"I see what you mean": Oral deaf individuals benefit from speaker's gesturing

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Oral deaf individuals benefit from speaker’s gesturing

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Short title: Oral deafs’ discourse comprehension

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Abstract

Recent studies in the psychological literature reveal that co-speech gestures facilitate the construction of an articulated mental model of an oral discourse by hearing individuals. In particular, they facilitate correct recollections and discourse-based inferences at the expense of memory for discourse verbatim. Do gestures accompanying an oral discourse facilitate the construction of a discourse model also by oral deaf individuals trained to lip-read? The atypical cognitive functioning of oral deaf individuals leads to this prediction. Our Experiments 1 and 2, each conducted on 16 oral deaf individuals, used a recollection task and confirmed the prediction. Our Experiment 3, conducted on 36 oral deaf individuals, confirmed the prediction using a recognition task.

Acknowledgements

We thank the Deafmute Institute of Pianezza (Turin) which allowed us to contact the participants in our experiments, and Bruno Bara for his helpful comments. This work was supported by Regione Piemonte of Italy, ATLAS project ID 44.

Introduction

When people talk, they make spontaneous movement of arms, hands and heads, called co-speech gestures. These gestures are closely time-locked to the syntactic and semantic properties of speech. McNeill (1992) identifies a number of different types of co-speech gestures: iconic gestures, that capture aspects of the semantic content of speech; metaphoric gestures, that convey abstract pictorial content; beat gestures, that occur along with the rhythmical pulsation of speech; deictic or pointing gestures, that indicate entities in the conversation. A series of experimental studies suggest that co-speech gestures have a role both for the speaker, because they favor the organization of thinking (e. g., Alibali, Kita & Young, 2000, Goodwin, 1986, McNeill, 1992) and for the listener, because they enhance his/her comprehension (Alibali, Flevares, & Goldin-Meadow, 1997; Cutica & Bucciarelli, 2008; Iverson & Goldin-Meadow, 2001; Kelly & Church, 1998; McNeill, 1992; McNeil, Alibali & Evans, 2000).

In discourse comprehension, gestures and speech form an integrated system: to fully understand speech it is necessary to interpret both the words the speaker utters and also his/her gestures (Goldin-Meadow, 2000). Gestures carry symbolic and/or analogic information that could reinforce, specify or add discourse contents (Iverson & Goldin-Meadow, 2001). 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 (Goldin-Meadow, 2000; Goldin-Meadow, Kim & Singer, 1999).

Cutica and Bucciarelli (2008) suggest that gestures are effective on deep comprehension and learning because they facilitate the construction of an articulated mental model of the discourse and assume that such enriched models facilitate the retention of content information, and the drawing of correct inferences, at the expense of reducing memory for the surface code. The authors, in a series of experiment on hearing adults summarized below, found that a discourse accompanied by gestures, as compared with a discourse not accompanied by gestures, results in a better recollection of conceptual information, in a greater number of discourse-based inferences drawn from the information explicitly stated in the discourse, and in a poorer recognition of verbatim of the discourse. Now, we wonder whether co-speech gestures may help the construction of a discourse model also by deaf individuals. As we are interested in how co-speech gestures affect the comprehension of a discourse uttered verbally, our investigation focuses on oral deaf individuals, rather than on signing deaf individuals. Oral deaf individuals understand verbal communication through lip-reading (or speech-reading), that is the ability to perceive what a person says by observing the movements of her/his lips (Alegria, 1998; Campbell, 1997). Oral deaf individuals have to process verbal information in a different way with respect to hearing individuals, because oral deafs receive the linguistic information not through the acoustic channel, but through the visual channel. Also gestures are received through the visual channel, and they are processed with visual modality. Then, does co-speech gestures sort on oral deafs exactly the same effects as on hearing individuals, despite the differences in processing verbal information? That is, might gesticulation accompanying speech facilitate lip-reading, or does it hinder it? The question is important as well as much delicate, because requiring oral deaf individuals to rely exclusively on lip-reading may deprive them of other sorts of information useful for a deep discourse comprehension (Andrews & Zmijewski, 1997).

In this paper we follow the tenets of the theory by Cutica and Bucciarelli (2008) and we extend its assumptions to account for deep comprehension from a discourse accompanied by gestures in oral deaf individuals. We predict that co-speech gestures have, on oral deaf individuals, effects which parallel those they have on hearing individuals: they lead to a better recollection of correct information, to a higher production of inferences, and to a worse recognition of verbatim. However, we also predict that co-speech gestures have on oral deafs some effects that are linked to the particular strategies that oral deafs use in comprehending a discourse. We will detail all these predictions in the following sections.

The contribution of co-speech gestures to the construction of a discourse model

Cutica and Bucciarelli (2008) follow the tenets of mental model theory, model theory for short (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991), and assume that deep comprehension and learning from a discourse involve the construction and manipulation of an articulated mental model of its contents, that is a mental representation that reproduces the states of affairs described in the discourse in a non-discrete representational format. Under the term “situation models”, mental models have been invoked as an important explanatory principle for comprehension processes at a discourse level (Kintsch, 1998; McNamara, Miller & Bransford, 1991; van Dijk & Kintsch, 1983). Many researchers have argued that the construction of a coherent mental model is tantamount to the successful comprehension of a text (e.g., Glenberg, Kruley & Langston, 1994; Graesser, Millis & Zwaan, 1997; McNamara et al., 1991; Zwaan, Magliano & Graesser, 1995; Zwaan & Radvansky, 1998), in that it integrates temporal, spatial, causal, motivational, person- and object related information stated explicitly in the text. In comprehending a discourse, people construct a model for each sentence, integrate such models also taking into account their prior knowledge, and consider what, if anything, follows. Mental models encode content information of the semantic and pragmatic sort, linked with the relevant individual’s prior knowledge, and in case with the inferences drawn; they generally do not encode surface information, i.e., the linguistic form of the sentences (Johnson-Laird, 1983; Johnson-Laird & Stevenson, 1970; Garnham, Oakhill & Cain, 1998). Hence, the construction of a model should lead to a poor retention of discourse verbatim; indeed, individuals who build a mental model of a given text material retain the verbatim level of the material less than individuals who do not build a mental model (see Many & Johnson-Laird, 1982 for experimental evidence in favor of this claim).

Cutica and Bucciarelli (2008) claim that co-speech gestures by the speaker facilitate the construction of a discourse model, because both gestures and models are non-discrete in nature. Mental models are non-discrete mental representations in that they encode external objects and events in such a way that these are represented holistically and to a certain degree analogically, differently from propositions, which are discrete, quasi-verbal way of representation (see also

Hildebrandt, Moratz, Rickheit & Sagerer, 1999; Rickheit & Sicheleschmidt, 1999). Cutica and Bucciarelli observe that co-speech gestures convey information in a non-discrete representational format (see Bucciarelli, 2007), too, and they argue that, as models are non-discrete mental representations, co-speech gestures may result in representations that are easily included together in the mental model of discourse. Thus, co-speech gestures facilitate the comprehension of a discourse acting on a global level, allowing the construction of an articulated and complete mental model of the discourse. Furthermore, we assume that co-speech gestures facilitate comprehension also acting at a local level, by facilitating the identification, and hence the disambiguation, of labial and phonemic information. Indeed, as gestures convey meaning, they can sustain the appropriate identification of the information conveyed through lips. Gestures' contribution to words identification is possible because the process of words identification is parallel to the process of assign meaning to words; the two elaboration paths are strictly interconnected (MacDonald, Pearlmutter & Seidenberg, 1994). Our assumption is in line with the literature revealing that co-speech gestures facilitate listeners' comprehension of speech particularly when the verbal message is ambiguous (Thompson & Massaro, 1986), highly complex (Graham & Heywood, 1976; McNeil et al., 2000), or uttered in a soft voice (Berger & Popelka, 1971). Such a function of gestures is much relevant for deaf individuals, as they need information that interacts with the linguistic source in order to disambiguate lip-reading information and to improve discourse comprehension (see below).

Cutica and Bucciarelli (2008) assume that well-articulated models facilitate the retention of content information and the drawing of correct inferences. Indeed, the literature suggests that individuals who have built an articulated model of a given material are more likely to draw correct inferences from the information explicitly contained in that material, compared to individuals who have built a less articulated model (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). An important distinction is made between discourse-based inferences and elaborative inferences, because only the former are based on mental models. Discourse-based inferences make explicit that information which is originally implicit in the text; they may regard, for instance, the causal antecedent, the causal consequent, and the character's mental states (i.e., beliefs and intentions) with respect to the actions described (Graesser, Singer & Trabasso, 1994). Elaborative inferences (e.g., Singer, 1994) are instead a sort of arbitrary enrichment of the original text; such an enrichment involves information which is not originally implicit in the text. Cutica and Bucciarelli also assume that articulated models of the discourse lead to a poor retention of the surface form of the text, as model representations do not generally contain surface information (i.e., the linguistic form of sentences, see Johnson-Laird, 1983).

The theory of discourse comprehension by model in oral deafs

We assume that deep comprehension from discourse in deaf individuals, like in hearing individuals, consists in the construction of a discourse model; further, we assume that co-speech gestures facilitate model construction also in deaf individuals. Indeed, speech and co-speech gestures by the speaker should be processed holistically by the partner, independently on she/he is deaf or hearing. Starting from the seminal works by McNeill (1985; 1992; 2005) and Kendon (1994), it is generally shared in the literature that gestures and speech function together as a unit, by forming a single, integrated system of communication, and that the information conveyed by speech and the information conveyed by co-speech gestures are processed together by the partner (see, e.g., Goldin-Meadow, 1999; Iverson & Goldin-Meadow, 2001; Kelly et al., 1999; McNeil et al., 2000).

How does oral deaf individuals understand a verbal communication? Most of oral deafs were born to hearing parents and they learnt to communicate orally and to read the words on the lips of the speakers. However, lip-reading alone does not guarantee a good understanding of speech, because visual information is far more ambiguous than auditory information: spoken words often occur phonetically underspecified on the lips of the speaker (Dodd, 1987**;** Miller, 2006). Furthermore, as pointed out by a series of studies (see, e.g., Alegria & Lechat, 2005; Gregory & Hindley, 1996), the articulation configuration of a certain phoneme may vary depending on the articulation configuration of the previous and the following phoneme (this phenomenon is called *co-articulation,*), and some letters (such as /B/P/ and /T/D) are generated by a visual identical lip pattern (*homologia*). In particular, grammatical morphemes such as articles, prepositions, conjunctions, pronouns, and verbal auxiliaries, are difficult to recognize as they are short items that are produced rapidly and with loss stress (Pizzuto, Caselli & Volterra 2000; Volterra, Capirci & Caselli, 2001). Finally, at the discourse level, lip-reading strategy seems to impair the ability to chunk sets of words and combining them into meaningful phrases and sentences (Brown & Brewer, 1996; Kelly, 2003). As a consequence, it may cause a difficulty in constructing a global mental representation of discourse content.

Thus, co-speech gesture should be relevant for deaf individuals, who need information that interacts with the linguistic source in order to disambiguate lip-reading information and to improve discourse comprehension. The characteristics of discourse processing by oral deaf individuals leads us to make two specific assumptions on discourse comprehension by oral deaf individuals:

(1) Enhanced visual processing. All hearing individuals process speech through the auditory channel and co-speech gestures through the visual channel. Oral deaf individuals, instead, process both speech and co-speech gestures through the visual channel. We assume that oral deaf individuals process effectively both speech and co-speech gestures through high spatially distributed attention. Our assumption is in line with studies in the literature showing that deaf individuals, as compared with hearing individuals, develop a more spatially distributed visual attention (Mitchell & Quittner, 1996; Parasnis & Long, 1979; Quittner, Smith, et al., 1994). This is the reason why deaf people perform as well as or even better than hearing people on tasks that involve visual or spatial processing (Conrad, 1972; Zarfaty, Numes & Bryant, 2004), and they rely more heavily on visuo-spatial working memory in order to retain information (Marschark & Mayer, 1998).

(2) The focus on words strategy. Oral deaf individuals, in speech processing, focus their attention on single items. This assumption is consistent with studies in the literature showing that oral deaf individuals focus on isolated items of an utterance rather than syntactic and semantic

processing of the text (Marschark, 2006; Miller, 2006; 2007; Mohammed, Campbell, Macsweeney, Barry & Coleman, 2006). This behavioural pattern can not be explained just in terms of a poor ability to identify words, as oral deaf people are comparable with hearing people in words identification (Wauters, Van Bon & Tellings, 2006). Rather, a possible reason underlying the focus on single words would be a poor ability to exploit the syntactic information in order to reconstruct the meaning of the global sentence (for the deaf Italian population, see, e.g., Radelli, 1998).

Our assumptions on the atypical processing of a discourse by of oral deaf individuals give rise to specific predictions on the role of co-speech gestures in their discourse comprehension. First, from the *enhanced visual processing* assumption we derive the prediction that oral deaf individuals benefit from the co-speech gestures of the speaker. The prediction is not obvious, because the concurrent double role of the visual channel in oral deaf individuals (lip-movements processing and co-speech gestures processing) might cause a cognitive overload and compromise discourse processing (Mayer & Moreno, 1998). We assume that this is not the case because oral deaf individuals, as compared with hearing individuals, rely on a higher visual processing ability, which allows them to accomplish the double task to process both speech and co-speech gestures (see also Marschark, 2006; Marschark & Mayer, 1998). A general prediction follows: co-speech gestures accompanying discourse facilitate in deaf people the construction of an articulated model of the discourse. In particular, in *recollection tasks*, we expect to find that a discourse accompanied by gestures, as compared with a discourse not accompanied by gestures, results in better recollection of correct information and a greater number of discourse-based inferences drawn from the information explicit in the discourse. This effect parallels the effect of co-speech gestures in discourse recollection by hearing individuals (see Cutica & Bucciarelli, 2008). In *recognition tasks*, we expect to find that a discourse accompanied by gestures, as compared with a discourse not accompanied by gestures, results in a poorer ability to recognize the utterance actually produced by the speaker. Again, this effect parallels the effect of co-speech gestures in discourse recollection by hearing individuals (see Cutica & Bucciarelli, 2008). A further prediction, specific for the deaf population, follows from the *focus on words* assumption. In absence of gesture, when faced with utterances differing in meaning from the original ones, but containing identical items (i.e., words), oral deaf individuals tend to assert that the presented utterances correspond to that one originally produced by the speaker. The strategy leads to successful performances with utterances that literally correspond to those actually produced by the speaker, but a poor performance with wrong sentences and paraphrases (they are confounded with the original sentences actually uttered by the speaker).

Evidence for gestures facilitating discourse recollection

Experiment 1: High-spatial and movement content discourse (Recall Task)

The experiment is a replication of an experiment conducted by Cutica and Bucciarelli (2008) on hearing individuals. We slightly modified the experimental procedure to make it more appropriate for the deaf population (see below). From our assumptions we derive the prediction that oral deaf individuals attending a discourse accompanied by spontaneous gestures, as compared with oral deaf individuals attending a discourse not accompanied by gestures, produce more correct recollections and draw more discourse-based inferences. This prediction parallels the prediction for hearing individuals and confirmed by Cutica and Bucciarelli's (2008) study. We have no predictions for the number of elaborative inferences and erroneous recollections: mental models do not prevent a person from making mistakes. In particular, if deaf individuals misunderstand some piece of a discourse, there is a chance that the misunderstood information will be included in the mental model, thus supporting an elaborative inference or a wrong recollection.

METHOD

Participants

The participants in the experiment were sixteen deaf adults (8 female and 8 males, whose age ranged from nineteen to forty years, mean age: 33 years) with a prelingually profound hearing deficit (>90 dB hearing loss). None of them had other disabilities. They came from middle class families. Their parents were hearing and native Italian, and educated them through an early and intensive oral method, based on lip-reading. None of the participants ever learned the Italian Sign Language. Also, all the participants had a senior school degree, obtained at public schools for hearing individuals. Thus, none of the participants was ever exposed, at school, to a conventional Italian sign system (simultaneous speaking and manual signs). The participants were recruited through the Deafmute Institute of Pianezza (Turin). Half of them were randomly assigned to the Gesture condition, and half to the No-Gesture condition.

Materials

The experimental materials comprised two videotaped fictions in which an actor produces a discourse about a series of events occurred at funfair park (see Appendix A). In particular, the actor tells a story in which a boy at the funfair finds, and later on, loses a girl. The discourse is the same used by Cutica and Bucciarelli (2008), but it is reduced in length (each fiction lasts 2 minutes). The discourse in both fictions is produced under two different conditions: the *Gesture condition*, in which the actor accompanies the discourse with spontaneous gestures (he was instructed to produce hand and arm movements as he felt appropriate with respect to the discourse flow), and the *No-Gesture condition*, in which the actor produces the discourse without gesticulating. In both conditions the actor's face is in close-up, and his lip movements are very slow, in order to facilitate lip-reading. Thus, as compared with the discourse used by Cutica and Bucciarelli, the discourse is uttered very slowly. The actor in the *Gesture condition* uses a wide variety of iconic, metaphoric and deictic gestures (see Appendix A1). In the gesture condition none of the gestures produced by the actor are I.S.L. (Italian Sign Language). Also, two judges excluded the possibility that any of the actor's gestures was of the symbolic type, namely a gesture with a widely-recognized conventionalized meaning, which could convey meaning also in absence of speech. Further, once identified the participants' recollections which corresponded to discourse-based inferences (see below), the two independent judges ascertained that the actor's gestures were not the source of any of those discourse-based inferences.

Procedures

The experiment was carried on individually, in a quiet room at the sole presence of one experimenter and one deafs' teacher assistant. Participants, randomly assigned to one of the two experimental conditions, were invited to attend the fiction carefully, and they were told that afterwards they would have been invited to recall as much information as they could, with no time limits. The experimenter explained that the experiment was concerned with how people comprehend stories. The instructions for the participants were as follows: "This is an experiment on how people comprehend a discourse. I'll show you a video depicting a young male making a discourse. You have to look at it carefully, paying attention to what he says orally. The discourse has an approximate length of 2 minutes and it is not easy. At the end of the tape, I will ask you to tell me all you can remember of the discourse. Your answer will be video-taped". The experiment then began and participants were invited to watch the video (the audio was excluded from the video because the participants were profoundly deaf). As soon as the video finished, participants were invited to recall as much information in the discourse as they could (free recollection task). Participants were video-recorded while recollecting the information.

Coding schema

To code the results, the discourse was divided into thirty seven semantic units, corresponding to as many main concepts that the participants could recall (see Appendix A). As compared with the segmentation in units of the original discourse used by Cutica and Bucciarelli (2008), we adopted a more fine grained segmentation, in order to increase the chance to recollect a significant number of units in our deaf participants. Each concept (semantic unit) recalled by the participants was evaluated 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.

Consider, for example, the following semantic unit in the funfair discourse: ‘It was there, at the funfair, it was there that I found her, and it was at the funfair that I lost her’. According to the coding schema, the statement: ‘The boy at the funfair found and later on lost a girl at the funfair’ is a correct recollection; the statement: ‘A boy is interested in retell that he met a girl and later he lost her, he was very attracted, and he wish know her’ is a discourse-based inference; the statement: ‘He saw a very nice girl’ is an elaborative inference, and the statement: ‘A boy lost a girl but later on he found her again’ is an erroneous recollection.

Two independent judges coded the participant’s recollections individually; for each experimental condition, they reached a significant level of agreement on their first judgements on each type of recollection (Cohen’s K ranging from .932 and .944, all $p<.001$). For the final score, the judges discussed each item on which they disagreed, until reaching a full agreement.

Results

Table 1 shows the mean scores of recollections and standard deviations in the two experimental conditions of the experiment.

Insert Table 1 about here

As predicted, discourse-based inferences were greater in the Gesture condition than in the No-Gesture condition (T-Test: $t(14)= 2.19$; tied $p<.03$). However, correct recollections were produced in the same measure in the Gesture and the No-Gesture conditions (T-Test: $t(14)= 1.36$; tied $p=.10$). The same result holds for elaborative inferences (T-Test: $t(14)=1.32$; $p=.21$) and erroneous recollections (T-Test: $t(14)= .41$; $p= .70$), for which we had no specific predictions.

Discussion

The results of Experiment 1 suggest that spontaneous gestures facilitate the construction of a mental model of the discourse content. In particular, co-speech gestures produced by the speaker facilitate in oral deafs the possibility of drawing inferences from the information explicitly contained in the discourse. The prediction for correct recollections is not confirmed: they are not more frequent in the Gesture condition than in the No-Gesture condition, although the difference in their production in the two conditions is in the predicted direction. We have a tentative explanation. If gesture facilitate in the deaf person the construction of a mental model of the utterance, the deaf person is very likely to make a discourse-based inference, maybe more likely than a hearing person who constructed a mental model of the utterance. The underlying reason would be that, due to their hearing impairment, deaf individuals are more likely than hearing individuals to exploit non-discrete (visual) information (Passig & Eden, 2003; Volterra, Pace, Pennacchi & Corazza, 1995; Zarfaty et al., 2004), and mental models are non-discrete (mental) representations. A great exploitation of modelistic representations results in great production of discourse-based inferences.

Thus, our predictions are partially confirmed, at least for the role of co-speech gestures in comprehending a discourse with a high-spatial and movement content. Indeed, a series of experimental studies (Alibali, Heath & Myers, 2001; Feyereisen & Harvard, 1999; Krauss, 1998) reveal that speakers tend to produce more spontaneous gestures when speaking about topics that involve spatial and movement content. However, not only spatial but also non-spatial contents ought to be equally well represented in a mental model, so we expect that discourse comprehension should benefit of gestures independently of a discourse content. Thus, in order to exclude the possibility that the influence of gestures on comprehension as found in Experiment 1 may depend upon the fact that the discourse had a significant spatial and movement content, we replicated Experiment 1 using an abstract and technical discourse, with little spatial and movement content.

Experiment 2: Low-spatial and movement content discourse (Recall Task)

Experiment 2 is a replication of Experiment 1, with the exception that the discourse produced by the actor had a low-spatial and movement content. The predictions for Experiment 2 were the same as those for Experiment 1. In particular, this Experiment 2 is also a replication of an experiment by

Cutica and Bucciarelli (2008) on hearing individuals, and the predictions for the deafs parallel the predictions for the hearing individuals.

METHOD

Participants

The participants in the experiment were sixteen deaf adults (10 female and 6 males, whose age ranged from twenty to forty-four years, mean age: 32 years) with a prelingually profound deficit (>90 dB hearing loss). None of them had took part in Experiment 1. None of the participants had other disabilities, and they came from middle class families. Their parents were hearing and native Italian, and educated them through an early and intensive oral method, based on lip-reading. None of the participants ever learned the Italian Sign Language. Also, all the participants had a senior school degree, obtained at public schools for hearing individuals (none of them was ever exposed, at school, to a conventional Italian sign system). The participants were recruited through the Deafmute Institute of Pianezza (Turin). Half of them were randomly assigned to the Gesture condition, and half to the No-Gesture condition.

Materials

The experimental materials comprised two videotaped fictions (approximate length of each was 2 minutes) in which an actor produces a discourse about color perception (see Appendix B). In particular, the actor describes the link between different colors and emotions. The discourse is the same used by Cutica and Bucciarelli (2008), but it is reduced in length. The discourse in both fictions is produced under two different conditions: the *Gesture condition*, in which the actor accompanies the discourse with non-symbolic gestures (he was instructed to produce hand and arm movements as he felt appropriate with respect to the discourse flow), and the *No-Gesture condition*, in which the actor produces the discourse without gesticulating. In the *Gesture condition* the actor uses a wide variety of iconic, metaphoric and deictic gestures (see Appendix B1). As in Experiment 1, two judges excluded the possibility that any of the actor's gestures was of the symbolic type, namely a gesture which could convey meaning also in absence of speech. Further, once identified the participants' recollections which corresponded to discourse-based inferences (see below), the two independent judges ascertained that the actor's gestures were not the source of any of those discourse-based inferences. In both conditions the actor's face is in close-up, and his lip movements are very slow, in order to facilitate lip-reading. As compared with the discourse used by Cutica and Bucciarelli, the discourse is uttered very slowly.

Procedures

The procedures were the same as those for Experiment 1. The experiment was carried on individually, in a quiet room at the sole presence of one experimenter and one deafs' teacher assistant.

Coding schema

To code the results, the discourse was divided into fourteen semantic units, corresponding to as many main concepts that the hearer could recall (see Appendix B). As compared with the segmentation in units of the original discourse used by Cutica and Bucciarelli (2008), we adopted a more fine grained segmentation, in order to increase the chance to recollect a significant number of units in our deaf participants. As in Experiment 1, each concept (semantic unit) recalled by the participants was evaluated as Correct recollection, Discourse-based inference, Elaborative inference, or Erroneous recollection. Consider, for example, the following semantic unit in the color perception discourse: 'There is a very widespread belief that the expression of colors is based on association'. According to the coding schema, the statement: 'I saw a man that explained the colors association theory' is a correct recollection; the statement: 'this fiction speak about colors and their association to particular feelings' is a discourse-based inference; the statement: 'the boy speak about conceptual association between colors and collective unconscious' is an erroneous recollection. Finally, consider for example the following semantic unit: '(red) reminds us of the connotations of fire'. According to the coding schema, the statement: 'red is associated to danger' is an elaborative inference.

Two independent judges coded the participant's recollections individually; for each experimental condition, they reached a significant level of agreement on their first judgements on each type of recollection (Cohen's K ranging from .909 and .944, all p<.001). For the final score, the judges discussed each item on which they disagreed, until reaching a full agreement.

Results

Table 2 shows the means of types of recollection (and standard deviations) in the two experimental conditions of the experiment.

Insert Table 2 about here

As predicted, discourse-based inferences were greater in the Gesture condition than in the No-Gesture condition (T- Test: t(14)= 2.41; p<.02). However, correct recollections were produced equally often in the two conditions (T-Test: t(14)= .70; p= .25). The same result holds for elaborative inferences (T-Test: t(14)=.40, p=.69) and erroneous recollections (T-Test: t(14)= -1.26; p= .23), for which we had no specific predictions.

Discussion

Our predictions are partially confirmed: discourse-based inferences, but not correct recollections, are greater in the Gesture condition than in the No-Gesture condition. Although the difference in number of Correct recollections is in the predicted direction, the statistical analysis did not yield a statistically significant result. This result, parallels the result concerning correct recollection in Experiment 1. Globally considered, our results support the assumption that discourse comprehension in oral deaf individuals is facilitated by the possibility of having access to the non-symbolic gesticulation of the speaker. In line with Cutica and Bucciarelli (2008) our results suggest that discourse comprehension benefits from co-speech gestures independently of the content of the discourse. These results are not surprising if we consider that in a mental model spatial and non-spatial content are both equally well represented. Thus, also in oral deaf people spontaneous gestures could be considered a valid support in order to full understanding a message uttered through the verbal channel. Our assumptions would be further supported by evidence that a oral deaf person attending a discourse of a speaker who does not gesticulate recovers the literality of the discourse more easily than a oral deaf person who sees the speaker gesticulate. We devised Experiment 3 to explore this possibility.

Evidence for gestures impairing memory for discourse verbatim

Experiment 3: A recognition task

In this experiment participants attended to a discourse, either in a Gesture condition or in a No-Gesture condition. Then, they were invited to consider whether some sentences were identical to those uttered by the actor. We assumed that in deaf people spontaneous gestures accompanying discourse facilitate at local level lip-reading discrimination, and at global level the construction of an articulated mental model of the discourse. A main consequence is that gestures compromise the retention of the linguistic form of the discourse sentences. In absence of gestures, instead, we assumed that oral deaf people focus on the single words uttered by the speaker: neither lip-reading nor the construction of a discourse model is facilitated. In our recognition task, we presented 3 sorts of written sentences: identical to those in the discourse (*literally correct*), with the same meaning, but partially said with different words (*paraphrases*), and inconsistent in meaning (*wrong content*). Paraphrases and Wrong content sentences were constructed so to contain many words identical to those contained in the original sentences actually uttered by the actor. Thus, it follows the prediction that the focus on the single words leads the deafs in the No-Gesture condition to accept as correct both Paraphrases and Wrong content sentences. This predictions concerning the role of the speaker's co-speech gestures when the task of the partner is to recognize, afterwards, the discourse verbatim, differs from the predictions made by Cutica and Bucciarelli (2008) for hearing individuals. Our detailed predictions are as follows:

1. In the Gesture condition, as compared with the No-Gesture condition, deaf people are poorer in identifying the sentences originally uttered by the speaker.

2. In the Gesture condition, as compared with the No-Gesture condition, deaf people perform better with Paraphrases and Wrong content sentences.

METHOD

Participants

The participants in the experiment were thirty-six oral deaf adults (24 female and 12 males, whose age ranged from twenty to forty-eight years, mean age: 34 years) with a prelingually profound hearing deficit (>90 dB hearing loss). None of them had took part in Experiment 1 or 2. None of the participants had other disabilities. They came from middle class families. Their parents were hearing and native Italian, and educated them through an early and intensive oral method, based on lip-reading. None of the participants ever learned the Italian Sign Language. Also, all the participants had a senior school degree, obtained at public schools for hearing individuals (none of them was ever exposed, at school, to a conventional Italian sign system). The participants were recruited through the Deafmute Institute of Pianezza (Turin). Half of them were randomly assigned to the Gesture condition, and half to the No-Gesture condition.

Materials and procedures

The materials were the same as in Experiment 1 and 2. In particular, we used the funfair videotape fiction (high-spatial and movement content) and the color perception videotape fiction (low-spatial and movement content) and we presented them in both the Gesture and the No-Gesture conditions. The experiment was carried on individually, in a quiet room at the sole presence of one experimenter and one deafs' teacher assistant. Participants, randomly assigned to one fiction and one condition, were instructed to watch the video of the discourse carefully, paying attention to what the actor said, and they were told that at the end of the videotape, the experimenter would ask them some questions. Thus, they were not told that later on they would be required to recognize the actual utterances they had lip-read. As soon the video finished, the participants were presented with a list of sentences, one by one in a random order, and they were invited to consider whether or not the sentences were identical to those actually articulated by the actor (recognition task). The sentences presented were 21: 7 *literally correct*, 7 *paraphrases*, and 7 *wrong content* (examples are in Appendix C). The instructions for the participants were the following: “This is an experiment on how people comprehend a discourse. I’m going to show you a video depicting a young male making a discourse. You have to look at it carefully, paying attention to what he says orally. The discourse has an approximate length of 2 minutes and it is not easy. At the end of the tape, I will ask you some questions.” The experiment then began and participants were invited to watch the video. The audio was excluded because the participants were profoundly deaf. As soon as the video finished, participants were invited to read carefully the sentences in order to recognize those actually uttered by the speaker (recognition task). We coded as correct *“Yes”* responses to literally correct sentences, and *“No”* responses to paraphrases and wrong content sentences.

Results

Our recognition tests were yes/no tasks involving signal trials. In each of the two tasks participants were presented with 7 signals (i.e., literally correct sentences) and 14 noise trials (7 paraphrases and 7 errors). On signal trials, *yes* responses were correct (*hits)*; on noise trials, *yes* responses were incorrect (*false alarms).* Table 3 illustrates the proportions of types of recognition in the Gesture and the No-Gesture conditions for the funfair discourse. We applied the signal detection theory (SDT) to assess sensitivity.

Insert Table 3 about here

In the Gesture protocol, the results of a paired t-test on d’ values for the comparison Literally correct-Paraphrases (the mean d’ was 1.74) and Literally correct–Wrong content (the mean d’ was 0.74) revealed a comparable sensitivity in both comparisons (t=.41; p=.70). Also, in the No-Gesture protocol the results of a paired t-test on d^1 values for the comparison Literally correct-Paraphrases (the mean d’ was .31) and Literally correct–Wrong content (the mean d’ was .12) suggested comparable sensitivity in both comparisons (t=.58; p=.58).

Table 4 illustrates the proportions of types of recognition in the Gesture and No-Gesture conditions for the colour discourse. We applied the SDT to assess sensitivity.

Insert Table 4 about here

In the Gesture protocol, the results of a paired t-test on d’ values for the comparison Literally correct-Paraphrases (the mean d’ was .04) and Literally correct–Wrong content (the mean d’ was .24) suggested comparable sensitivity in both comparisons (t=1.06; p=.32). The same results holds for the No-Gesture protocol: a paired t-test on d^1 values for the comparison Literally correct-Paraphrases (the mean d’ was .43) and Literally correct–Wrong content (the mean d’ was .27) suggested comparable sensitivity in both comparisons (t=.94; p=.38).

Table 5 shows the mean correct performance (and standard deviations) with the different sorts of sentences in the two experimental conditions of the funfair discourse (high-spatial and movement content discourse).

Insert Table 5 about here

As predicted, participants in the No-Gesture condition performed better than participants in Gesture condition in recognizing the sentences actually uttered by the actor (answering “YES”) (t(16)=-4.13, tied p=.001). Also, as predicted, participants in the Gesture condition performed better than participants in the No-Gesture condition in recognizing paraphrases (answering “NO”) (t(16)=2.34, tied p=.03), and in recognizing wrong content sentences (answering “NO”) (t(16)=4.86, p=<.001).

Table 6 shows the mean correct performance (and standard deviations) with the different sorts of sentences in the two experimental conditions of the color perception discourse (low-spatial and movement content discourse).

Insert Table 6 about here

As predicted, participants in the No-Gesture condition performed better than participants in the Gesture condition in recognizing sentences actually uttered by the actor (answering “YES”) (t(16)=-4.38, tied p=<.001). Also, as predicted, participants in the Gesture condition performed better than participants in the No-Gesture condition in recognizing paraphrases (answering “NO”) (t(16)=2.36; tied p=.031), and in recognizing wrong content (answering “NO”) (t(16)=2.61, p=.019).

Discussion

The results of Experiment 3 confirmed our assumption, because independently of the content of the discourse, co-speech gestures impair memory for discourse verbatim. However, deaf people who attend a discourse accompanied by gestures have the possibility to comprehend in depth the holistic meaning of the message. Our results are in line with previous studies on hearing individuals (Cutica and Bucciarelli, 2008): also in deaf people the lack of co-speech gestures facilitates the possibility to retain discourse verbatim.

Conclusion and general discussion

Globally considered, our results support the assumption that discourse comprehension by oral deaf individuals is facilitated by the possibility of having access to co-speech gestures. The results of Experiment 1 and 2 showed that a discourse accompanied by gestures, as compared with a discourse not accompanied by gestures, facilitates a greater production of discourse-based inferences in oral-deaf people, independently of the content of the discourse. The results of Experiments 3 showed that spontaneous gestures accompanying discourse facilitate both words and discourse comprehension and, as a side effect, losing memory for verbatim. An obvious consideration is that gestures are not beneficial in cases in which it is important to remember discourse surface form.

A main assumption of our investigation was that deaf individuals should benefit from a speaker's gesturing in discourse comprehension, such as hearing individuals do. In particular, we assumed that for oral deaf individuals, thanks to their high distributed visual attention and high spatial working memory, should be easy to process simultaneously the two sorts of visual information: lip-reading and co-speech gestures. Our predictions are confirmed by the results of our experiments when compared with the results of the studies by Cutica and Bucciarelli (2008) on hearing individuals. The comparison reveals that our deaf participants benefits from co-speech gestures as hearing participants do. More into detail, in the recollection tasks, we observe an increase in production of discourse-based inferences from the No-Gesture to the Gesture condition for the deaf participants as well as for the hearing participants. Further, the deafs' production of erroneous recollection decreases from the No-Gesture to the Gesture condition as well as the hearings' production of erroneous recollection. As regards the recognition tasks, the comparison reveals that both deaf individuals and hearing individuals benefit from the absence of co-speech gestures: there is an increase in correctly recognizing Literally correct from Gesture to No-Gesture condition. Also, we observe that in the hearing population the memory for discourse verbatim resulted also in the capacity to recognize that Paraphrases did not correspond to the original utterances uttered by the actor. On the contrary, in the deaf population, the absence of co-speech gestures positively affected the performance with Literally correct, but not the performance with Paraphrases (and Wrong content). This may be due to the peculiar reliance of deaf individuals on the *focus on words strategy*, that lead them to perform differently, at least in part, from hearing individuals. Indeed, hearing individuals who attend a discourse not accompanied by gestures are able to recognize that paraphrases and wrong content sentences differ from the original assertions of the actor. On the contrary, deaf individuals in the no-gestures condition faced with utterances differing in meaning from the original ones, but containing identical items (i.e., words), tend to assert that the presented utterances correspond to that one originally produced by the speaker. As a result, a discourse not accompanied by gestures, as compared with a discourse accompanied by gestures, results in a poorer ability to recognize that the wrong sentences and the paraphrases do not correspond to the original sentences actually uttered by the speaker.

Our results are also consistent with the fact that other types of manual communication are beneficial for deafs' comprehension. In particular, we refer to manual codes in which hands and fingers' movements, in conjunction to sequential order of the words, provide further information in addition to speech. One code is finger-spelling, a system with an alphabetic writing system in which specific handshapes represent the letters of the alphabet, and spoken or written words can be articulated as handshapes sequences (Pizzuto et al., 2000). A second code is bimodal communication, a manual coded speech in which the content words occurring in sentences (nouns, verbs, adjectives, adverbs) are combined simultaneously with the corresponding signs (Greenberg, Calderon & Kusché, 1984; Musselman & Akamatsu, 1999; Nicholas & Geers, 1997). A third code is Cued Speech (CS), a system of hand gestures at positions near and around the mouth; that allow to specify the discourse both at the syllabic and at the phonemic levels. Thus, to each syllable and to each phoneme corresponds one and only one combinations of labial and manual information (Alegria, Charlier & Mattys, 1999). Within our theoretical perspective, non-symbolic gestures accompanying discourse, like these types of manual communication, do not interfere with speech information processing. Rather, gestures offer to deaf people the possibility of constructing an articulated model of the discourse.

As a final remark, we claimed that co-speech gestures may be beneficial in two ways: on one side they help oral deafs to reach a good understanding of words, by disambiguating ambiguous words and lowering the effects of co-articulation and homologia; on the other side they help to build a complete mental model of the discourse. However, our experiments does not allow to draw conclusions on the weight of these two effects; it would be interesting to further explore how co-speech gestures contribute to each of them.

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Appendix A

The discourse “At the funfair” (Cocteau). Semantic units are separated by slashes.

It was there, at the funfair, it was there that I found her, and it was at the funfair that I lost her./It was a vast funfair./A funfair with shooting-ranges/and candy floss/and Japanese bagatelle tables,/booths with bottles of champagne/and showmen’s booths/big showmen’s booths,/and roundabouts./And the roundabouts revolved and creaked/and the bagatelle tables clincked/and the candy floss scented the air/and the rifles shot./I was shooting at the target /I can shoot at the target very well and I am proud of it /No, wait a moment, I am wrong!/I did not meet her at the shooting-range/.I met her at the candy floss’ desk. Yes, it was at the candy floss’ that I found her./The candy floss scented the air/, and she was eating it/and she blew on her candy/and I was all covered with white powder./She started laughing /and I asked her:“What’s your name?”/And she yelled to me: “I’ll tell you later”./Later, we went to the shooting-range/and it was there that I lost her./I aimed at the target breaking all the clay pipes/and every time she yelled to me:“Well done!”/And then, when no pipes were left to break,/I aimed at the egg,/the one held up by the jet of water/and while I was aiming I shouted to her: “What's your name?”/And she replied: “I’ll tell you later.”/ I shot,/ the egg popped up./I turned aside and she wasn’t there any more.

Appendix A1

Description of the gestures performed by the actor in the discourse "At the funfair"

	The gesture took place while the actor was saying…	**Gesture description**	**Gesture type**
1	Been there	the index finger of the left hand in front of the trunk swings outwards twice	deictic
2	That I lost her	the left hand, with the palm facing upwards, moves outwards	metaphoric
3	A vast funfair	the right hand and the left hand with the palms facing forward, cross over in front of the trunk and open outwards	iconic
4	With the shooting-range	the index finger of the left hand on a level with the trunk shifts leftwards with a slight movement	iconic
5	And the candy floss	the index finger of the left hand on a level with the trunk moves towards the mouth	metaphoric
6	And the Japanese bagatelle tables	the index finger of the left hand on a level with the trunk shifts to the left with a slight movement	deictic
7	Bottles of champagne	the index finger of the right hand shifts to the right with a slight movement	deictic
8	Huts	the right hand with the palm facing downwards rotates to the right	deictic
9	Booths	the right hand with the palm facing downwards rotates to the right	deictic
10	Roundabouts	the two closed hands open quickly outwards	metaphoric
11	Roundabouts turned and creaked	the two hands rise simultaneously from the trunk and rotate alternately about themselves four times in succession	iconic
12	The pinball machines clinked	the left hand closed in the shape of a chestnut rises from the trunk to the level of the left ear and swings three times close to the actor's left ear	metaphoric
13	Scented the air	the fingers of the right hand and of the left hand move slowly towards the actor's mouth rubbing against one another several times	iconic
14	And the rifles shot	the index finger of the right hand and of the left hand at trunk level move twice towards the left side of the actor's trunk	iconic
15	I was shooting at the target	the thumb and index finger of the right hand and of the left hand are at the center of the actor's trunk, they move	iconic

		twice towards the left side of the trunk	
16	Very well	the left hand moves slightly downwards and towards the actor’s trunk	batonic
17	I am confused	the index finger of the left hand swings once at the center of the trunk, while the right hand stays still at trunk level	metaphoric
18	I did not met her	the index finger of the right hand and the index finger of the left hand swing once at the center of the trunk	metaphoric
19	Everything was scented	the two hands are parallel, with the palms downwards they rise quickly, while the fingers open by turns and as they move upwards they brush against the actor’s nose	iconic
20	And she blew	the two hands parallel with the palms upwards move quickly from the center of the trunk to mouth level, and then move quickly down and outwards	iconic
21	Every time	the left hand move quickly to the level of the actor’s neck and then moves quickly down	batonic
22	I aimed at the egg	the hands parallel and in a vertical position in front of the face move simultaneously to the left	iconic

Appendix B

The discourse “The reactions to colors”. Semantic units are separated by slashes.

It’s beyond dispute that the colors carry strong expressive components./ Some attempts have been done to describe the specific expressive characters of the various colors / and to draw some general conclusions from the symbolic use the different cultures have made of them./ The is a very widespread belief that the expression of colors is based on association. / Therefore, red should be considered exciting / because reminds us of the connotations of fire,/ blood/ and revolution./ Green evokes the restorative thought of nature,/ and blue is refreshing like water./ However, the theory of association is not more interesting/ or prolific in this field than in others / The effects of colors are too direct and spontaneous to be only the results of a interpretation given through knowledge./ On the other hand, no hypothesis has been advanced so far on the kind of physiologic process which could help explaining the influence of colors on the organism.

Appendix B1

Description of the gestures performed by the actor in the discourse "The reactions to colors"

	The gesture took place while the actor was saying…	Gesture description	Gesture type
1	Through	the palm of the right hand is facing downwards, at the level of the actor's trunk and is immobile, and meanwhile the left hand moves from the center of the trunk and comes to rest on top of the right hand	metaphoric
2	Out of discussion	the right hand with the palm facing downwards moves to the right and at the same time the left hand facing downwards moves to the left	metaphoric
3	Attempts	left hand moves slowly from the center of the trunk to the left of the actor's trunk	batonic
4	Specific	the clenched fist of the left hand swings twice and moves towards the level of the left shoulder	metaphoric
5	General	the two hands are at trunk level, close together, with the palms facing downwards, the right hand moves slowly to the right, and at the same time the left hand moves slowly to the left	metaphoric
6	Different cultures	the two hands are at trunk level, close together, with the palms facing downwards, the right hand moves slightly and slowly to the right, and at the same time the left hand moves slightly and slowly to the left. These movements are repeated by both hands twice in succession	metaphoric
7	On association	the left hand move from the right side to the left side of the actor's shoulder, forming a small arch	metaphoric
8	Widespread	the two hands, open, with the palms facing downwards, and close together in front of the trunk, move slightly outwards	iconic
9	Exciting	both hands are open and at trunk level, with the palms facing upwards, and they move simultaneously upwards	metaphoric
10	Evokes	the index finger of the right hand moves slowly from the level of the trunk to the	metaphoric

		level of the actor's temple	
11	Fire	both hands are half open, with the palms facing inwards, and move outwards from the center of the actor's trunk	batonic
12	Blood	the right hand moves slowly from the center of the actor's trunk to the left, and indicates the right arm which is stretched out	deicitc
13	Revolution	the fingers of both hands close, each forming a clenched fist and move close to the center of the actor's trunk	metaphoric
14	Restorative effect of nature	the left hand, open, with the palm facing upwards, makes three rotations movements	batonic
15	Refreshing	the hands simultaneously assume a chestnut shape (the fingers' tips are closed) and the fingers of each hand brush against one another, while the hands move to the actor's face	metaphoric
16	More interesting	both hands have their palms facing upwards and move slightly away from the center of the actor's trunk	metaphoric
17	In this field	the hands are parallel and at a slight distance apart from the center of the actor's trunk and simultaneously move upwards and downwards	deictic
18	In others	the hands are parallel with the palms facing upwards, and they move simultaneously outwards from the center of the actor's trunk	deictic
19	Direct	the hands are parallel and at a distance from one another, they move rapidly and simultaneously forward in front of the actor's trunk	iconic
20	Spontaneous	the palms of both hands are facing upwards in front of the actor's trunk, they open and move slightly and simultaneously forward	metaphoric
21	Hypothesis	the thumb and the index finger of the left hand are in front of the trunk, they join and move to the actor's temple	metaphoric
22	Physiological process	the left hand is shaped like a chestnut and performs two rotating movements at trunk level as it moves towards the actor's left ear	metaphoric
23	Of color on the organism	the two hands are parallel with the palms facing upwards level with the actor's trunk, they move simultaneously and slowly first to the right and then to the left of the trunk	metaphoric

Appendix C

Examples of sentences used for the Recognition Task of Experiment 3

"At the funfair" discourse

Literal It was there, at the funfair, it was there that I found her, and it was at the funfair that I lost her.

Paraphrases At the funfair I met her and then I lost her.

Wrong At the funfair I found a girl, I lost her, but afterwards I found her again.

"The reactions to colors" discourse

Literal Blue is refreshing like water.

Paraphrases Blue color gives a feeling of freshness like water

Wrong Blue color is fresh like sea

Table 1.

Means of types of recollection (and standard deviations in parenthesis) in the Gestures and in the No-Gestures conditions in Experiment 1.

Condition	Correct recollections	Discourse-based inferences	Elaborative inferences	Errors
Gestures (N=8)	10.63	2.13	1.00	1.63
	(7.11)	(2.03)	(.76)	(1.85)
No-Gestures (N=8)	6.50	.50	.50	2.00
	(4.81)	(.54)	(.76)	(1.85)

Table 2.

Means of types of recollection (and standard deviations in parenthesis) in the Gestures and in the No-Gestures conditions in Experiment 2.

Condition	Correct recollections	Discourse-based inferences	Elaborative inferences	Errors
Gestures (N=8)	4.38	1.25	1.25	.63
	(2.07)	(.89)	(.89)	(.74)
No-Gestures (N=8)	3.50	.38	1.00	1.38
	(2.93)	(.52)	(1.51)	(1.51)

Table 3

Proportions of Sorts of Recognition in the Gestures and No-Gestures Conditions in the Recognition Task of Experiment 3 – "At the Funfair" discourse.

Condition	Hit	Miss	False Alarm Paraphrases	Correct Rejections Paraphrases	False alarm Errors	Correct Rejection Errors
Gestures (N=9)	24/63	42/63	18/63	45/63	20/63	43/63
No-Gestures (N=9)	44/63	21/63	35/63	28/63	39/63	24/63

Table 4

Proportions of Sorts of Recognition in the Gestures and No-Gestures Conditions in the Recognition Task of Experiment 3 - "The reactions to colour" discourse.

Condition	Hit	Miss	False Alarm Paraphrases	Correct Rejections Paraphrases	False alarm Errors	Correct Rejection Errors
Gestures (N=9)	21/63	42/63	21/63	42/63	25/63	38/63
No-Gestures (N=9)	46/63	17/63	37/63	26/63	29/63	24/63

Table 5.

Mean correct performances (and standard deviations in parenthesis) with the different sorts of sentences in the Gestures and in the No-Gestures conditions of Experiment 3 – "At the funfair discourse"

Condition	Literally correct	Paraphrases	Wrong content
Gestures (N=9)	2.7	5.0	4.8
	(1.22)	(1.65)	(.44)
No-Gestures (N=9)	4.9	3.1	2.7
	(1.05)	(1.76)	(1.22)

Table 6.

Mean correct performances (and standard deviations in parenthesis) with the different sorts of sentences in the Gestures and in the No-Gestures conditions of Experiment 3 – "The reactions to colours discourse"

Condition	Literally correct	Paraphrases	Wrong content
Gestures (N=9)	2.3	4.7	4.2
	(1.58)	(1.87)	(1.09)
No-Gestures (N=9)	5.1	2.9	2.7
	(1.05)	(1.26)	(1.41)