A Written Version of Sign Language can Enhance Signing Deaf Individuals' Comprehension and Learning from Texts

Mara Vendrame (mara.vendrame@unito.it)*
Ilaria Cutica (ilaria.cutica@unimi.it)°
Monica Bucciarelli (monica.bucciarelli@unito.it)*

*Department of Psychology, Via Po 14, 10123 Turin, Italy
°Department of Economy, Management and Quantitative Methods, Via Conservatorio 7, 20132 Milan, Italy

Abstract

Deaf individuals have difficulties in comprehending written text, as well as oral language. As a consequence, learning from text is compromised in deaf individuals. We hypothesized that a transposition of the Italian Sign Language to its written counterpart could enhance signing deaf individuals' comprehension and learning from text. We confirmed our prediction for comprehension and learning for technical texts in Experiment 1 and for narrative texts in Experiment 2; signing deaf individuals' text comprehension and learning therefore benefit from a written language whose structure reflects the structure of their visual-spatial sign language. We speculate that, for signing deaf individuals, practice in reading written sign language texts might positively affect the ability to comprehend the written oral language texts.

Keywords: deaf individuals; text comprehension; learning; Italian Sign Language

Introduction

Those who are unfamiliar with deafness may assume that the deaf individuals' auditory deficit can easily be circumvented through the use of written communication: if you have hearing problems, we can easily communicate through written texts. This naïve assumption disregards the nature of profound deafness. The ability to understand written texts presupposes high linguistic competence such as the ability to integrate information from different parts of a text and to derive its inner coherence. Due to their profound hearing loss, prelingually deaf individuals, who have never experienced oral language, have difficulties in comprehending the lexical, morphosyntactic, and pragmatic aspects of written verbal language (Van Hoogmoed et al., 2011). In addition, compared to hearing individuals, deaf individuals are less able to comprehend and remember details from a written text and to reason about the information contained in it (Marschark & Wauters, 2008). Their specific difficulty in comprehending the holistic meaning of written texts seems to derive from difficulties in connecting different information together and in drawing inferences (Miller, 2002). Indeed, prelingually and profoundly deaf individuals possess adequate single-word reading ability and vocabulary knowledge (Oakhill & Cain, 2000). More generally, deaf individuals' poor linguistic competence must be imputed to their atypical cognitive development (Marschark & Hauser, 2008). For a start, in hearing individuals, sound plays a role from the earliest months of life in organizing *visual attention*: when a new event is signaled by sound, visual attention may be shifted appropriately (Smith et al., 1998). Hearing people use audition to monitor both their immediate and distant environment for changing events, while allowing vision to focus narrowly on the task at hand. In deaf individuals, the limited access to auditory information alters the way visual attention skills are deployed: visual attention becomes responsible for both focusing on the task at hand and monitoring events elsewhere in the visual field (Mitchell & Maslin, 2007). As a consequence, deaf individuals tend to adaptively develop a more spatially distributed visual attention, whereas highly selective visual attention tends to prove difficult (Bavelier, Dye & Hauser, 2006).

Auditory deprivation also has a direct impact on *memory capacity*: when hearing individuals are requested to remember simple stimuli such as words, pictures, or numbers, they tend to use a verbal-sequential coding of a phonological or acoustic nature (Marschark & Mayer, 1998). Deaf individuals appear instead to rely heavily on visuo-spatial coding: their incomplete mastery of language skills detracts from using language as an effective cognitive tool. Consequently, deaf people tend to have a shorter memory span for linguistic materials, compared to hearing people (Logan, Mayberry & Fletcher, 1996). By contrast, deaf people perform as well as or even better than hearing people on tasks that involve visual or spatial processing (Cattani, Clibbens & Perfect, 2007).

Furthermore, it has been shown that deaf individuals, in comparison to hearing individuals, have more difficulty with *abstract reasoning* (Marschark & Hauser, 2008). In particular, they have difficulties in verbal—analogical reasoning, which requires high-level linguistic skills, and the ability to understand not simple items but complex structures (Edwards et al., 2010). By contrast, deaf people are not impaired at perceptually based reasoning: they perform as well as hearing people on non-verbal cognitive tasks that do not require the overt use of verbal language, such as figural-geometric analogy tasks, and in visual-spatial information processing (Marschark & Hauser, 2008). However, deaf individuals' moderate skills with abstract reasoning are also due to their broader difficulty with verbal language (Easterbrooks & Scheetz, 2004).

All this considered, providing deaf individuals with suitable forms of written materials to support their comprehension and learning from texts in educational contexts, is a very important challenge. The focus of our investigation are signing deaf individuals, who are exposed to a natural sign language at birth. Sign languages exhibit grammatical structure at all linguistic levels. However, the acquisition of sign languages features constraints unique to the visual modality (Morgan, Barrett-Jones & Stoneham, 2007).

A Written Form of Sign Language

Sign language is visuo-spatial in nature and has no written counterpart. Some attempt were made to devise appropriate means for representing sign languages: examples are Stokoe-based notations for notating single, decontextualised and standard signs (Pizzuto, Rossini & Russo, 2006), and Sign Writing, a writing formalism based on transcription of manual and also non-manual elements of non-standard signs and complex units through symbols (Sutton, 1999). These methods require a training to learn to interpret the proposed notations.

Within a less ambitious perspective, we reasoned that some of sign language's features could, however, be reflected in its transposition to a written form. We assumed that such a written sign language might improve signing deaf individuals' comprehension and learning from text by promoting the activation of the visual thought schemata that are activated by the sign language itself (Wilbur, 2000). In particular, our assumption is based on considerations concerning the structural features of written sign language along with the particular cognitive functioning of signing deaf individuals.

First, the written form of sign language offers deaf individuals the possibility to process written linguistic information provided in a syntactic structure that reflects the structure of the corresponding sign language. In sign languages, space has a grammatical function, i.e. it is used to create and maintain cohesion among the different parts of the discourse (Morgan et al., 2008). Thus, for example, sentences in sign languages begin by identifying one or more *loci* in the *spatial mapping*, "the process used by the signer to reflect mental representations in physical space for reference and subsequent coreference in discourse as a cohesive device" (Winston, 1995, p.87). Subsequently, signers point to a precise locus in space in order to evoke to the interlocutors the element that was originally 'placed' there. The particular function of space in sign languages generates a different discourse structure that has no counterpart in oral languages (Pyers et al., 2010).

Second, the text of a phrase in an oral language is longer than the corresponding text in the written sign language version: the written sign language text, like the sign language itself, lacks articles, prepositions, conjunctions, pronouns, and verbal auxiliaries. This claim holds at least for Italian Sign Language (LIS), which makes little use of finger spelling. As signing deaf individuals have a shorter memory span for linguistic material than do hearing individuals, they should benefit from this feature of the written sign language.

Third, signing deaf individuals, as compared to hearing individuals, have a more spatially distributed visual attention; this cognitive peculiarity, along with the consideration that a phrase in written sign language is shorter than the corresponding written phrase from the oral language, leads to the hypothesis that signing deaf individuals can extract in a glance more information from the written sign language text than from the written oral language text.

We tested the prediction derived from our assumptions on Italian signing deaf individuals.

Experiment 1: Does Written LIS Facilitate Text Comprehension in Signing Deaf Individuals?

The deaf participants in the experiment were invited to carefully read two texts; they were then invited to recall as much information as they could. Each participant was presented with one text in Italian and another in LIS. We predicted a better recall for the LIS text. Hence, although we did not measure the participants' reading abilities, we made each participant act as his/her own control in the two experimental conditions.

Method

Participants Twelve signing deaf adult individuals (5 females and 7 males; mean age: 26 years) with a prelingual and profound hearing deficit (>90 dB hearing loss) and no other disabilities voluntarily took part in the experiment. They were all university students who learned the LIS as their first language from their first year of life.

Materials and Procedures The experimental materials comprised two technical written Italian texts, one concerning the principles of how airplanes fly (Airplane flight, 312 words), and one about the effect on individuals produced by color perception (Responses to color, 315 words) (for excerpt see Appendix 1). For each text, we produced a written LIS version, parallel to the written

Italian version (266 and 243 words for Airplane flight and Responses to color, respectively). To create the written LIS version, a native-speaking signing deaf Italian university student read each Italian text carefully several times and was then video-recorded while translating the text into LIS. She then transcribed the signs produced in the translation into Italian words. The punctuation was introduced for each pause, in order to segment the different phrases, taking into account both manual (signs) and non-manual (facial expressions and body movements) markers occurring simultaneously. Consider, for example, the following excerpt from the Airplane flight written Italian text: “When an aeroplane is in flight, the air divides as it hits the front of the wing. Some of it flows over the upper part of the wing, and the rest over the lower part. The two air flows come together again behind the wing.” As an example of the results of the translation, consider the parallel written LIS version of the excerpt above: “Example, plane flies, wing air hits wing in front of, then air divided 2, to go wing over, to go wing under, after air together to go wing behind.” Obviously, the English translation of the written LIS texts is not equivalent to the result of transposing the British Sign Language or American Sign Language texts to their written counterparts.

The translations of the two Italian texts to written LIS were evaluated individually by a LIS interpreter and by a LIS deaf teacher to ascertain that the translations as provided by a native signing deaf individual were also acceptable on behalf of them. For the goal of our investigation, it is important to test the beneficial effect of the written sign language when realized by a native signing deaf individual, naïve with respect to trainings and education to become either an interpreter or a deaf teacher. At first, the interpreter and the deaf teacher were invited to watch carefully the two videos, one at a time, and afterwards they considered each single sign produced, taking into account both the manual and the non-manual components. For each semantic unit they were invited to evaluate the appropriateness and comprehensibility of the LIS translation through the following judgments: “Not at all adequate”, “Barely adequate”, “Adequate on the average”, “Adequate”. On average, the 93% of the semantic units from the Airplane flight text, and the 96% of the semantic units from the Responses to color text were judged as at least “adequate on the average”; none of the translations were judged as not adequate at all.

The participants encountered both texts (Airplane flight and Responses to color), one in Italian and the other in LIS. In each group, half of the participants dealt first with the Airplane flight text and the other half with the Responses to color text, so that, overall, the occurrence of each text in the Italian version and the LIS version was counterbalanced. The participants were invited to read each text carefully, one at a time, with no time limits; as soon as they finished reading each text, they were asked to recall as much information as they could. The recollection was in LIS. All of the participants were video-recorded.

To code the results, each text was divided into 41 semantic units, corresponding to as many main concepts as the hearer could recall. For each text, there is a strict correspondence between the semantic units in the two versions (Italian and written LIS). Two independent judges coded the participants’ recollections individually; the judges reached a significant level of agreement on their first judgments for the overall group of participants in the two experimental conditions, calculated using Cohen’s K (Cohen’s K ranging from .87 to .97, p always <.001). For the final score, the judges discussed each item on which they disagreed, until they reached full agreement. Each concept (i.e., semantic unit) recalled by the participants was evaluated according to the following coding schema (see also Cutica & Bucciarelli, 2008; 2011, Vendrame, Cutica & Bucciarelli, 2010):

Correct recollection: a semantic unit recollected either literally or as a paraphrase;

Discourse-based inference: a recollection in which the participant gives explicit information that was originally implicit in the semantic unit;

Elaborative inference: a semantic unit recollected with the addition of plausible details;

Error: a recollection whose meaning is inconsistent with the semantic unit.

Each participants’ recollection was coded as pertaining to just one category. Correct recollections and discourse-based inferences were considered indicators of comprehension and learning from text. Consider, for example, the following semantic units in the Italian color text: “He observed that the function deteriorated in low light but increased in bright light” and the following recollection by a participant: “Example: bright light finger to tap fast; low light finger to tap slow; finger to tap normal normal light”. According to the coding schema, we considered the statements “Example: bright light finger to tap fast” and “low light finger to tap slow” as correct recollections, and the statement: “finger to tap normal normal light” as a discourse-based inference.

As a further example, considering the semantic unit in the Written LIS aeroplane text “Wing over this is pressure less”, the recollection “the air under pressure to increase, it makes a support, an help” has been coded as a discourse-based inference, whereas the sentence “the pressure to increase wing over” has been coded as an error.

Results and Discussion The two texts were comparable in difficulty; considering each type of recollection separately, we found no differences in performance with the two texts in either the LIS or the Italian versions (unpaired T-test: t(22) comprised between .0 and 1.48, p comprised between .15 and .1). Hence, we pooled together the results for the two Italian versions and those for the two LIS versions.

Table 1 illustrates the mean types of recollection for both the LIS and the Italian versions of the texts. The results show that they produced more correct recollections and fewer errors in the written LIS version than in the written Italian version (T-test: t(11)=3.43, tied p=.003, and t(11)=3.095, p=.01, respectively), whereas there was no difference in production of discourse-based (T-test: t(11)=.82, tied p=.22) and elaborative (T-test: t(11)=0, p=1) inferences.

Table 1: Mean types of recollection (and standard deviation in parenthesis) by the participants in Exp. 1.

Signing deaf (N=12)	Correct recollections	Discourse-based inferences	Elaborative inferences	Errors
Written LIS	21.42 (6.00)	.58 (.67)	.08 (.29)	.75 (.75)
Written Italian	16.75 (3.67)	.33 (.49)	.08 (.29)	2.25 (1.87)

The results of Experiment 1 confirmed our predictions. Signing deaf individuals benefited from the written LIS version of the technical texts. However, maybe because of the considerable technical content of the two texts, we did not observe a benefit from the LIS versions in terms of discourse-based inferences, which denote a deep comprehension of the text (Cutica & Bucciarelli, 2008). A related, more general question is whether the observed facilitatory effect of the written LIS versions depends on the discourse content, be it technical or narrative in nature. The aim of Experiment 2 was to replicate the findings of Experiment 1 with narrative texts.

Experiment 2: Does Written LIS Facilitate Comprehension Independently on the Text Content?

Experiment 2 set out to replicate Experiment 1 with narrative texts.

Method

Participants Twelve signing deaf individuals (4 females and 8 males; mean age: 26 years), university students with a prelingual profound hearing deficit (>90 dB hearing loss), took part in the experiment voluntarily. They had learned LIS as their first language since their first year of life. None of them had other disabilities, nor had they taken part in Experiment 1.

Materials and Procedures The experimental materials comprised two texts, one about the Savannah and one about Mammals (each text contained 346 words) (for excerpts see Appendix 2). For each text, we created a written LIS version (183 and 204 words for the Savannah and the Mammals texts, respectively), following the same procedures used in Experiment 1.

As for Experiment 1, the translations of the two Italian texts to written LIS were evaluated individually by a Italian LIS interpreter and by a LIS deaf teacher, the same as in Experiment 1. On average, the 100% of the semantic units from the Mammals text, and the 99% of the semantic units from the Savannah text were judged as at least “adequate on the average”; none of the translations were judged as not adequate at all.

Each participant dealt with both the Savannah and the Mammals text, one in Italian and the other in LIS. Half of the participants dealt first with the Savannah text and the other half with the Mammals text, so that, overall, the occurrence of each text in the Italian and the LIS version was counterbalanced. The participants were invited to read each text carefully, one at a time, with no time limits. As soon as they finished reading each text, they were invited to recall in LIS as much information as they could, during which time they were video-recorded.

To code the results, the two versions of both texts were divided into 38 semantic units, corresponding to as many main concepts as the hearer could recall. As for Experiment 1, for each text (Savannah and Mammals), there is a strict correspondence between the semantic units in the two versions (Italian and Written LIS). Two independent judges coded the participants’ recollections individually; the judges reached a significant level of agreement on their first judgments for the overall group of participants with the two versions of the texts, calculated using Cohen’s K (Cohen’s K ranging from .82 to .89, p always <.01). For the final score, the judges discussed each item on which they disagreed, until they reached full agreement. Each concept (i.e., semantic unit) recalled by the participants was evaluated according to the same coding schema used in Experiment 1. Consider, for example, the following semantic unit in the written LIS Savannah text: “Food gives animal which? Giraffe”; according to the coding schema, the statement: “Acacia leaves to serve as food giraffe” has been coded as correct recollection, the statement: “Plant acacia serves for improving existence, growth giraffe” as elaborative inference, and the statement: “Animals do not eat acacia” as an erroneous recollection. As a further example, the recollection “Mother pecks egg, exit with help mother” has been coded as a discourse-based inference with respect to the semantic unit in the Italian text “(The shell is to tough) that the mother ostrich sometimes needs to help the chicks to break out”.

Results and Discussion The two texts were comparable in difficulty; considering each type of recollection separately, we found no differences in performance with the two texts in either the LIS or the Italian versions (unpaired T-test: t(10) ranging from 0 to 1, p ranging from 1 to .34). Hence, we pooled together the results of the two Italian versions and those of the two LIS versions. Table 2 illustrates the mean types of recollection for each coding category for both versions of the texts.

Table 2: Mean types of recollection (and standard deviation in parenthesis) by the participants in Exp. 2.

Signing deaf (N=12)	Correct recollections	Discourse-based inferences	Elaborative inferences	Errors
Written LIS	11.17 (5.24)	.58 (.67)	.25 (.45)	1.00 (.74)
Written Italian	8.50 (4.36)	.33 (.49)	.08 (.29)	1.50 (1.38)

The results show that signing deaf individuals produced significantly more correct recollections in the LIS than in the Italian version (T-test: tied $t(11)=2.13$, $p<.03$), yet they produced comparable numbers of discourse-based inferences in the two versions (T-test: tied $t(11)=1$, $p=.17$). Furthermore, the differences in production of elaborative inferences and errors in the two versions were not statistically significant (T-test: $t(11)=1$ and 1.15, $p=.34$ to .28, respectively).

The results of Experiment 2 replicated those of Experiment 1: written LIS facilitated deep comprehension and learning from text, in terms of an increase in correct recollections. The conclusion holds independently of the nature of the text, be it technical or narrative. A possible reason why we failed to detect a beneficial effect for written LIS in terms of discourse-based inferences is that deaf individuals have difficulty in drawing inferences (see also Easterbrooks & Scheetz, 2004).

General Discussion

When reading and processing written texts of vocal languages, deaf individuals are more likely to treat written information as unrelated pieces rather than seeking commonality. Crucial features of all sign languages are the spatial arrangement of the signs, the highly characteristic, marked facial expressions or postures, and the gaze direction. Unlike the sequential ordering of the sentence elements in verbal languages, the rich morphosyntactic structure of visual-gestural languages is organized in spatial terms. We assumed that signing deaf individuals' comprehension and learning benefit from a written text that reflects the structure of their sign language, because such written texts might be comprehended using categories that belong to the sign language organization rather than the natural language organization. The results of our experiments on 24 profoundly deaf individuals confirmed the predictions derived from our assumptions. In particular, in both experiments we observed the beneficial effects of the written LIS compared to the written Italian in terms of an increase in correct recollections by the signing deaf participants.

These results are in line with our assumptions: the written form of sign language offers deaf individuals the possibility to process written linguistic information provided in a syntactic structure that reflects the structure of the corresponding sign language; signing deaf individuals, who have a shorter memory span for linguistic material than do hearing individuals, benefit from the lack of articles, prepositions, conjunctions, pronouns, and verbal auxiliaries in the written sign language; signing deaf individuals, who compared to hearing individuals have a more spatially distributed visual attention, can extract in a glance more information from the written sign language text which is shorter than the written oral language text.

Our finding has strong implications; as deaf people have difficulties in comprehending the written versions of oral languages, their opportunities to learn from written texts – and therefore to benefit from school and university education – are heavily restricted. Providing them access to written texts reflecting their sign language would be a step towards an improvement of their ability to comprehend the written versions of oral languages. Consistent, Oakhill and Cain (2000) already hypothesized that for deaf individuals who are fluent in signing, "it would be possible to present written texts via sign language in order to teach skills such as inference making, comprehension monitoring, and the planning and structuring of stories" (ib., p.58). On the basis of the results of our study, we argue that a written version of LIS could be used as an educational tool, in order to approach signing deaf children onto written verbal languages and improve their comprehension skills. Further studies would be useful to investigate in depth the effectiveness of trainings on texts comprehension exploiting written sign language both on adult signing deaf individuals, as well as on signing deaf children.

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Appendix 1. Material from Experiment 1
(Semantic Units are Separated by Slashes)

Excerpts from Responses to colour (translated to English)
Written Italian version The idea that the various colours can arouse emotions/ is well known./ Red is considered exciting,/ because in our minds it evokes fire,/ blood/ and revolution./ Green brings relaxing thoughts of nature;/ blue is refreshing, like water./
Written LIS version People many think what?/ Colours various to give emotion./ Colour red to give excitation,/ reason what? We remember fire,/ blood,/ revolution./ Colour green to give relaxation reason? To view nature,/ colour blue to give feeling fresh like water./

Appendix 2. Material from Experiment 2
(Semantic Units are Separated by Slashes)

Excerpts from The savannah (translated to English)
Written Italian version Thirty million years ago,/ tropical Africa was covered in jungle. Things have since changed./ In eastern Africa, the forest has disappeared,/ and the new landscape is very different from its predecessor./ Everything began in the forest./ Chimpanzees are perfectly adapted to life in the trees./
Written LIS version Million thirty years ago where?/ Africa tropical forest covered./ Now Africa eastern forest there is not,/ landscape new, instead past different./ Forest now begins/ tree, area monkeys suitable live they where? Trees./