Cognitive change in learning from text: Gesturing enhances the construction of the text mental model.

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Cognitive change in learning from text:

Gesturing enhances the construction of the text mental model

Ilaria Cutica° and Monica Bucciarelli*

° Department of Economy, Management and Quantitative Methods, University of Milan

*Department of Psychology and Center for Cognitive Science, University of Turin

Corresponding author:

Ilaria Cutica

University of Milan

Department of Economy, Management and Quantitative Methods

Via Conservatorio, 7

20133 Milan, Italy

e-mail: ilaria.cutica@unimi.it

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Abstract

The literature on co-speech gestures has revealed a facilitating effect of gestures on both the listener's discourse comprehension and memory, and the speaker's discourse production. Bucciarelli (2007) and Cutica and Bucciarelli (2008) advanced a mental model account for the cognitive change produced by gestures: gestures, whether observed or produced, favor the construction of a mental model of the discourse they accompany. In this paper, we focus on gesturing while studying, assuming that gesturing while reading a text also favors the construction of a mental model of the text. In two experiments we invited adult participants to study two scientific texts and confirmed the predictions deriving from the assumption that gestures favor the construction of a mental model of the text: gesturing while studying resulted in more correct recollections and text-based inferences (Experiment 1) and loss of verbatim recall (Experiment 2).

Keywords: mental models, gestures, text comprehension, learning

Introduction

It is well known that gestures have a facilitating effect on different aspects of speech comprehension and production. Studies on the enactment effect purport that gestures enhance memory for speech: free recall of action phrases like “Break the toothpick” is superior when participants perform the action during encoding (subject-performed task, SPT), compared to a situation where they read or hear the sentence (verbal task, VT). This effect has been consistent across numerous studies carried out since the early 1980s (for a review see Zimmer, 2001). Furthermore, some studies have revealed that enactment is effective, although not to the same extent, also when the individual observes another person performing the action (experimenter-performed task; EPT) (e.g., Hornstein & Mulligan, 2004).

A further relevant finding is that the actual pattern of movements constituting an SPT is not crucial in determining the recall level, as long as the patterns are appropriate to the accompanying speech. For instance, Noice and Noice (2007) detected the so-called non-literal enactment effect: performed actions that are not literally congruent with the verbal material, but related at a higher order level (e.g., action goal level) result in action-enhanced memory for the verbal material.

Enacted speech closely resembles co-speech gestures. However, differently from studies on co-speech gestures, those on the enactment effect are mainly concerned with lists of words or phrases, and focused on memory for sentences and memory for speech, rather than memory for discourse. As a consequence, they disregard the beneficial effect of gestures on comprehension and learning from a broader perspective. In this respect, studies on co-speech gestures are more relevant, as they also deal with the role of gestures in discourse comprehension. Studies on co-speech gestures have revealed that gestures by the speaker facilitate discourse comprehension by the hearer (see, e.g., Wagner Cook, Mitchell & Goldin-Meadow, 2008). Co-speech gestures provide symbolic and/or analogic information that interacts with that conveyed by speech to reconstruct the communicative meaning by reinforcing, specifying or adding discourse contents. Indeed, when gestures convey the same information as speech, they facilitate comprehension of that speech;

conversely, when gestures convey different information from speech, they hinder comprehension of that speech (see, e.g., Goldin-Meadow, 2000). Unfortunately, none of the studies in the literature on co-speech gestures have accounted for the cognitive mechanisms underlying their facilitating effect.

Following the tenets of the mental model theory (Johnson-Laird, 1983; 2006), we advanced an account for the facilitating effects of co-speech gestures for the hearer: the information conveyed by the speaker's co-speech gestures, represented in a non-discrete format, is easily included in the mental model of the discourse (Bucciarelli, 2007, Cutica & Bucciarelli, 2008), because mental models too are non-discrete representations (see, e.g., Hildebrandt, Moratz, Rickheit & Sagerer, 1999). In other words, co-speech gestures might lead to the construction of representations that are easily incorporated into the discourse model, alongside the representations constructed on the basis of the verbal information, enriching these and completing the mental model. We collected experimental data consistent with this view (e.g., Cutica & Bucciarelli, 2008; 2011).

In the learning literature, several studies on spontaneous gestures produced by the learner (in the learning phase) found that concepts may be initiated in gesture before they are conveyed in speech (e.g., Wagner Cook et al., 2008); Goldin-Meadow (2001) argued that gestures may provide a vehicle that allows the individual to express thoughts difficult to express in speech. And indeed, several findings in the literature have suggested that gesticulation is also involved in the speaker’s mental organization of the discourse by helping to organize the stream of thought (see e.g., Alibali, Kita & Young, 2000), by reducing the cognitive load and leaving more resources available for other tasks (see, e.g., Alibali & DiRusso, 1999), as well as by helping in the conceptual planning of utterances (see, e.g., Kita, 2000). Thus, gestures also have a facilitating effect for the speaker. Within our framework, gestures by the speaker facilitate the speaker’s construction of a mental model of the discourse. In line with our assumption, experimental studies have revealed that a speaker who has a good mental model of the concept to be expressed has less need to gesticulate than a speaker who has a poorer mental model (Cutica & Bucciarelli, 2011).

The leading question of our investigation is: Does inviting a learner to gesticulate while studying a text have a beneficial effect on the construction of a complete mental model of the text content? This assumption is consistent with the results reported in the enactment literature suggesting that non-spontaneous gestures may also facilitate memory; it is, however, grounded on a unifying mental model framework, where gestures, whether observed or produced, facilitate the construction of a mental model of the text/discourse.

How Gestures Enhance the Construction of a Mental Model of the Text

The mental model theory may account for the cognitive changes brought about by gesturing while reading a text, and thus for the role of gesturing in the construction of the meaning of the text. Our main assumption is that gestures facilitate deep comprehension and learning from text because they favor the construction of a mental model of the text. The aim of our study was to test the deriving prediction that gesturing while studying a text favors deep comprehension and learning from text. We considered the discourse-based inferences produced by the learner and poor verbatim recognition of the text as indicators of model construction. Individuals who have built a mental model of a given material are more likely to recall more correct information. But, more importantly, they are more likely to draw correct inferences from the information explicitly contained in the material, with respect to individuals who, faced with the same material, have built a poorer mental model (Johnson-Laird, 1983). Previous studies in the literature on the function of gestures for comprehension and learning did not investigate or evaluate deep learning through the possibility of drawing inferences. More specifically, we distinguish between discourse-based inferences, based on mental models, and elaborative inferences, which embellish or add details to the text (see, e.g., Singer, 1994). Thus, elaborative inferences may interfere with the recovery of previously presented information, whereas discourse-based inferences are proper inferences. According to the search-after-meaning theory, examples of discourse-based inferences are concerned with the causal antecedent, the causal consequent, the character’s emotional reaction and mental states (Graesser, Singer & Trabasso, 1994).

Another possible indicator of the building of an articulated mental model of some given material is poor retention of the text or discourse surface form (for experimental evidence see, e.g., Garnham, Oakhill & Cain, 1998). This happens because mental models derived from a text or discourse do not encode the linguistic form of the sentences on which they are based. It follows that if the person constructs an articulated mental model of the information she/he has been exposed to, she/he will recognize less information at verbatim level with respect to a person who does not construct a mental model. As gestures favor the construction of mental models, which in turn lead to loss of verbatim recall, it follows that gestures do not favor the retention of the text/discourse verbatim.

The findings within the enactment domain only apparently contrast with our expectation that gestures, by enhancing model construction, lead to loss of verbatim recall of the discourse. Indeed, within our proposed framework, a distinction is made between the effect of co-speech gestures on memory for sentences and on memory for discourse. In the case of co-speech gestures accompanying single sentences we assume that, in line with the enactment literature, gestures provide information that contributes to the creation of distinctive traces of the single sentences in the long-term memory. In the case of co-speech gestures accompanying connected sentences (i.e., discourse), we assume instead that co-speech gestures favor the construction of a mental model of the discourse. Multiple connected sentences give rise to the need to build an articulated discourse model. During this process, new pieces of information have to be integrated with one another and/or with prior knowledge, and any inconsistencies have to be solved. This is done by means of explanations, after which the discourse model that has been built so far has to be revised (see Khemlani & Johnson-Laird, current edition). Once a mental model of the discourse has been constructed, at the time of retrieval the representation of the information in the discourse is not in the form of distinctive traces; rather, the original information has been integrated into a single articulated mental model of the discourse. Hence, in order to tackle the construction of a mental model of the text, we invited the participants in our experiments to study a complete text. This gave them the possibility to build a single articulated mental model of the text and, as a consequence, draw discourse-based inferences and recognize less content at the verbatim level.

Experiment 1: Gesturing Enhances Learning from Text (Free Recall task)

The participants in the experiment were invited to study two scientific texts, one while gesticulating and the other without gesticulating. Then they were invited to recall as much information as they could. We expected to find that when people gesticulate while studying they (1) retain more information, and (2) draw more discourse-based inferences than when they do not gesticulate. We had no predictions for the number of elaborative inferences and errors. The former do not depend upon model construction, while errors are still possible when constructing a mental model of a text; any misunderstood information may be included in the mental model, thus supporting erroneous recollection.

Method

The experimental material consisted in two scientific texts, one concerning airplane flight (from now on, Airplane, see Appendix A.1) and the other concerning the nature of sound (from now on, Sound, see Appendix B.1). Each participant encountered both texts, one in the Gesture condition and the other in the No Gesture condition. In the Gesture condition participants were invited to gesticulate while studying the text: they were asked to represent the concepts they read in the text with gestures. Participants in the No Gesture condition were invited to study the text while keeping their hands still. Participants in each experimental condition read each text twice, following the same experimental procedure. Half of the participants dealt first with the Airplane text and half with the Sound text, and the occurrence of each text in the Gesture and No Gesture conditions was balanced across all participants. After completing the second reading of each text, participants were invited to recollect as much information as they could. All of the participants were video-recorded.

To code the results, each text was divided into 52 semantic units, corresponding to as many main concepts that the learner could recall. Each concept (i.e., semantic unit) recalled by the participants was evaluated by two independent judges according to the following coding schema:

- *Correct recollection*: a semantic unit recollected either in its literality or as a paraphrase.
- *Discourse-based inference*: a recollection in which the participant gave explicit information that was originally implicit in the semantic unit.
- *Elaborative inference*: a semantic unit recollected with the addition of plausible details.
- *Erroneous recollection*: a recollection with a meaning that was inconsistent with the semantic unit.

Two more judges examined the gestures produced by the participants while reading the texts. We defined hand movements that had a clear beginning and an end point, and that were also temporally linked to the reading of an utterance in the text as gestures. None of the participants in the No Gesture condition produced any gestures.

Participants

Forty adults took part in the experiment (27 females, 13 males, mean age: 22); all were university students attending a course in General Psychology, and all took part voluntarily.

Results and Discussion

Two independent judges coded the participants' recollections individually; they reached a significant level of agreement on their first judgments (Cohen's K ranging from .80 to .89, all $p < .001$). For the final score, the judges discussed each item on which they disagreed, until reaching a full agreement. Consider, for instance, the following semantic unit in the text: "Some of the air flows over the upper part of the wing". According to the coding schema, the statement "part of the air that hits the wing runs on the upper side of the wing" is a correct recollection, and the statement "the air hits the wing and passes underneath the wing" is an erroneous recollection. With respect to the semantic unit: "For an example where this can be seen (*the perturbation in the environment begins to spread out, away from the source in all directions*) think of waves on water", the sentence "An example is when an object falls into the water and produces concentric circles" is a discourse-based inference (it cites the cause of the effect that is mentioned). Finally, the sentence "How is it possible that an airplane can go up and fly for long distances?" is an elaborative inference of the semantic unit: “What makes an airplane rise into the sky and stay there even though it is heavier than air?”.

Two more independent judges examined the gestures produced by each participant in the Gesture condition and initially agreed to recognize 95% of their hand movements as gestures; they achieved a significant level of agreement (Cohen’s *K* ranging from .82 to .89, all $p < .001$). For the final score, the judges discussed each item on which they disagreed, until reaching a full agreement. By way of example, the following movement was considered to be an accompanying gesture; while reading the sentence: “The upper surface of the wing is longer and more curved (than the lower surface)”, the participant raised his right hand until it was level with his chest, holding it palm down and slightly concave, then drew an arc with his hand (moving it first upward then downward), outward with respect to the axis of the right-hand side of his body. The two texts were comparable in difficulty: considering each type of recollection separately we found no differences in performance between the two texts (unpaired t-test: $t(38)$ between 0 and .92, p between .37 and 1). Furthermore, participants in the Gesture condition produced a comparable number of gestures while studying the Airplane and the Sound texts (over the two readings, a mean of 59.76 while studying the Airplane text and a mean of 56.42 while studying the Sound text; unpaired T-test: $t(38) = .55$, $p = .59$). Hence, we pooled the results for the two texts. As a general result, participants in the Gesture condition produced a comparable amount of gestures in the first reading (a mean of 28.53 gestures) and the second reading (a mean of 29.65 gestures: paired T-test: $t(39) = .86$, $p = .40$) of the texts. Table 1 shows the mean scores for types of recollection in the Gesture and No Gesture experimental conditions.

Insert Table 1 about here

As predicted, there were more correct recollections and discourse-based inferences in the Gesture condition than in the No Gesture condition (t-test for dependent samples: $t(39) = 4.79$, *tied* $p < .0001$ and $t(39) = 2.13$, *tied* $p = .02$, respectively). Elaborative inferences and erroneous recollections occurred to the same extent in the Gesture condition and in the No Gesture condition (t-test for dependent samples: $t(39) = 30$, $p = .77$ and $t(39) = 1.40$, $p = .85$, respectively). The results of the experiment confirmed the prediction that when people gesticulate while studying they retain more information, and draw more discourse-based inferences than when they do not gesticulate. Both sorts of recollection denote learning from text.

Experiment 2: Gesturing Enhances Learning from Text (Recognition task)

The participants in the experiment were invited to study two scientific texts, one while gesticulating and the other without gesticulating. Then they were presented with a list of sentences and were invited to say whether each sentence was present in the original text. We expected to find that when people gesticulate while studying they have worse verbatim recognition of the text than when they do not gesticulate.

Method

The experimental material consisted of the same two scientific texts used in Experiment 1. For each text we chose 9 sentences, and for each sentence we created a triplet: (1) the very same sentence present in the text (*literally correct*); (2) a sentence with the same meaning, but expressed with different words (*paraphrase*); (3) a sentence inconsistent in meaning (*wrong content*). We thus created 27 sentences, with 9 in each category (literally correct; paraphrase; wrong content); see Appendix A.2 and B.2 for examples.

As in Experiment 1, each participant encountered both texts, one in the Gesture condition and the other in the No Gesture condition, and participants in the Gesture condition were invited to represent the concepts they read in the text with gestures. Participants in the No Gesture condition were invited to study the text while keeping their hands still. The participants in each experimental condition read each text twice, following the same experimental procedure. Half of the participants dealt first with the Airplane text and half with the Sound text, and the occurrence of each text in the Gesture and No Gesture conditions was balanced across all participants. As soon as the participants had finished studying each text, they were presented with the list of sentences, one by one in random order, and were asked to say whether or not the sentences were identical to those they had actually read in the text (recognition task). We coded responses of "*Yes*" to literally correct sentences, and responses of "*No*" to paraphrases and wrong content sentences as correct.

Participants

Forty students at Turin University (29 females, 11 males, mean age: 22), attending a course in General Psychology took part in the experiment. All took part on a voluntary basis and none had participated in Experiment 1.

Results and Discussion

The two texts were comparable in difficulty: considering each type of sentence separately (i.e., literally correct, paraphrase, wrong content) we found no differences in performance between the two texts (unpaired t-test: $t(38)$ between .04 and 1.36, p between .19 and .94). Two independent judges examined the gestures produced by the participants in the Gesture condition, and initially agreed to recognize 97% of their hand movements as gestures; they reached a significant level of agreement (Cohen's K ranging from .79 to .87, all $p < .001$). For the final score, the judges discussed each item on which they disagreed, until reaching a full agreement. Participants in the Gesture condition produced a comparable number of gestures while studying the Airplane and the Sound texts (over the two readings, a mean of 58.84 while studying the Airplane text and a mean of 55.43 while studying the Sound text, T-test: $t(38) = .76$, $p = .45$). Hence, we pooled the results for the two texts. As a general result, participants in the Gesture condition produced a comparable amount of gestures in the first reading (a mean of 28.50 gestures) and in the second reading (a mean of 29.03 gestures: T-test: $t(39) = .41$, $p =.68$) of the texts.

We also conducted several analyses of variance (Cochran's Q test) to verify an implicit assumption of our study, namely that participants would experience the same level of ease/difficulty in recognizing the stimuli pertaining to each sentence category. The results revealed that the stimuli were comparable in difficulty in both the Gesture (Q value ranging from 14.23 to 19.41; p value ranging from .12 to. 42) and No Gesture (Q value ranging from 11.79 to 22.12; p value ranging from .10 to .48) conditions.

Table 2 illustrates the mean correct performance in the Gesture and No Gesture conditions.

Insert Table 2 about here

As predicted, a series of t-tests for dependent samples revealed that participants performed worse in the Gesture condition than in the No Gesture condition in recognizing sentences that were actually present in the original texts ($t(39) = 3.14$, *tied* $p = .003$). Moreover, performance with paraphrases ($t(39) = .08$, $p = .93$) and wrong content sentences ($t(39) = .84$, $p = .41$) was comparable for participants in the two conditions.

General Discussion

Previous studies in the literature have revealed that gestures facilitate both discourse comprehension and production. Our studies also revealed that gestures facilitate learning while studying a text. We advanced a mental model account for the role of gestures in the construction of the meaning of a discourse/text, thus offering a unifying perspective on the role of gestures for the speaker and for the listener, as well as for the learner.

Is there any possible alternative account for the role of gestures in the cognitive change underlying learning from text/discourse? One of the most influential theories of discourse comprehension is the Construction Integration (CI) model of comprehension advanced by Kintsch (1998), which is an extension of the theory formerly advanced by van Dijk and Kintsch (1983). According to this theory, text comprehension occurs through the construction of a situational model of the text contents. Disregarding their different theoretical roots, the terms “situational model” and “mental model” can be considered to be equivalent. However, in our view the concept of “mental model” can more easily accommodate the role of gestures in text/discourse comprehension. In the CI model, Kintsch recognizes the importance of incorporating extralinguistic knowledge in the modeling of discourse processing, but acknowledges that his model does not deal with this easily. In the CI model, images, perceptions, concepts, ideas or emotional states are translated into predicate-argument units because of practical considerations (Kintsch, 1998 reprinted 2007, p. 45):

“We know how to work with predicate-argument units, and it is not clear how to interface linear or spatial analog representations with such units”. Kintsch claims that “The predicate-argument schema does not necessarily highlight relations that are significant in the realm of action and perception in a direct, analogous manner.” (ib. 47). And, indeed, what he tries to grasp in his notation (network of nodes) is the analogical structure of mental models à la Johnson-Laird (ib. pp. 108-109).

Our assumptions on the role of gestures do not contrast with the CI model by Kintsch (1998) which, however, faces several problems for the implementation of mental models constructed from non-verbal information. We argue that the mental model theory is a better candidate for explaining the mechanisms underlying the role of gestures in discourse and text comprehension because of its emphasis on the non-discrete nature of mental models; the theory allows us to envisage a role for co-speech gestures (which visually convey information in a non-discrete representational format) within a theory of discourse/text comprehension. A further challenge for the CI model is to account for the loss of verbatim recall following the construction of a mental model of the discourse/text; one further main difference between the mental model theory and the CI model is that the former emphasizes the fact that text verbatim is lost once the model has been constructed; this prediction was verified by the results of our former and present studies.

In conclusion, the mental model theory appears to provide the best account for the cognitive change produced by gestures in discourse/text comprehension, production, and learning.

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Table 1.

Mean Types of Recollections in the Gestures and No Gestures Conditions in Experiment 1.

Condition (N=40)	Correct recollections	Discourse-based inferences	Elaborative inferences	Errors
Gesture				
M	16.08	.35	.18	.83
SD	(6.62)	(.53)	(.39)	(.78)
No Gesture				
M	12.40	.10	.15	1.18
SD	(5.26)	(.44)	(.36)	(1.22)

Table 2.

Mean Correct Performance with the Different Sorts of Sentences in the Two Experimental Conditions in Experiment 2.

Condition (N=40)	Literally correct (n=9)	Paraphrases (n=9)	Wrong content (n=9)
Gestures			
M	6.10	5.05	5.80
SD	(1.59)	(1.73)	(2.44)
No Gestures			
M	7.65	5.10	5.25
SD	(1.53)	(2.10)	(1.65)

Appendix A

A.1 The airplane flight text used in both Experiments 1 and 2 (Semantic units are separated by slashes)

What makes an airplane rise into the sky and stay there, even though it is heavier than air?/ The answer lies/ in an aerodynamic principle/ suggested by Daniel Bernoulli/ in 1738./ The Bernoulli principle describes how upward forces,/ known as lift,/ act on the aircraft as it moves through the air./A transverse section of a bird's wing,/ a boomerang/ and a "Stealth" bomber/ all share a similar form to that of an airplane wing./ The upper surface of the wing is longer/ and more curved than the lower surface./ This difference creates what is known as an aerofoil./ To generate lift, air must flow over the wing./ A 747 has a wingspan/ of over 200 feet,/ which is more than the height of a 15-storey building./ As it moves around the wing,/ the air presses on it in all directions,/ at right angles to its surface./ When an airplane is in flight,/ the air divides as it hits the front of the wing./ Some of the air flows over the upper part of the wing,/ and the rest over the lower part of the wing./ The two air flows come together again behind the wing./ The upper part of the wing is highly curved./ The air flowing over the upper part of the wing therefore/ has a greater distance to travel/ in the same period of time./ This means that the air flow over the top/ travels at a higher speed/ than that under the lower surface./ When air moves faster, its pressure reduces./ You will probably have noticed, when you turn on the water in the shower,/ that the curtain moves inwards./ The running water /makes the air inside the shower move faster./ At this higher speed, it exerts a lower pressure against the curtain/ than that exerted by the stationary air on the other side./ The curtain is thus forced inwards./ A similar principle applies to the aircraft wings./ Given that the air above the wing moves quicker,/ it tends to spread out./ The pressure on the upper part of the wing reduces./ The upper surface of the wing is at lower pressure/ than the lower surface of the wing./ The downward force exerted by the air flowing over the wing/ is less than the upward force from the air underneath,/ thus creating a net upward force on the wing – this is lift./ The lift generated by the wings must exceed the aircraft's weight./

A. 2 Examples of sentences used for the Recognition Task of Experiment 2

Literal	When an airplane is in flight, the air divides as it hits the front of the wing
Paraphrases	During flight, the aircraft's wings split the air into two parts
Wrong	During flight, the air striking the aircraft's tail splits into two parts

Literal	When air moves faster, its pressure reduces.
Paraphrases	As the air moves faster, the pressure that it exerts decreases
Wrong	Air moving very slowly is at lower pressure

Literal	The lift generated by the wings must exceed the aircraft's weight.
Paraphrases	The aircraft must weigh less than the lift generated by its wings
Wrong	An aircraft's weight must be greater than the lift generated by its wings

Appendix B

B.1 The nature of sound text used in both Experiments 1 and 2 (Semantic units are separated by slashes)

Physically, sound is a waveform:/ it consists of mechanical waves conveying energy/ away from the sound source,/ which is a vibrating object./ What travels, then, is not material but rather a signal,/ a continual vibration of some element/ of the environment in which the sound propagates./ It all starts with the vibration of an object/ or part of it,/ as with the tip of a tuning fork./ The perturbation in the environment begins to spread out /away from the source in all directions,/ for an example where this can be seen think of waves on water/. This perturbation or signal makes every object vibrate that it meets on its path./ When the wave has passed by,/ everything returns to its original position./ There are two types of wave: longitudinal/ and transverse./ With the former, the vibration occurs along the same axis/ as the wave's direction of travel;/ with the latter, the vibrations/ are at right angles to the wave's direction of travel./ An example of a longitudinal wave is the signal/ created by pressing on the end of a spring:/ the coils rhythmically/ move closer and further apart,/ while the signal propagates along the same axis on which the pressure was applied./ For a transverse wave, consider the signal/ created by a movement at one end of a rope:/ the signal propagates along the rope on an axis at right angles/ to the direction of the original movement./ Sound is a longitudinal wave,/ because the sound source vibrates in the same direction as the sound spreads./ This is what happens in a loudspeaker./ The waves may encounter many different objects as they spread out,/ but one of them is rather special: the eardrum./ This encounter triggers a highly intricate process/ that takes a sound signal/ and enables us to recognise a person's voice/ and understand the words they spoke,/ or to identify a musical instrument/ and even the musician playing it./ But this only explains part of what sound perception is all about./ Once our hearing apparatus has completed its work,/ we hear music,/ a deliberate and structured combination of sounds/ created to give aesthetic pleasure,/ language,/ a deliberate and structured combination of sounds/ created to convey verbal information,/

noise,/ an ill-defined term used to refer to all other kinds of /unstructured, unpleasant, unwanted sounds./

B. 2 Examples of sentences used for the Recognition Task of Experiment 2

Literal	Physically, sound is a waveform
Paraphrases	From a physics standpoint, sound is a wave
Wrong	Physically, sound is sudden and irregular in nature

Literal	It all starts with the vibration of an object
Paraphrases	Sound is created by a vibrating object
Wrong	Sounds are created by the body of a tuning fork

Literal	This perturbation or signal makes every object vibrate that it meets on its path
Paraphrases	Sound waves make every object vibrate that they meets on their path
Wrong	Sound signals avoid the objects that they encounter on their path