will look vicious.

To ensure that the musical gesture PSYCHO was not interpreted as a non-restrictive relative clause in the control premise in (37), we used the deictic "this" in "and does so like **this** - PSYCHO" to make the informational content of the musical gesture at-issue.

(37) **Control premise**
   If the dog comes to her and does so like this - PSYCHO, Marie will cross the street.

   Original stimulus

   Si le chien s' approche d' elle et qu' il le fait comme ça - PSYCHO, Marie
   If the dog self approaches to her and that it-NOM. it-ACC. does like this - PSYCHO, Marie
   changera de trottoir.
   changes of sidewalk.

The use of "this" now makes the informational content of the musical gesture at-issue and thus targeted by the conditional "if", leading to the inference in (38) that the dog will not necessarily look vicious. Just like Tieu *et al.* (2019), we opted for a simpler formulation of the weaker control inference in (38) instead of the more convoluted exact negation of the target inference, "It is not the case that if the dog comes to Mary, it will look threatening."

(38) **Baseline inference**
   If the dog comes to Mary, it won't necessarily look vicious.

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[9]In this paradigm, we embedded complex music in language and uncovered rich linguistic inferences. A non-trivial extension of our paradigm may in future test if such logical inferences can arise in purely musical environments.
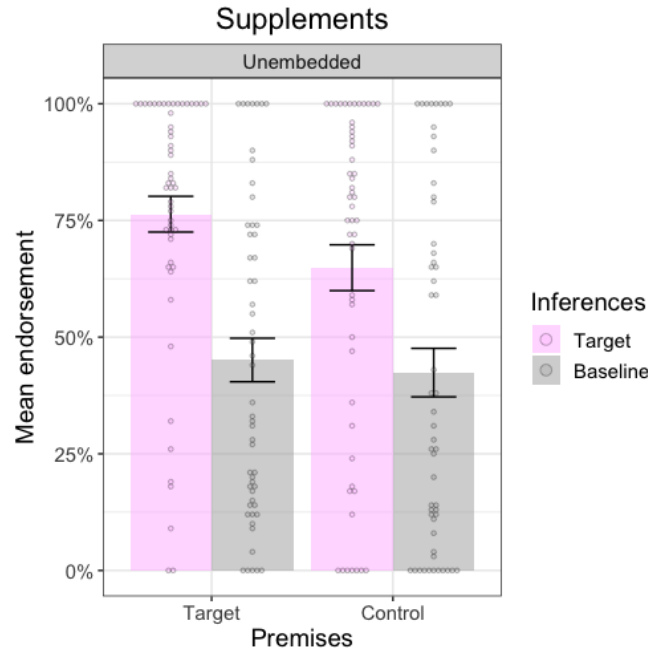
3.3.3 Results

Figure 4: Mean endorsement rate for supplements

If participants accessed the supplement from the target premise, we expected to find a higher endorsement of the target inference compared to the baseline inference. As expected, we found a significant statistical interaction between inference type and premise type ($\chi^2 = 31$, $p < 0.001$). Interestingly, we found the same unexpected pattern for the control inference as in Tieu *et al.* (2019).

3.3.4 Discussion

The paradigm we used was slightly different from the test for supplements in Tieu *et al.* (2019), as we chose to introduce the content of the music explicitly in the context, while in Tieu *et al.* (2019), the gesture HIT mimicking a punching only occurred in the target sentences. We reasoned that introducing the content of the gesture would not affect its logical behavior. On the one hand, indeed, introducing the content of a pro-speech gesture would have jeopardized the validity of the results for inferences that can be easily lexically encoded, such as presuppositions under certain theories. On the other hand, because non-restrictive relative clauses are sentence-level constructions, there is not even the possibility that they are encoded in the meaning of a specific word.

Our paradigm did not aim at showing that subjects could derive a meaning from music but, rather, that they could treat a musical gesture as a non-restrictive relative clause when given its meaning. We thus introduced this meaning explicitly in the context, so that participants did not reject the target inference only because they perceived the excerpt as conveying a feeling other than fear. In Tieu et al's, the gesture HIT mimicking someone hitting someone else was used in lieu of a non-restrictive relative clause. It is quite unambiguous that HIT means something like *hit*. On the other hand, the meaning of the musical gesture, an excerpt from real complex film music, would have been hardly the same for all participants.[10] [11]

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[10] Although this music unambiguously conveys a feeling of fear, danger or suspense, there are many possible situations this music can refer to that would trigger such feelings, considering that music can indeed refer to several external non-musical situations sharing some structural and/or emotional properties (Schlenker, 2017, 2019b)

[11] As music is never directly used to communicate ideas or convey information about the world, investigating the intermediary case of onomatopoeia may bridge our findings with the results from Tieu *et al.* (2019). Since onomatopoeia are both used in combination of language and highly iconic, there are substantial reasons to believe that any of the inference types from the typology we replicated with musical gestures can just as well be replicated with onomatopoeia. To this end, we ran a similar experiment with onomatopoeia instead of musical stimuli.

3.4 Homogeneity inferences

3.4.1 In language and from visual stimuli

Homogeneity inferences arise from definite plural noun phrases behaving universally in positive sentences, but existentially under negation (Križ, 2015; Križ & Spector, 2020; Spector, 2013; Löbner, 2000; Križ, 2016; Gajewski, 2005). Sentence (39)a has a universal reading: we understand that Mary found all of her presents. Under negation, however, the definite plural has an existential reading (i.e. "at least one"). Sentence (39)b is understood as *Mary did not find any of her presents*, and not as *Mary found some, but not all of her presents*, which involves the logical negation of "all of her present".

(39) a. Mary found her presents.
       ⤳ Mary found all of her presents.

      b. Mary did not find her presents.
       ⤳ Mary did not find any of her presents.

Tieu *et al.* (2019) investigated whether pro-speech gestures and visual animations used in lieu of both a verb *and* a definite plural noun phrase could generate homogeneity inferences. For instance, in (40) and (41), the gesture TAKE-2-HANDED-RIGHT replaced both a verb meaning *take* and a definite plural. The definite component was realized by means of pointing, and the plural component was realized by means of the iteration of a gesture representing a coin, which is a common way of signaling plural in sign languages (Pfau & Steinbach, 2006). In the positive environment in (40), the pro-speech gesture triggers the universal inference that all coins were indeed taken.

(40) Sam will TAKE-2-HANDED-RIGHT.
       ⤳ Sam will take all of the coins.

Under negation, sentence (41) gives rise to an existential reading of the gesture TAKE-2-HANDED-RIGHT ("at least one coin") instead of the universal reading found in the positive environment ("all of the coins"). *Not*-TAKE-2-HANDED-RIGHT is interpreted as *not at least one coin*, i.e. no coin at all, rather than *not all of the coins*, i.e. some but not all of the coins.

(41) Sam will not TAKE-2-HANDED-RIGHT.
       ⤳ Sam will not take any coin.

While most research on homogeneity inferences focuses on the role of the noun phrase, more recent work has suggested that these inferences rather originate in the predicate associated with the noun phrase (Križ, 2019). We thus proceeded by case: in section 3.4.2.1, we report the results for stimuli in which the musical gesture replaced a noun phrase, while in section 3.4.3.1 we report a parallel paradigm but with the musical gesture in lieu of the predicate.

3.4.2 From music

3.4.2.1 Pro-speech music in lieu of the noun phrase

While the two components of the definite plural were visually realized in Tieu *et al.* (2019), it was not possible to realize them both in the auditory modality. The auditory counterpart of iteration, marking plural, was straightforward, and we used the iteration of a same musical note to mark plural. Crucially, however, we could not find an auditory counterpart of pointing to reproduce the definite component. We thus chose to focus on manipulating the iterative component only and on verifying that the musical gesture was interpreted as a definite plural.

In (42), HARP×3 stands for three repetitions of a same harp sound evoking three harp players in an orchestra, while FLUTES×3 stands for three repetitions of a same flute sound evoking three flute players in the same context.

(42) **NP Positive Context:** Every Thursday, the students of a music school are gathering, and the conductor chooses some of them to play for the evening concert. Tonight, three harp-players - HARP×3 and three flute-players FLUTE×3 are present.

Results were not significant for all inference types (see Appendix for details). However, the results were not significantly different across the two experiments, leaving open the possibility that the onomatopoeia experiment, which we ran on less participants, was lacking power.

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We performed a first test in a positive environment, as shown in (43).

(43) **Target positive premise**
The conductor made HARP×3 play.

    Original stimulus

Le   chef d' orchestre a   fait   jouer HARP×*3.*
The chief of orchestra has made play   HARP×3.

The musical gesture HARP×3 is expected to have a universal reading and be interpreted as *all harps*, leading to the inference in (44), which we expect to be significantly more endorsed than its negation, the baseline inference in (45).

(44) **Target inference**
All harps played.

(45) **Baseline inference**
Some but not all of the harps played.

Negation constitutes a crucial test to correctly explain the pattern observed in the positive environment, for two reasons. First, homogeneous expressions behave as existentials in negative environments. Second, an alternative explanation of the pattern we observe for the positive environment is that HARP×3 elicits a numeral, i.e. *exactly three harps*. Under negation, the two explanations come apart.

If HARP×3 is understood as a numeral, i.e. *three harps*, its negation *not-HARP×3'* should mean *not exactly three harps*, i.e. two or less, or four or more. This is compatible with the control in (48). If, by contrast, HARP×3 is understood as a definite plural, we expect it to be interpreted existentially under negation, i.e. *not-HARP×3* is interpreted as *not at least one harp*, i.e. no harp at all.

(46) **Target negative premise**
The conductor did not make HARP×3 play.

    Original stimulus

Le   chef d' orchestre n'   a   pas fait   jouer HARP×*3.*
The chief of orchestra NEG has not made play   HARP×3.

If HARP×3 is interpreted as a definite plural, then we expect a higher endorsement of the homogeneous target sentence in (47) resulting from an existential reading of the musical gesture under negation, compared to the baseline inference in (48) resulting from a universal reading of the musical gesture (i.e., "The conductor did not make *all harps* play").

(47) **Target inference**
No harp played.

(48) **Baseline inference**
Some but not all of the harps played.
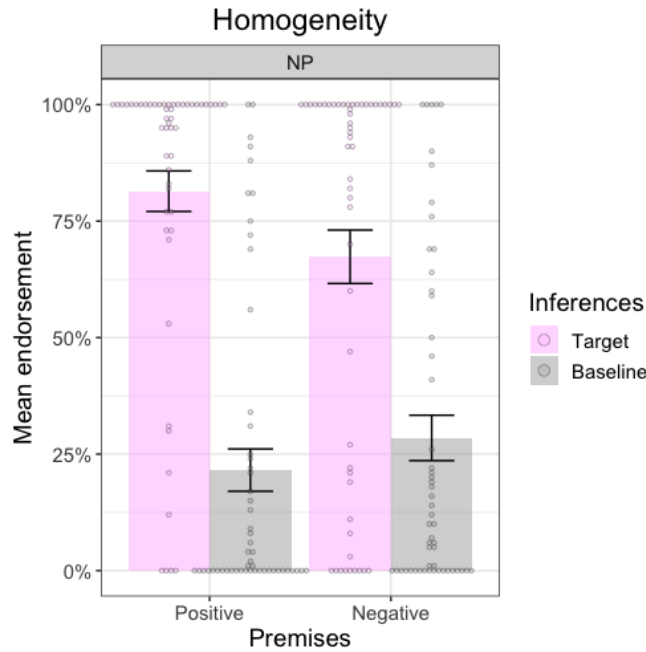
3.4.3 Results

Figure 5: Mean endorsement rate for homogeneity (NP)

The results show a significant effect of inference type in both the positive ($\chi^2 = 66$, $p < 0.001$) and the negative environments ($\chi^2 = 24$, $p < 0.001$), and provide evidence that the target sentences behaved homogeneously, i.e. HARP×3 had a universal reading in the positive environment, and an existential reading under negation. This suggests that pro-speech musical sounds replacing plural noun phrases can produce homogeneity inferences.

3.4.3.1 Pro-speech music in lieu of the predicate

Recent work suggested that homogeneity inferences might not be systematically linked to a definite plural noun phrase, but rather to the kind of predicate associated with the noun phrase (Križ, 2019). If definite noun phrases were responsible for homogeneity inferences, it would be difficult to explain how non-homogeneous readings arise from sentences like (49).

(49) The students are numerous.
 a. ?? Each of the students is numerous.

Križ (2019) argues that predicates, rather than bare plurals, are responsible for the presence or absence of homogeneity . While in Tieu *et al.* (2019), the test for homogeneity involved the gesture TAKE_ALL encompassing both the predicate TAKE and a definite plural noun phrase THE_COINS, the test we presented in section 3.4.2.1 only involved a musical gesture replacing the noun phrase.

Since there is the theoretical possibility that homogeneity comes from the predicate, we also tested whether sentences in which pro-speech music is inserted in lieu of the *predicate* can give rise to homogeneity inferences as well. In (50), the musical gesture MARSEILLAISE featuring a children's choir singing the French national anthem was used to evoke the action of singing.

(50) **Positive Context (predicate)**
 The students of a class are learning to sing the Marseillaise - MARSEILLAISE.

We applied the same protocol as in section 3.4.2.1. We performed a first test in a positive environment, where we expected sentence (51) to give rise to the universal inference in (52).

(51) **Target positive premise**
On the 14th of July, the class has MARSEILLAISE.

Original stimulus

Le   jour du 14   juillet, la   classe a   MARSEILLAISE.
The day of 14th July,   the class   has MARSEILLAISE.

(52) **Target inference**
The children in the class all sang the Marseillaise.

Just as in 3.4.2.1, the target inference in (52) needs to be contrasted with the non-universal baseline inference in (53).

(53) **Baseline inference**
Some but not all of the children in the class sung the Marseillaise.

We then performed a second test in a negative environment, i.e. the predicate MARSEILLAISE was in the scope of negation, as in (54).

(54) **Target negative premise**
On the 14th of July, the class did not MARSEILLAISE.

Original stimulus

Le   jour du 14   juillet, la   classe n'   a   pas MARSEILLAISE.
The day of 14th July,   the class   NEG has not MARSEILLAISE.

The negation of the musical predicate (*not*-MARSEILLAISE) now applies homogeneously to each member of the set denoted by the group singular noun phrase "the class", leading to the inference in (55) that no child in the class sang the Marseillaise, which we expected to be highly endorsed.

(55) **Target inference**
None of the children in the class sang the Marseillaise.

By contrast, we expected a low endorsement of the logical negation of this inference, i.e. the weaker baseline inference in (56) that some but not all of the children in the class sang the Marseillaise.

(56) **Baseline inference**
Some but not all of the children in the class sung the Marseillaise.

In this paradigm, none of the tested inferences involve a definite plural noun phrase, so that the effect of the musical predicate could be isolated if there is one. If the sentence gives rise to a homogeneity inference, we expect a strong endorsement of the target inferences (i.e. a universal reading of the sentence in the positive environment, and an existential one under negation) compared to the baseline inference.

An intuitive objection is that these inferences are not due to the predicate but to the group singular noun phrase "the class". In this case, however, the homogeneity inference originates in the noun phrase and thus our paradigm presented in 3.4.2.1 provides the relevant evidence. If, on the other hand, homogeneity originates in the predicate, the results presented in this section provide evidence that pro-speech music predicates can give rise to homogeneity inferences.
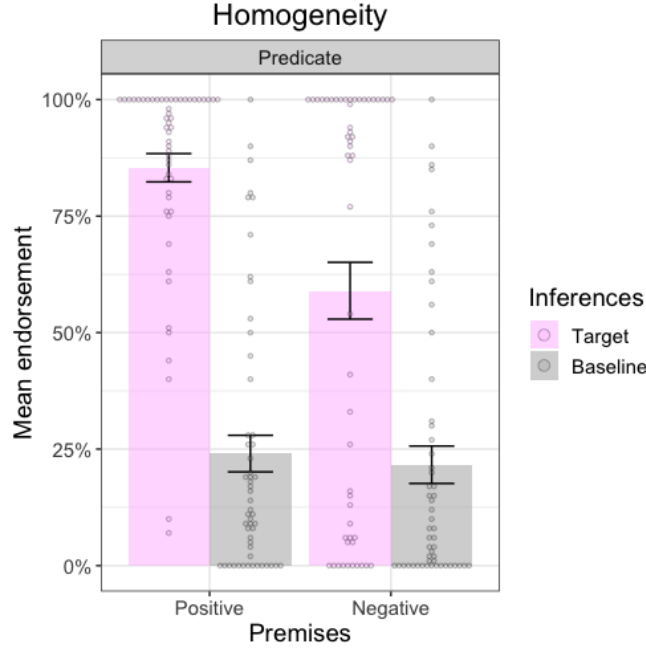
Figure 6: Mean endorsement rate for homogeneity (predicate)

The results show a significant effect of inference type in both the positive ($\chi^2 = 96$, $p < 0.001$) and the negative environments ($\chi^2 = 24$, $p < 0.001$). This suggests that it is possible to give rise to homogeneity inferences by means of a musical gesture replacing the predicate instead of the definite plural noun phrase.

4 Iconicity controls

4.1 Experimental paradigm

As mentioned in section 1, an alternative explanation of our data is that musical gestures gave rise to the observed inferences simply because they are systematically translated into words. Note that Tieu *et al.* faced the very same concern with pro-speech gestures and visual animations, which was also addressed by including iconicity controls throughout the experiment.

To rule out this alternative explanation, we included 8 iconicity trials randomly displayed throughout the experiment. We manipulated these stimuli to check whether participants were able to interpret their modification iconically. To this end, we used two different realizations of an upward scale, a normal and a fast one, to refer to a hiker climbing either slowly or quickly. We used two other realizations, a very long musical scale and a shorter one, to evoke the height of the mountain, in the same context as the one used in 3.2. The target sentences were then paired up with a matching or a mismatching inference. If participants were able to retrieve the expected iconic informational content from the musical gesture, we expected a significantly higher endorsement of the matching inference for the target premise with respect to the mismatching inference.

For the first iconicity control in (57), LONG_UPWARD_SCALE stands for a C major scale played over a wide pitch range of four octaves (i.e., four full upward scales, from middle pitch to very high), used to evoke a very high mountain.

(57) **Target premise**

The next hiker will LONG_UPWARD_SCALE.

Original stimulus

Le prochain randonneur va LONG_UPWARD_SCALE.
The next   hiker   will LONG_UPWARD_SCALE.

We expected participants to be able to (i) perceive the difference between the two realizations of the upward scale and (ii) interpret them iconically in terms of the height of the mountain in the context. Consequently, we expected a high endorsement of the inference containing the matching iconic component in (58).

(58) **Matching inference**
     The mountain the hiker is about to climb is high.

In (59), UPWARD_SCALE stands for the same scale played at the same speed but over a narrower pitch range of two octaves (i.e., two full upward scales only, from middle pitch to moderately high), to evoke a mountain of average height. Note that this musical gesture was the one used in 3.2 to test for presupposition projection. Our prediction was that the longer the scale, the higher the inferred height of the mountain.

(59) **Control premise**
     The next hiker will UPWARD_SCALE.

Original stimulus

Le prochain randonneur va UPWARD_SCALE.
The next   hiker   will UPWARD_SCALE.

We expected that this neutral realization of the scale would convey information about the mountain being of average height, and thus a high endorsement of the inference in (60), in which the iconic component allowing subjects to assess the mountain to be very high was absent.

(60) **Mismatching inference**
     The mountain the hiker is about to climb is not very high.

For the second iconicity control, we contrasted the baseline realization of the scale UPWARD_SCALE in (63) evoking a neutrally fast hike with SLOW_UPWARD_SCALE in (61), in which the pitch range remained the same but the speed was slowed down four times to evoke a slower climbing of the mountain.

(61) **Target premise**
     The next hiker will SLOW_UPWARD_SCALE.

Original stimulus

Le prochain randonneur va SLOW_UPWARD_SCALE.
The next   hiker   will SLOW_UPWARD_SCALE.

Similarly, participants should be able to both perceive and interpret the difference between the two realizations iconically in terms of the hiking speed, and we expected a high endorsement of the inference in (62) containing the iconic component.

(62) **Matching inference**
     The hiker will climb the mountain slowly

By contrast, the control inference in (61) involved the baseline realization of the scale UPWARD_SCALE.

(63) **Control premise**
     The next hiker will UPWARD_SCALE.

Original stimulus

Le prochain randonneur va UPWARD_SCALE.
The next   hiker   will UPWARD_SCALE.

The iconic component allowing for the inference about a high hiking speed was absent from this control premise, which we expected to give rise to the inference in (64).

(64) **Mismatching inference**
   The hiker will climb the mountain fast.

We found a significant effect of inference type ($\chi^2 = 63$, $p < 0.001$ for the first iconicity control, $\chi^2 = 28$, $p < 0.001$ for the second). This means that listeners were able to both perceive subtle musical changes and interpret them iconically.

4.2 Discussion

We have shown that musical gestures convey fine-grained iconic information. Specifically, the pitch range of the stimulus was interpreted as the height of the mountain, and the tempo at which the upward scale was played was interpreted as the hikers' speed. It is very unlikely that these musical gestures were merely translated in words, because all these iconic dimensions are absent from reasonably simple translations. For instance, the information about height conveyed by UPWARD_SCALE is absent from a simple translation as "go up". It could still be, however, that more complex translations are involved. These would have to be extraordinarily rich: "The hiker will LONG_UPWARD_SCALE" would have to be translated as something like "The hiker will climb a mountain of such-and-such height at such-and-such a speed...". However, even if pro-speech music were indeed translated into such long chains of words, the music-as-translation theory makes wrong predictions on the projection patterns of these iconic dimensions. Consider a translation of the target premise which, for ease, we simplify as (65).

(65) The hiker will climb up the mountain slowly.

The music-as-translation theory predicts that all pieces of fine-grained information iconically conveyed be *systematically at-issue* when not *lexically* encoded as non-at-issue. Any musical gesture conveying fine-grained iconic information should therefore systematically give rise to a scalar implicature. That is, SLOW_UPWARD_SCALE would mean *climb slowly*, thus its negation *not*-SLOW_UPWARD_SCALE should give rise to the scalar implicature that there is still some climbing involved, given that the more informative *not*-UPWARD_SCALE was not uttered. This prediction seems right if we look at the negation of (65), as in (66).

(66) The hiker will not climb up the mountain slowly.
   ⤳ The hiker will not climb up the mountain slowly, but will still climb up the mountain.

The premise in (66) does not, however, trigger the same inference when using the musical gesture LONG_UPWARD_SCALE.

(67) The hiker will not LONG_UPWARD_SCALE.
   a. ⤳ The hiker will not climb up the mountain slowly, but will still climb up the mountain.
   b. ⤳ The hiker will not climb the mountain at all, but if she did, she would have done so slowly.

A first possible reading of the sentence in (67) is the same scalar implicature found in (67)a. However, another possible reading is (67)b, where the iconic information paraphrasable as "slowly" is not at-issue anymore. While this reading is not the most obvious, it becomes completely salient in context. Consider the following example:

(68) **Context:** Mary and John are playing a snail race, and they want their snails to climb all sorts of obstacles.
   Mary tells John: "Your snail will not SLOW_UPWARD_SCALE."
   ⤳ John's snail will not climb the next obstacle but if it had climbed it, it would have done so slowly.
   ⤃ John's snail will not climb the next obstacle slowly, but will still climb it.

This inference is a typical cosupposition (Schlenker, 2018a) of the form *x did not Q, but if x did Q, x would have Qed like this*. Crucially, it is not triggered in the purely linguistic example in (66), as shown in (69).

(69) The hiker will not climb up the mountain slowly.
   ⤃ The hiker will not climb the mountain at all, but if she did, she would have done so slowly.

If the musical gesture is only translated into words and no other non-translatable iconic enrichment is involved, then there is at least one available reading which cannot be explained. Consequently, there is no real alternative to the conclusion that there is a non-verbal component to pro-speech music. It is worth noting that similar inferences were found to be triggered by co-speech sounds and auditory animations (Tieu *et al.*, 2018), which make non-at-issue contributions to the sentence.

5 Conclusion

The purpose of this study was to replicate the inferential typology tested on pro-speech gestures and visual animations of inferences in Tieu *et al.* (2019) with pro-speech music. Participants behaved systematically in response to novel stimuli, suggesting that a general cognitive algorithm is responsible for the appropriate arrangement of content, rather than a purely linguistic procedure relying on word meaning. Specifically, our results show that pro-speech music can give rise to four types of inferences. We showed that musical gestures can assume different levels of informativity and compete, resulting in the computation of scalar implicatures (cf: section 3.1). Moreover, we showed that pro-speech music can convey presuppositions. Presupposed content projected under question (cf. section 3.2), but failed to project under "none". Conditional inferences typical of supplements, i.e. non-restrictive relative clauses, can also arise from rich pro-speech music (cf. section 3.3). In section 3.4, we showed that pro-speech music can give rise to homogeneity inferences, both when replacing a definite plural noun phrase and when inserted in lieu of a predicate. Section 4 finally illustrated why it is very unlikely that these results are explained by the mere translation of musical gestures into words.

Together, these findings suggest that the mechanisms responsible for these inferences and for the division of meaning along different slots of the inferential typology are productive. First, participants were able to draw the expected inferences in absence of previous exposure with the musical gestures. Second, they were able to operate logical computations on auditory, non-linguistic stimuli. This supports the idea that meaning production is a domain-general phenomenon rather than a purely linguistic one.

While we acknowledge that the question of the existence of a music semantics, which has recently been raised (Schlenker, 2017, 2019b), is a very exciting and promising one, our results do not allow us to make any claim about musical meaning. However, we think that the evidence we provide about the interaction between language structure and musical content constitutes a first step to better understand what musical meaning is and how it behaves logically. In particular, the extent to which some of the observed inferences may arise in music alone, i.e. not embedded in language, is an inspiring question for future research.

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Appendix: Musical gestures and vocal gestures

As mentioned in section 3.3, we ran a parallel experiment on a different pool of participants using pro-speech onomatopoeia, i.e. iconic vocal sounds replacing one or several words in sentences, that we call 'vocal gestures', instead of musical gestures. The same four inference types were tested: scalar implicatures, presuppositions, supplements and homogeneity inferences, using paradigms and stimuli that were either perfectly analogous to the ones described throughout this paper, or very slightly different when vocal counterparts to musical stimuli could not be found. For instance, wherever an upward scale was used in our stimuli to evoke a rise in space to test for presuppositions, we used a whistle rising in frequency, and wherever a choir singing the French national anthem was used to evoke the action of singing to test for homogeneity inferences, we used a similar stimulus where the very same song was whistled instead of sung. Wherever a drum was used to evoke someone punching to test for scalar implicatures, we used the onomatopoeia BOOM vocally pronounced.

We found a difference in the results collected from the experiment on musical gestures and the one on vocal gestures, which is surprising as most paradigms were perfectly symmetric. However, this experiment was ran on a smaller pool than the musical gestures experiment, and the lack of systematically significant effects of the inference type might thus be explained by a lack of power. We found indeed that the differences in the endorsement rates across both experiments were mainly not or marginally significant themselves, i.e. the responses given for the experiment on vocal gestures were not significantly different from the ones given for the experiment on musical gestures. The table below summarizes the comparisons of the distribution of the data between both experiments. For each inference type, we computed the interaction between inference type and the *Experiment* factor, whose two levels corresponded to the two experiments. [12]

Inference type	Environment	*p*-value for the [*Inference type x Experiment*] interaction	Significance interpretation
Scalar implicatures	Positive	0.74	No interaction
	Negative	0.08	Marginally significant interaction
Presuppositions	Question	0.61	No interaction
	None	0.43	No interaction
Supplements		< 0.001	Significant interaction (as expected)
Homogeneity	NP	0.05	Low interaction
	Predicate	0.29	No interaction

Comparison between musical gestures and vocal gestures experiments

The table above displays the figures assessing the significance of the difference in distribution of the data collected across experiments. None of the data subsets were significantly different across both experiments, except for supplements, for which we found no contrast in endorsement due to an unexpected interpretation of the vocal stimulus.

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[12]The detailed analyses and statistical scripts to compute interactions are available in the RESULTS folder at https://osf.io/hw45u/?view_only=89f983db777f49e9a6f5b41b3dea60d6