TOWARDS A PRAGMATICS OF NEGATION: THE INTERPRETATION OF NEGATIVE SENTENCES IN DEVELOPMENTAL DYSLEXIA

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1. WHAT IS DEVELOPMENTAL DYSLEXIA? THE WORKING MEMORY DEFICIT HYPOTHESIS

Developmental Dyslexia is a learning based disability that interferes in particular with the acquisition of language. One of the most easily detectable symptoms of dyslexia, to which this disorder actually owes its name, is the failure to properly acquire reading and spelling skills. This impairment is particularly surprising in children who are otherwise intelligent and adequately exposed to literacy. In particular, dyslexics perform very poorly when asked to read or spell irregular words or non-words.

Obviously, these difficulties are much more evident in languages with an "opaque" orthographic system, as English, where there is more than one possible mapping between a letter and its sound. In these languages phoneme-grapheme correspondence rules are less reliable than in transparent languages, such as Italian, where mappings between phonemes and graphemes are more regular. This cross-linguistic discrepancy can be held responsible for the different percentages concerning the distribution of dyslexia that can be found across countries: in Italy, it is argued that dyslexia affects 3-4% of the population (www.aiditalia.org), whereas the percentage rises to reach 15-20% in the USA (www.dyslexia-usa.com). Of course, this discrepancy does not imply that dyslexia is more widespread in one country than in another one; it simply reflects the fact that it is easier to detect reading difficulties in children whose mother-tongue has an opaque orthography. On the contrary, the difficulties experienced by those children whose mother-tongue has a transparent orthography may go unnoticed.

However, it has been shown that the reading deficit manifested by dyslexics is merely one of the symptoms of a more complex and multifaceted disorder. Dyslexics manifest significant difficulties in those tasks which require both accuracy of phonological processing and speed, such as picture naming tasks (Swan & Goswami 1997a), tasks tapping phonological awareness (Swan & Goswami 1997b), tasks testing the repetition of words and nonwords (Miles 1993) and finally verbal working memory tasks.

Specifically, it has been demonstrated that 100% of the dyslexic population exhibits difficulties in phonological processes. Even though the phonological domain has been especially investigated in the research conducted on developmental dyslexia since now, impairments have been found also in vocabulary development and in the morpho-syntactic domain (Scarborough 1990, Wolf & Obregón 1992, Wilsenach 2006, Joanisse et al. 2000, Stein et al. 1984, Bar-Shalom et al. 1993).

Recently, a number of studies (Nelson & Warrington 1980, Gathercole et al. 2006, Fiorin 2010, Vender 2010) have shown that dyslexia can be also associated with a deficit affecting the verbal component of Working Memory (WM).

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1.1. Dyslexia and Verbal Working Memory

Working Memory is the system which provides temporary storage and manipulation of the information necessary for cognitive tasks as, among others, language comprehension, learning and reasoning (Baddeley 1986). According to Baddeley's well-known model, WM is composed of a limited capacity attentional controller, the Central Executive, and two slave subsystems, one performing operations with acoustic and verbal information, dubbed Articulatory (subsequent Phonological) Loop, and the other concerned with visual and spatial information, the Visuospatial Scratchpad (subsequent Sketchpad). Due to the need to integrate information from the subsidiary systems and from long term memory allowing at the same time their manipulation and maintenance, a fourth component has been added to Baddeley's model, the episodic buffer (Baddeley 2000) which has the task of linking information across domains, forming integrated units of visual, spatial and verbal material.

The phonological loop is generally referred to as the Verbal component of Working Memory (vWM), in order to underline its strict relation with language, which is not limited to phonology, but should rather include also morpho-syntax, semantics and pragmatics.

A rich body of evidence demonstrates that the vWM is significantly impaired in dyslexic children, who perform poorly at repeating single non-words and recalling word lists, even in comparison to younger children: according to Gathercole & Baddeley (1990), their repetition skills were delayed by about four years. Although dyslexic children perform worse than age-matched typically developing children on all phonological loop measures, they behave as well as controls on working memory visuo-spatial sketchpad measures and visual-motor coordination tasks (Jeffries & Everatt 2004), suggesting that their vWM is impaired, whereas their visuo-spatial competence is relatively spared. These data are in line with the results obtained by a very recent experimental protocol specifically testing dyslexics' WM and showing that disordered children are remarkably impaired in the tasks tapping the phonological loop and the Central Executive, while they behave as controls in visuo-spatial tasks (Vender 2010).

To sum up, a rich body of evidence demonstrates that dyslexics display working memory impairments, affecting in particular the verbal domain and the control of attention.

2. NEGATION

Negation is a highly specific linguistic tool, peculiar of human language, which is employed to accomplish different tasks such as denying, contradicting, refusing concepts, correcting wrongly made inferences, but also lying and speaking ironically.

For its fundamental role in human language, negation has been extensively studied throughout the centuries. It has been a matter of research for philosophers as Plato and Aristotle and it has been dealt with in classical logic. In the late eighties and in the nineties, research on negation has been linked to the study of presuppositions and has gained increasing attention.

In the present study, we will concentrate on the processing of negative sentences and on the pragmatic considerations about negation proposed first by researchers as Wason, Givón and Horn, and, more recently, by Kaup, Zwaan and Lüdtke.

2.1. The processing of negation

The processing of negation has been matter of a considerable amount of research in the sixties and in the seventies. In most of the studies conducted (Wason 1959, 1961; Carpenter & Just 1975) participants were asked to verify affirmative and negative sentences either against their background knowledge (sentence-verification task), or against a picture (picture-verification task). From the results, it clearly emerged that negative sentences were more difficult to process than their affirmative counterparts, as shown by higher error rates or longer reaction times.

The most persuading hypothesis formulated to explain the higher processing difficulty of negation is one of a pragmatic nature, claiming that negative sentences are particularly difficult to process when they are used in an unsupportive context.

The basis of this orientation is Wason's (1965) proposal, known as the hypothesis of the 'Contexts of plausible denial'. Observing sentences like those reported below, Wason notes that (1b) seems odder than (1a).

(1) a. The whale is not a fish.
    b. The whale is not a bird.

Even though both statements are negative and share the same truth-value, (1b) takes longer to be processed and seems less appropriate. Wason focuses precisely on this feeling of inappropriateness, noting that there is an association between the appropriateness of a negative sentence and the plausibility of its affirmative counterpart. In fact, it seems perfectly plausible to wonder whether a whale is a fish, whereas it would seem far stranger to wonder whether it is a bird.

According to Wason, (1a) is pronounced in a supportive context, because there is an expectation to be denied (i.e. that the whale is a fish) or an exception to be noted (i.e. that the whale is a mammal). In this sense, negatives have the function to emphasize a fact that deviates from the expectations and therefore they depend on a prior state of affairs that has to be negated.

In this approach, the plausibility of a negative sentence is indissolubly connected to the presence of a prior statement that is to be denied. In other words, it is possible to say that negative statements presuppose the existence of an affirmative sentence that has to be denied.

A number of studies have provided results which corroborated this hypothesis, showing that negation is processed more easily and more rapidly when it is used to negate a proposition previously introduced in the context and when its affirmative counterpart is plausible. Interestingly, this tendency has been shown also by two- three- and four-year old children, who appear to be aware of the pragmatic requirements of negative sentences (De Villiers & Flusberg 1975).

A similar proposal is made by Givon (1978), who argues that negative sentences require a particular pragmatic context within which they are processed to counter presuppositions held by the listener. This view is also shared by Horn (1989), who claims that the prototypical use of negation consists in denying a previously asserted proposition.

Summarizing, it seems that negative sentences presuppose the existence of a prior statement which presents a state of affairs that must be corrected. In those cases where there is no previous appropriate background (e.g. 'Eric didn't eat fish at the restaurant' uttered out of the blue), the presupposition is disregarded and the sentence sounds infelicitous. Hence, to understand these sentences, comprehenders must accommodate the presupposition and reconstruct on their own a supportive context (e.g. 'Eric was supposed to eat fish at the restaurant').

2.2. The Two-Step Simulation Hypothesis

The belief that negative sentences presuppose the existence of a prior statement which must be corrected is the central idea of the Two-Step Simulation Hypothesis recently proposed by

Kaup, Zwaan & Lüdtke (2007).

The Two-Step Simulation Hypothesis rests upon the experiential view of language comprehension, claiming that comprehending a text involves the construction of a mental representation of the described state of affairs, the so-called *situation model* (also *mental model*; for a review, see Zwaan & Radvansky 1998). This hypothesis is supported by a large body of empirical evidence, suggesting that comprehenders mentally simulate the state of affairs which is described in the utterances in a way that is similar to directly experiencing it. Neuroscience studies have demonstrated that there is a significant overlap between the mental subsystems involved in the representation of linguistically conveyed information and those used to perceive or enact the same situations (Pulvermüller 2002). Moreover, behavioral experiments have shown that nonlinguistic cognitive processes such as perception, action planning or imagery depend on the same mental subsystems involved in the creation of representations used for language comprehension (see Kaup et al. 2007 for a detailed review). However, the existence of linguistic operators such as negation poses a potential problem for this view, since they do not seem to have a direct equivalent in experience (but see Tettamanti et al. 2008 for updated discussion from a neurolinguistic perspective). Therefore, researchers tried to answer the question of how negative text information is represented.

First, it has been proposed that negated information is simply absent from the experiential representation of the state of affairs; however, this hypothesis has been discarded, considering examples as the following.

(2) Charles had been very lucky to get hold of tickets for a concert by the Berlin Philharmonic Orchestra for tonight. He was now sitting in the fifth row of the concert hall, from where he had a real good view of the stage. Finally, the musicians entered the hall. Charles knew that the concert would begin any minute now. Then, he suddenly realized that the conductor was not present (Kaup et al. 2007:266).

In this case, the presence of the conductor is explicitly negated and thus the simulation of the situation should not contain a representation of the conductor. However, if it were the case, the comprehender would not be able to understand what the text is about or, more specifically, “whether the text specified the conductor as being absent, or whether there just had not been any information regarding the conductor” (ibid).

In other cases, however, the representation of a negated entity can be obtained representing its affirmative counterpart: when simulating a sentence like (3), for instance, the comprehender would represent a turned-on television.

(3) When she entered the room, Lisa noticed that the television was not off.

To solve this impasse, Kaup and colleagues resort to an idea very similar to the pragmatic considerations about negation proposed by Wason, Givón and Horn, who argue that negative statements are generally uttered to deny a corresponding positive presupposition attributed to the listener.

Kaup et al. observe that negation seems to be used to communicate to the listener a deviation from her expectations. For instance, (3) can be uttered felicitously only in a context in which the television should have been turned off, i.e. where its being turned off was presupposed. Intuitively, thus, it seems that negation invites to delete a previously built *expected state of affairs* (e.g. the television being turned off), replacing it with the representation of the *actual state of affairs* (e.g. the television being turned on). Comparing these two simulations allows the comprehender to determine what the sentence is about.

According to the Two-Step Simulation Hypothesis, the comprehension of negation involves (i) the retrieval (or the construction, e.g. in unsupportive contexts) of a simulation of the expected state of affairs, which corresponds to the state of affairs that is being negated in the sentence and (ii) the construction of a simulation of the actual state of affairs.

Two cases can be distinguished. When the negated state of affairs is already present in the discourse representation before encountering negation, the comprehender must simply correct the expectations by simulating the actual state of affairs. Conversely, when the negated state of affairs is not present in the discourse context, e.g. when the sentence is uttered out of the blue, the comprehender must construct a mental simulation of the expected state of affairs and then turn towards representing the actual state of affairs.

Importantly, this hypothesis permits also to explain why negation is more easily processed when it occurs in a felicitous supporting context. Consider the following examples:

(4) a. Lisa finished late working. While she was driving home, she thought that her husband was preparing dinner. But when she arrived home, she realized that her husband was not there.

b. When she arrived home, Lisa realized that her husband was not there.

In (4a) the context informs the comprehender that Lisa's husband is expected to be at home preparing dinner. This information constitutes the simulation of the expected state of affairs: all the comprehender has to do in order to process the negative sentence "Her husband was not at home" is to correct the expectation and to construct a mental simulation of the actual state of affairs, which deviates from the prior simulation, representing, for instance, an empty house.

Conversely, when (4b) is uttered out of context, an additional step is required: first, the comprehender has to create a mental simulation of the expected state of affairs, corresponding to the state of affairs which is being negated in the utterance (e.g. Lisa's husband being at home). Secondly, she has to construct a mental simulation of the actual state of affairs. Consequently, the comprehension of a negative sentence uttered out of a supportive context is expected to be more difficult, since it requires constructing a simulation of the expected state of affairs, demanding higher processing resources.

It is often not possible, as Kaup and colleagues observe, to infer precisely the actual state of affairs with respect to the dimension affected by negation. The utterance in (5), for instance, does not specify what Eric was doing at the moment.

(5) Eric was not preparing dinner.

In cases like this, the dimension of the negated property (i.e. what Eric was doing) remains unspecified.

Only with complementary negation is it possible to infer the actual state of affairs with certainty; in (6), for instance, the comprehender can safely simulate a state of affairs in which Eric was sleeping.

(6) Eric was not awake.

To summarize, the Two-Step Simulation Hypothesis claims that negation represents a deviation from a previous expectation and that it involves a comparison between the expected and the actual state of affairs.

2.3. An original proposal to account for the processing of negation in sentence-picture verification tasks: the Model of Sentence-Picture Match Processing for Negative Sentences

In the previous sections, we have seen that a number of experimental protocols have demonstrated that processing difficulties arise when subjects are asked to interpret negation. The tasks used to test the subjects' competence were mainly sentence-picture verification tasks, where participants had to verify sentences against pictures. The results show a significant effect of negation, with negative sentences taking longer to process than their affirmative counterparts. Moreover, a significant effect of truth has also been found, with true negative sentences being the most difficult ones to process, with the highest error rates. This result was quite surprising, since it was expected that false affirmatives were harder than true affirmatives and that false negatives were harder than true negatives. Instead, an asymmetry was found between affirmative and negative sentences, with the following ranking:

(7) True affirmatives > false affirmatives > false negatives > true negatives

To explain these results, we have developed a model that can account for the greater processing difficulties of (i) negative sentences in comparison to affirmative sentences, (ii) false affirmatives in comparison to true affirmatives and (iii) true negatives in comparison to false negatives. In this model, we account for the greater processing difficulty imposed by negative sentences by crucially exploiting the Two-Step Simulation Hypothesis.

Since the sentences presented in the experimental protocols that we have discussed are uttered out of a specific supporting context, we propose that subjects must create a mental simulation of the expected state of affairs and compare it to the simulation of the actual state of affairs. An operation which is remarkably demanding in terms of working memory resources and which is responsible for the higher difficulty of negative sentences.

Moreover, in sentence-picture verification tasks subjects have to cope with an additional difficulty: they have to compare the representation of a sentence to that of a picture in order to decide if the sentence describes correctly what happens in the picture. We propose that the picture provided in the experiment can be used to create the mental simulation: if the picture does not provide the subject with a representation of what the sentence is about (e.g. 'It is not true that the dots are black' against a picture of red dots), the subject has to correct this mismatch, by creating a representation of the sentence which can be compared against the picture (e.g. a representation of black dots). When the picture and the sentence match, instead, the subject's task is facilitated. This difference can explain the longer latencies reported for false affirmatives in comparison to true affirmatives and for true negatives in comparison to false negatives. In fact, in the 'false affirmative' condition as well as in the 'true negative' condition there is arguably a mismatch between the sentence and the picture, which we consider as responsible for their higher complexity of the sentence-types at stake.

According to the Model of Sentence-Picture Match Processing for Negative Sentences, three main steps are required to evaluate target sentences against pictures:

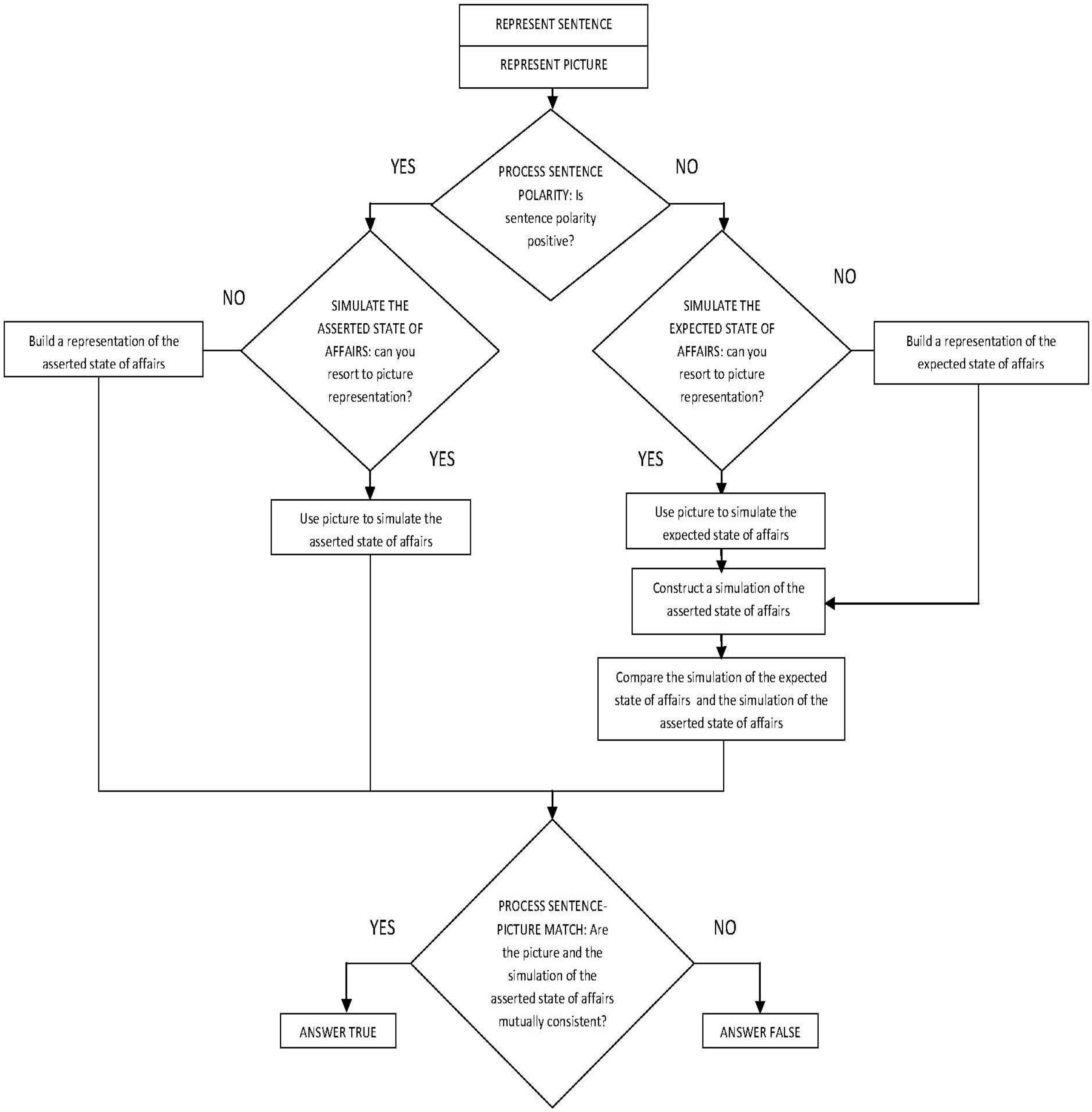
(i) *Sentence-Polarity Processing*: the subject has to process sentence polarity. If the polarity is positive, she can represent the actual state of affairs, but if it is negative, she has to simulate first the expected state of affairs and then the actual state of affairs. Arguably, negative sentences are predicted to be more difficult than affirmative sentences, since they require the construction of two different representations, in accordance with the Two-Step Simulation Hypothesis.

(ii) *Simulation of the Asserted State of Affairs*[1]: after polarity has been processed, the subject has to create the representation of the asserted state of affairs. When possible, the subject can resort to the picture to simulate the state of affairs. Otherwise, if the picture does not match with the event described in the target sentence, an additional step is required, since the subject needs to build the simulation by herself. The prediction is thus that a greater effort is required when the subject cannot resort to the picture in order to represent the state of affairs.

(iii) *Sentence-Picture Match Processing*: in the final passage, the subject has to verify if the picture and the representation of the asserted state of affairs are mutually consistent. If they are, she can answer ‘true’, otherwise, she will answer ‘false’.

The model of verification for negative sentences that we would like to propose is reported below.

[1] We prefer to use the term ‘asserted’ state of affairs instead of ‘actual’ state of affair to avoid ambiguities between the state of affairs described by the sentence and the one depicted in the picture.



Let us see how this model works, examining each condition. Suppose that the subject is presented with a picture depicting Cinderella who is combing her hair, like the one reported below, and afterwards with the target sentence.

Figure 1

(i) *True affirmative*: the target sentence is “Cinderella is combing her hair” According to the model, the subject has first to consider sentence polarity. Since it is positive, she can move to the second step, concerning the simulation of the asserted state of affairs. In this case, the picture provides the subject with a representation of what the sentence is about, namely Cinderella who is combing her hair. Therefore the subject can use it as a source of help to simulate the asserted state of affairs. Finally, she has to compare the picture and the simulation: given that they are mutually consistent, she can answer “true”

(ii) *False affirmative*: the target sentence is “Cinderella is cleaning the house” Again, sentence polarity is positive and the subject needs to represent the asserted state of affairs. In this case, however, the picture does not help the subject to build a representation of what the sentence is about and the subject must construct a mental representation of Cinderella cleaning the house. Arguably, this causes an extra-effort that may be taken as responsible for the longer latencies required by false affirmatives in comparison to true affirmatives. At last, the subject has to match the picture and the simulation of the asserted state of affairs: since they are not mutually consistent, she answers “false”

(iii) *False negative*: the target sentence is “Cinderella is not combing her hair” In this case, polarity is negative and thus the subject has to simulate first the expected state of affairs (e.g. Cinderella who is combing her hair) and afterwards the asserted state of affairs (e.g. Cinderella who is doing something else, possibly unspecified), consistently with the Two-Step Simulation Hypothesis. This additional passage results in the higher processing load required by negative sentences in comparison to affirmative sentences. In order to represent the expected state of affairs, the subject can resort to the picture, since it actually offers a representation of what the sentence is about. Finally, she has to compare the simulation of the actual state of affairs with the representation in the picture. Since they are not mutually consistent, the sentence is judged false.

(iv) *True negative*: the target sentence is “Cinderella is not cleaning the house” Also in this case, the polarity of the sentence is negative, requiring the simulation of both the expected state of affairs (e.g. Cinderella who is cleaning the house) and the asserted state of affairs (e.g. Cinderella who is doing something else, possibly unspecified). However, the subject cannot resort to the picture to create the two simulations, she has rather to mentally simulate them. Finally, since the simulation of the asserted state of affairs and picture representation are mutually consistent, the target sentence is judged true. Summarizing, the greatest difficulty found in the processing of negative true sentences is due to two distinct factors: firstly, to the negative polarity of the sentence, requiring the subject to construct and compare two representations, and secondly to the impossibility for the subject to use the picture as a source of help in order to generate the simulation of the state of affairs at stake. This second factor is responsible for the longer latencies found with negative true sentences in comparison to negative false sentences.

In conclusion, this model of verification can account for the greater difficulty found with negative sentences in comparison to affirmative sentences, assuming that the subjects are forced to simulate two representations when processing a negative sentence, both for the expected and the actual state of affairs. It can also account for the higher complexity of false affirmatives in comparison to true affirmatives and of true negatives in comparison to false negatives, arguing that false affirmatives and true negatives require the subject to create *ex novo* a representation of what the sentence is about, without using the picture representation as a source of help.

3. EXPERIMENTAL PROTOCOL: THE INTERPRETATION OF NEGATION IN DYSLEXIA

In this section we will present and discuss the results of an experimental protocol administered to test how dyslexic children compute negative sentences in sentence-picture verification tasks in comparison to age-matched typically developing children.

The experimental protocol comprised four different tasks, testing respectively (i) the computation of negative sentence (Exp. 1), the computation of negative passive sentences (Exp. 2), the computation of sentences containing negative quantifiers (Exp. 3) and the computation of sentences with Negative Concord (Exp. 4). Both error rates and response times were considered.

As we will see throughout the discussion, dyslexic children manifested greater difficulties in comparison to control children in all tasks, as demonstrated by higher error rates and slower response times.

To interpret these results we adopt the framework outlined by Kaup et al. (2007), according to which negation communicates a deviation from expectancies. Specifically, negation invites the comprehender to retrieve, or, if necessary, to build a simulation of the expected state of affairs, which has the role to represent the affirmative counterpart of the negative sentence.

The experimental hypothesis is that this operation is remarkably expensive in terms of processing resources. Therefore, assuming that dyslexic children display a working memory limitation, higher error rates are expected.

3.1. Experiment 1 – The interpretation of negative sentences

The experimental task was performed to test the computation of negative sentences. Both internal negation and external negation have been tested.

3.1.1. *Participants*

The experiment was conducted on a group of dyslexic children (mean age 9 years and 8 months) and a group of 17 age-matched typically developing control children (mean age 9 years and 8 months).

The group of Dyslexic children (DC) included 17 children (11 males), all native speakers of Italian. At the moment of testing, the group mean age was 9 years and 8 months (*SD* 0;11). All children have been chosen from those who had independently received a diagnosis of dyslexia, specifically by the "Servizio di Neuropsichiatria Infantile" in Rovereto (Trento, Italy): in particular, dyslexic children were selected according to different factors: (i) absence of neurological diseases or genetic pathologies, (ii) absence of sensorial diseases, (iii) absence of psychopathological diseases, (iv) IQ > 80 (WISC –R) and (v) fluent and correct reading and writing abilities under 2 SD (Tressoldi et al. Battery, Prove MT).

The group of age-matched control children (AMCC) was composed by 17 primary school children (4 males), all native speakers of Italian. At the moment of testing, the group mean age was 9 years and 8 months (SD 1;5). Children were selected from those who had no history of reading problems or language disorders.

3.1.2. *Design and procedure*

A picture-sentence verification task was administered. The subjects were presented with a picture depicting a situation, as the one reported below. The experimenter introduced them with a puppet, Little Red Riding Hood, who had the task to explain what was happening in the picture. The subject was told that Little Red Riding Hood was not always able to describe correctly what was happening in the story. Therefore, the subject's task was to decide if Little Red Riding Hood described the picture correctly or not by pressing a smiling face for the right answer and a crying face for the wrong answer. Response times were measured using the SuperLab software, starting from the moment when the experimenter uttered the target sentence up to the moment when the subject pressed the button to give the answer. The task involved 4 different conditions, with 12 experimental items (3 per condition) intertwined with 6 fillers.

An example of Experiment 1 is reported below. The subject is presented with a picture depicting a hen reading the newspaper, as in Figure 2. An example of each condition, with the target sentence uttered by Little Red Riding Hood, is provided below.

Figure 2: An example of Exp. 1

(i) *Condition A*: True Negative Sentence with Internal Negation (NT)
La gallina non sta facendo la spesa.
'The hen is not going shopping.'

(ii) *Condition B*: False Negative Sentence with Internal Negation (NF)
La gallina non sta leggendo il giornale.
'The hen is not reading the newspaper.'

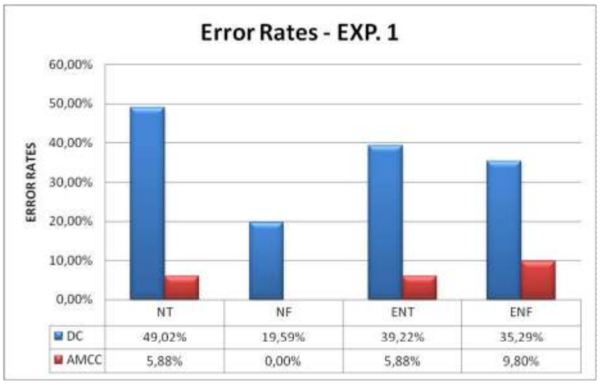
(iii) *Condition C*: True Negative Sentence with External Negation (ENT)
Non è vero che la gallina sta facendo la spesa.
'It is not true that the hen is going shopping.'

(iv) *Condition D*: False Negative Sentence with External Negation (ENF)
Non è vero che la gallina sta leggendo il giornale.
'It is not true that the hen is reading the newspaper.'

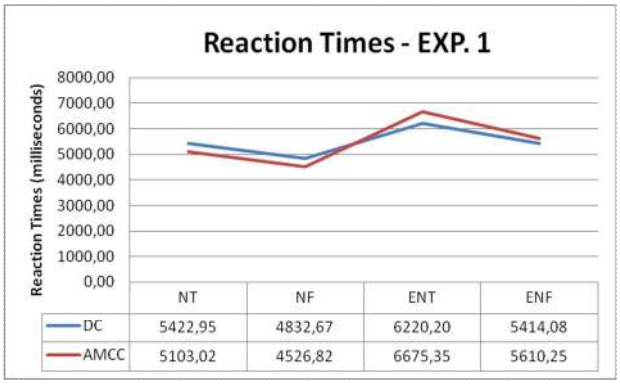
3.1.3. *Results*

All subjects were able to complete the test and to respond correctly to the vast majority of the fillers; therefore nobody was excluded from the sample.

The error rates displayed by the two groups of children are reported in Graph 1, where dyslexic children are represented by the blue bar and typically developing children by the red bar. Reaction times are reported in Graph 2, where dyslexics are represented by the blue line and controls by the red line.



Graph 1



Graph 2

Observing graph 5.1, it appears immediately clear that dyslexics commit far more errors in comparison to control children. More specifically, it seems that NT is the most difficult condition for dyslexic children with an error rate of 49,02%, followed by ENT (39,22%). The “false” conditions, in contrast, appear to be easier, even though the error rate is still quite high: 19,59% for NF and 35,29% for ENF.

A statistical analysis has been conducted on these data, to determine if there were statistically significant differences between the performances shown by the two groups of children. A 2 x 2 mixed design ANOVA was conducted. *Group* (DC; AMCC) was the between-subject variable. *Type of negation* (internal; external) was the first within subject variable, considering subjects’ performance in sentences constructed with internal negation and with external negation (comparing Conditions NT and NF to Conditions ENT and ENF). *Truth* was the second within subject variable, comparing true sentences with false sentences (Conditions NT and ENT to Condition NF and ENF). There was a highly significant *Group* effect, F (1, 32) = 16.910, p = .000, indicating that dyslexic children performed significantly worse than control children. The *Type of Negation* variable was not significant, F (1, 32) = 1,884, p = .179, demonstrating that the form of negation (internal vs. internal) did not affect the performance; moreover, there was no significant *Type of Negation* × *Group interaction*, F (1, 32) = .116, p = .736, showing that the type of negation was significant neither for DC nor for AMCC. The *Truth* variable, instead, was significant, F (1, 32) = 5,308, p = .028, even though the significant *Truth* × *Group* interaction, F (1, 32) = 4,332, p = .048, indicates that this variable is significant only for DC. This effect indicates that true sentences are more difficult to process than false sentences only for dyslexic children.

For what concerns response times, instead, a series of t-tests administered for each condition resulted non-significant, showing that there were not significant differences between dyslexic children and control children.

3.1.4. *Discussion*

Analyzing the results, three main findings can be noted: (i) Dyslexic children perform more poorly than control children when asked to interpret negation, committing more errors in all conditions; (ii) True sentences are more difficult for dyslexic children than false sentences, as predicted by the Verification Model for Negative Sentences; (iii) The type of negation – whether it is internal or external – does not affect the performance.

The data show clearly that dyslexic children perform more poorly than age-matched typically developing children when asked to interpret negative sentences. Dyslexics commit significantly more errors in all conditions in comparison to control children, even though no differences have been found for what concerns response times.

These results are consistent with the Two-Step Simulation Hypothesis, assuming that negation generally expresses a deviation from a prior expectancy. In this perspective, what renders negative sentences more difficult to process in comparison to affirmative sentences is the need to retrieve or build a simulation for the expected state of affairs and a simulation of the actual state of affairs. In this experiment, the task is further complicated by the request to verify the target sentence against a picture.

As predicted by the Model of Sentence-Picture Match Processing for Negation outlined in section 2.4., negative true sentences are more difficult to process than false sentences, as shown by a significantly higher error-rate.

This result is due to the fact that in the "true" conditions (NT and ENT) the picture does not provide the comprehender with a representation of the event described in the sentence. As a consequence, the subject must create by herself a mental representation of the sentence to be compared against the picture. This operation is arguably expensive in terms of processing resources and it contributes to make negative true sentences more difficult than negative false sentences.

However, the statistical analysis has also revealed that this operation has a visible cost only for dyslexic children: we can argue that the absence of this effect for control children is due to their more efficient working memory, which allows them to accomplish the task effortlessly. On the contrary, dyslexic children's poor working memory is not able to cope with the tasks, resulting in higher error rates.

A third interesting result of this experiment confirms that the performance is not affected by the type of negation – whether it is internal or external. This result is consistent with the Two-Step Simulation Hypothesis, since it claims that negation is generally more difficult than assertion for pragmatic and not for structural reasons, regardless of form.

Finally, these results contribute to corroborate the Working Memory Deficit Hypothesis, claiming that dyslexia is associated with a Working Memory limitation, causing dyslexics' difficulties in processing complex sentences.

3.2. Experiment 2 – The interpretation of passive negative sentences

The experimental task was performed to test the computation of passive negative sentences. Both internal negation and external negation have been tested.

3.2.1. *Participants*

The experiment was conducted on the same subjects who took part in Experiment 1, namely 17 dyslexic children (mean age 9;8) and 17 age-matched typically developing children (mean age 9;8).

3.2.2. *Design and procedure*

A sentence-picture verification task has been used with the same procedure used in Exp. 1. Also in this case, the task involved 4 conditions, with 12 experimental items (3 per condition), intertwined with 6 fillers. Both sentences with internal negation and external negation were tested. An example of each condition, with the target sentence uttered by Little Red Riding Hood, is provided below.

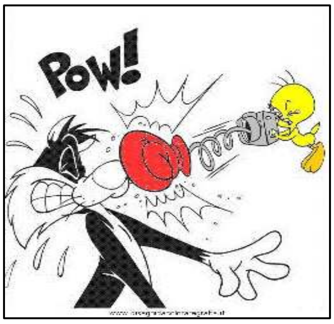


Figure 3. An example of Exp. 2

(i) *Condition A*: True Negative Passive Sentence with Internal Negation (NPT)
Titti non è colpito da Gatto Silvestro.
"Tweety is not hit by Sylvester."

(ii) *Condition B*: False Negative Passive Sentence with Internal Negation (NPF)
Gatto Silvestro non è colpito da Titti.
"Sylvester is not hit by Tweety."

(iii) *Condition C*: True Negative Passive Sentence with External Negation (ENPT)
Non è vero che Titti è colpito da Gatto Silvestro.
"It is not true that Tweety is hit by Sylvester."

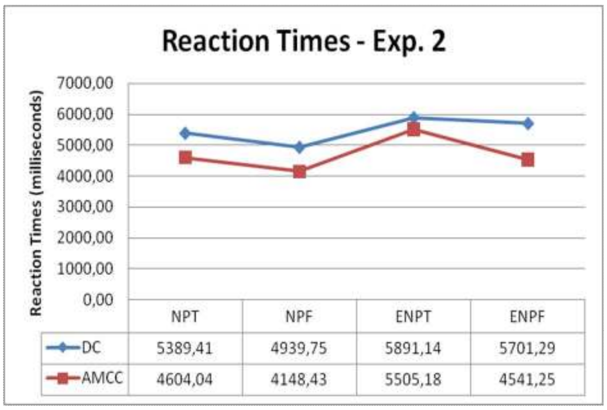
(iv) *Condition D*: False Negative Passive Sentence with External Negation (ENPF)
Non è vero che Gatto Silvestro è colpito da Titti.
"It is not true that Sylvester is hit by Tweety."

3.2.3. *Results*

All subjects were able to complete the test and to respond correctly to the vast majority of the fillers.

The error rates displayed by the two groups of children are reported in Graph 5.3, where dyslexic children are represented by the blue bar and typically developing children by the red bar. Reaction times are reported in Graph 5.4, where dyslexics are represented by the blue line and controls by the red line.

Graph. 3



Graph. 4

The results are similar to those obtained in Experiment 1. Also in this case, it appears immediately clear that dyslexics commit more errors in comparison to control children. Specifically, it seems that NPT is the most difficult condition for dyslexic children with an error rate of 49,02%, followed by ENPT (45,10%). The ‘false’ conditions, instead, appear to be easier, even though the error rates are still quite high: 11,77% for NPF and 24,51% for ENPF.

A statistical analysis has been conducted on these data, to determine if there were statistically significant differences between the performances shown by the two groups of children. A 2 x 2 mixed design ANOVA was conducted. *Group* (DC; AMCC) was the between-subject variable. *Type of negation* (internal; external) was the first within subject variable, verifying if the type of negation affected performance (comparing Conditions NPT and NPF with Conditions ENPT and ENPF). *Truth* was the second within subject variable, comparing true sentences to false sentences (Conditions NPT and ENPT to Conditions NPF and ENPF). There was a highly significant *Group* effect, F (1, 32) = 19.761, p = .000, indicating that dyslexic children performed significantly worse than control children. As in Experiment 1, the *Type of Negation* variable was not significant, F (1, 32) = 2,721, p = .109, demonstrating that the form of negation (internal vs. internal) had no influence on the performance; moreover, there was no significant *Type of Negation* × *Group interaction*, F (1, 32) = .318, p = .577, showing that the type of negation was not significant either for DC or for AMCC.

The *Truth* variable, in contrast, was significant, F (1, 32) = 11,117, p = .002. Furthermore, in this case there is a non-significant *Truth* × *Group* interaction, F (1, 32) = 2,206, p = .064, indicating that this variable is significant for both groups. The discrepancy found between Experiment 1 and Experiment 2 in this respect can be explained assuming that the overall difficulty of this task is greater, since it involves a further complication, namely the computation of a passive sentence.

For what concerns reaction times, Graph. 5.4 shows that dyslexic children seem to have slower response times in comparison to control children in all conditions. To verify if these differences were statistically significant, t-tests have been applied for each condition. The results show that there are significant differences between dyslexics and controls only in Condition B, testing false sentences with internal negation (t(32) = 3,034, p = .007) and in Condition D, testing false sentences with external negation (t(32) = 3,324, p = .002). There are no significant differences for Conditions A and C, testing true sentences with internal and external negation. However, note that dyslexic children’s error rates are significantly higher precisely in Conditions A and C, where the error rate approaches chance level. We can explain these data arguing that in Conditions B and D dyslexics need more time to accomplish the task and commit fewer errors, even though their performance is still much worse than controls’ performance. In Conditions A and C, instead, it seems that the task is too difficult for dyslexic children, who get stuck and resort to guess, as shown by the nearly 50% error rates.

3.2.4. *Discussion*

In the case of negative passive sentences, as in the preceding case, dyslexic children are significantly more impaired than age-matched typically developing children, as confirmed by higher error rates in all conditions.

Furthermore, the data reveal that the interpretation of true sentences is more difficult than the interpretation of false sentences, as predicted by the Model of Sentence-Picture Verification for Negative Sentences. In particular, the statistical analysis shows that dyslexics have slower response times in both false conditions, even though they commit more errors than controls. The higher complexity of true conditions, instead, is demonstrated by very high error rates, that approach chance level, even if there are no statistically significant differences for what concerns reaction times. These results seem to suggest that dyslexic children perceive false sentences as less difficult than true sentences, trying to spend more time to evaluate the target sentences. Since true sentences are perceived as more difficult, impaired children seem to devote less time to give the answer, resorting to a guessing strategy.

Moreover, the higher complexity of true sentences is also confirmed by the statistical analysis, which revealed that the *Truth* variable does not affect only the performance of dyslexic children, as in Experiment 1, but also affects the performance of control children. This fact can be explained by acknowledging the higher complexity of the sentences used in Experiment 2, which also involves the processing of the passive construction. Arguably, then, we can claim that the greater processing difficulty associated with true sentences is determined by the higher amount of working memory resources required for the interpretation of passive sentences.

The results demonstrate that also in this case the type of negative construction (internal vs. external) does not influence performance.

In sum, the results are consistent with both the Two-Step Simulation Hypothesis, showing that negative sentences require additional processing resources in comparison to their affirmative counterparts, and with the Model of Sentence-Picture Match Processing for Negative Sentences, demonstrating that true negative sentences are more difficult than false negative sentences.

Finally, the results support the Working Memory Deficit Hypothesis, claiming that dyslexia is associated with a processing limitation caused by a poor verbal Working Memory.

3.3. Experiment 3 – The interpretation of negative quantifiers

The experimental task was performed to test the computation of negative quantifiers.

3.3.1. *Participants*

The experiment was conducted on the same subjects who took part in Experiment 1, namely 17 dyslexic children (mean age 9;8) and 17 age-matched typically developing children (mean age 9;8).

3.3.2. *Design and Procedure*

Also in this case, a sentence-picture verification task has been used with the same procedure used in Exp. 1 and Exp. 2. However, in this case the target sentences were presented in a felicitous context, to verify if performance was influenced by this factor. The task involved 8 experimental items, intertwined with 4 fillers. There were four experimental conditions, with four experimental items for each condition. An example is reported below.

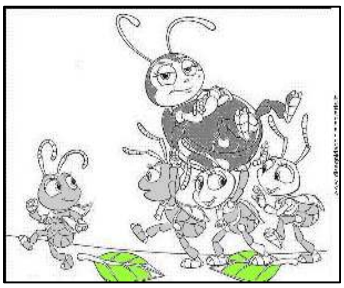


Figure 4. An example of Exp. 3

(i) *Condition A*: Negative Quantifier True (NQT)

Sperimentatore: "Guarda, queste formiche stanno correndo verso il formicaio con la loro regina. Sono talmente di fretta che non hanno tempo di riposare e di bersi un caffè."
Cappuccetto Rosso: "Nessuna formica sta bevendo il caffé."
'Experimenter: "Look, these ants are running to the anthill with their queen. They are such in a hurry that they have not time to rest and drink a coffee."'
'Little Red Riding Hood: "No ant is drinking a coffee."'

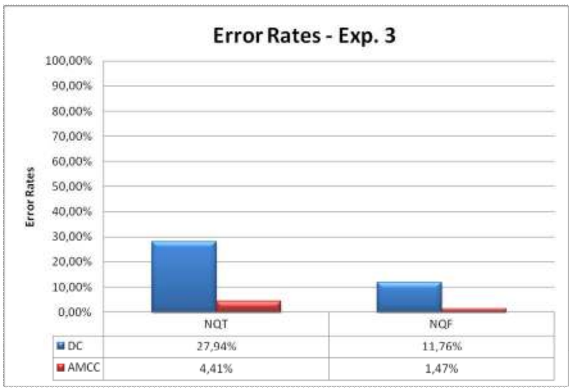
(ii) *Condition B*: Negative Quantifier False (NQF)

Sperimentatore: "Guarda, queste formiche stanno correndo verso il formicaio con la loro regina e sono molto di fretta."
Cappuccetto Rosso: "Nessuna formica sta correndo verso il formicaio."
'Experimenter: "Look, these ants are running to the anthill with their queen. They are really in a hurry."'
'Little Red Riding Hood: "No ant is running to the anthill."'

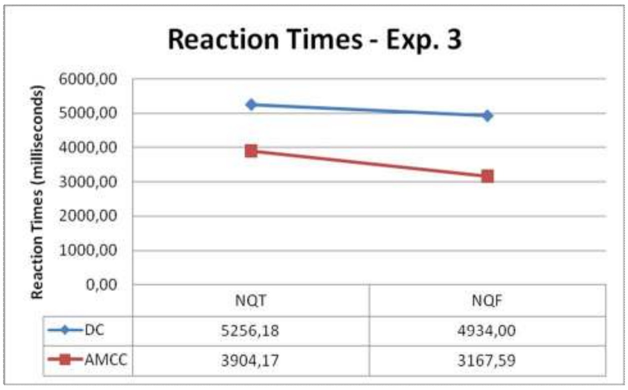
3.3.3. *Results*

All subjects were able to complete the test and to respond correctly to the vast majority of the fillers; therefore nobody was excluded from the sample.

The error rates are reported in Graph 5.5 where dyslexic children are represented by the blue bar and typically developing children by the red bar. Reaction times are represented in Graph 5.6, where dyslexics are represented by the blue line and controls by the red line.



Graph. 5



Graph. 6

Also in this case, dyslexics commit more errors in comparison to control children. As predicted, the error rates are higher in Condition A (NQT), where the sentence is true, for both groups. The error rates are equal to 27,94% for DC and 4,41% for AMCC. Moreover, DC perform more poorly in Condition B (NQF) as well, with a 11,76% error rate, while AMCC' performance is generally correct (1,47%).

Moreover, looking at Graph 5.6, it is evident that response times are much longer for dyslexic children than for control children.

A t-test has been conducted on the error rates, to verify if there were statistically significant differences amongst the two groups of children. An α level of 0.05 was adopted. Levene's test for the Homogeneity of Variance resulted significant for both Condition A '(NQT' (F (32) = 39,337, p = .000) and Condition B '(NQF' (F (32) = 8,171, p = .007). Therefore an independent sample t-test for equal variances not assumed has been conducted. The t-test revealed that there is a significant difference between DC and AMCC in Condition

A ‘NQT’ (t = 2,283, p = .035), whereas there is no significant difference in Condition B ‘NQF’ (t = 1257, p = .226).

Two t-tests have also been used to verify if there were significant differences between DC and AMCC in response times. A significant difference has been found both in Condition A ‘NQT’ (t(32) = 3,221, p =.003) and in Condition B ‘NQF’ (t(32) = 7,870, p = .000).

As predicted, the presence of a supportive context has an impact on the performance, as demonstrated by two facts: first, by the fact that the error rates were lower in this experiment in comparison to the error rates reported in Experiments 1 and 2. Second, the slower response times shown by dyslexics in this experiment can be interpreted as a piece of evidence for the fact that dyslexics perceive the task as easier in comparison to the previous experiments and try to provide an answer. The faster response times reported in Experiments 1 and 2, instead, can be read as an incapacity to cope with the test, leading them to adopt a guessing strategy.

3.3.4. *Discussion*

The results show that dyslexic children are significantly impaired in comparison to control children when asked to interpret sentences containing negative quantifiers. In particular, their performance is poorer when they are asked to evaluate true sentences containing the quantifier *nessuno* ‘nobody’, whereas they do not commit significantly more errors than control children when asked to evaluate false quantified sentences. However, the statistical analysis of response times reveals that latencies are longer for dyslexics in both conditions, suggesting that they are experiencing more difficulties in comparison to control children. Moreover, the significantly higher error rate in Condition A (NQT) confirms that true sentences are more difficult than false sentences, as predicted by the Model of Sentence-Picture Match Processing for Negative Sentences.

As predicted by the Two-Step Simulation Hypothesis, the presence of a supportive context indeed enhanced the performance: in fact, both dyslexics’ and controls’ error rates are lower in this experiment, in comparison to the error rates exhibited in Exp. 1 and Exp. 2. Moreover, the slower response times shown by dyslexics seem to suggest that they perceive the task as easier, concentrating more on the task in order to provide the correct answer.

Summarizing, dyslexic children manifest a significantly poorer performance in comparison to control children when asked to evaluate sentences containing the negative quantifier *nessuno* ‘nobody’. This result is consistent with all predictions, showing that the comprehension of negative sentences is remarkably problematic for dyslexic children, due to their processing limitations.

3.4. Experiment 4 – The interpretation of Negative Concord

The experimental task was performed to test the computation of Negative Concord. Both the quantifiers *niente* ‘nothing’ and *nessuno* ‘nobody’ were tested.

3.4.1. *Participants*

The experiment was conducted on the same subjects who took part in the previous experiments, namely 17 dyslexic children (mean age 9;8) and 17 age-matched typically developing children (mean age 9;8).

3.4.2. *Design and procedure*

As in the previous experiments, a sentence-picture verification task has been administered with the same procedure. As in Experiment 3, the target sentences are presented in a supportive context. The task involved 12 experimental items, intertwined with 4 fillers. There were four experimental conditions, with three experimental items for each condition. Both the quantifiers *niente* ‘nothing’ and *nessuno* ‘nobody’ were tested. Two examples are reported below.

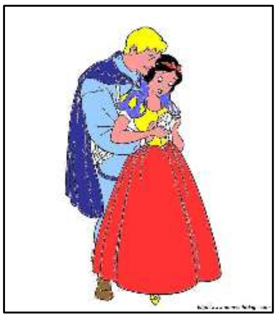


Figure 5. An example of Exp. 4

(i) *Condition A*: Negative Concord with *nessuno* True (Nessuno_T).

Sperimentatore: “Guarda il Principe e Biancaneve si sono finalmente conosciuti. Meno male che non c’è più la Matrigna, altrimenti il Principe l’avrebbe rincorsa per darle una lezione! Ora invece sta abbracciando Biancaneve: sono proprio innamorati!”

Cappuccetto Rosso: “Il Principe non sta rincorrendo nessuno.”

‘Experimenter: “Look, the Prince and Snow White have finally met each other. Thank goodness the Stepmother is not there anymore, otherwise the Prince would have chased her to teach her a lesson!”’

‘Little Red Riding Hood: “The Prince is not chasing anyone.”’

(ii) *Condition B*: Negative Concord with *nessuno* False (Nessuno_F)

Sperimentatore: “Guarda il Principe e Biancaneve si sono finalmente conosciuti. Meno male che non c’è più la Matrigna, altrimenti il Principe l’avrebbe rincorsa per darle una lezione! Ora invece sta abbracciando Biancaneve: sono proprio innamorati!”

Cappuccetto Rosso: “Il Principe non sta abbracciando nessuno.”

‘Experimenter: “Look, the Prince and Snow White have finally met each other. Thank goodness the Stepmother is not there anymore, otherwise the Prince would have chased her to teach her a lesson!”’

‘Little Red Riding Hood: “The Prince is not hugging anyone.”’

Figure 6. An example of Exp. 4

(iii) *Condition C*: Negative Concord with *niente* true (Niente_T).

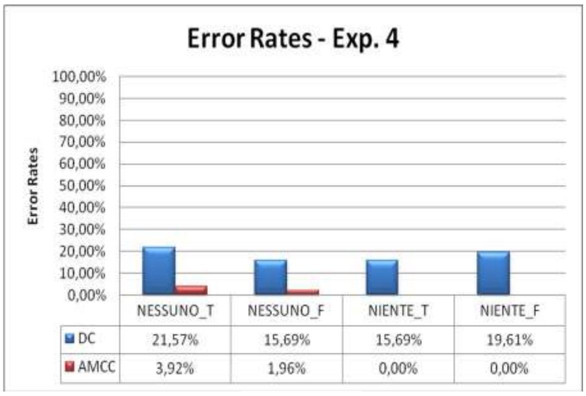
Sperimentatore: “Guarda, questo è un mammut molto grande! Per fortuna non sta schiacciando niente con i piedi! Invece tiene un animaletto nella proboscide.”
Cappuccetto Rosso: “Il mammut non sta schiacciando niente con i piedi!”
‘Experimenter: “Look, this is a very big mammoth! Fortunately, it is not squeezing anything under his feet! Instead, it is holding a small animal in its trunk.”
‘Little Red Riding Hood: “The mammoth is not squeezing anything under its feet.”’

(iv) *Condition D*: Negative Concord with *niente* false (Niente_F).

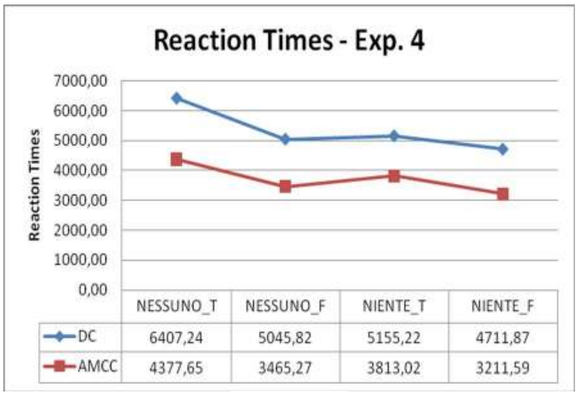
Sperimentatore: “Guarda, questo è un mammut molto grande! Invece tiene un animaletto nella proboscide. Per fortuna non sta schiacciando niente con i piedi!”
Cappuccetto Rosso: “Il mammut non tiene niente nella proboscide.”
‘Experimenter: “Look, this is a very big mammoth! It is holding a small animal in its trunk. Fortunately, it is not squeezing anything under his feet!”’
‘Little Red Riding Hood: “The mammoth is not holding anything in its trunk.”’

3.4.3. *Results*

All subjects were able to complete the test and to respond correctly to the vast majority of the fillers; therefore nobody was excluded from the sample.



Graph. 7



Graph. 8

As in previous experiments, it seems immediately evident that dyslexics underperform in comparison to control children in all conditions. Moreover, reaction times appear to be much slower for dyslexics. However, the error rates appear to be significantly lower in comparison to Experiment 1 and Experiment 2, where the error rates approached chance level, arguably due to the presence of a supportive context.

Control children’s performance is generally very correct.

A statistical analysis has been conducted on these data, to determine if there were statistically significant differences between the performances shown by the two groups of children. A 2 x 2 mixed design ANOVA was conducted. *Group* (DC; AMCC) was the between-subject variable. *Type of concord* (*nessuno*; *niente*) was the first within subject variable, verifying if the type of concord affected performance (comparing Conditions Nessuno_T and Nessuno_F to Conditions Niente_T and Niente_F). *Truth* was the second within subject variable, comparing true sentences to false sentences (Conditions Nessuno_T and Niente_T to Conditions Nessuno_F and Niente_F). There was a significant *Group* effect, F (1, 32) = 6.407, p = .016, indicating that dyslexic children performed significantly worse than control children. The *Type of Concord* variable was not significant, F (1, 32) = .665, p = .421, demonstrating that the form of concord (with *nessuno* vs. *niente*) had no impact on the performance; moreover, there was no significant *Type of Concord* × *Group interaction*, F (1, 32) = 1.325, p = .258, showing that the type of concord was not significant either for DC or for AMCC.

The *Truth* variable was not significant, F (1, 32) = .131, p = .720. Furthermore, there is a non-significant *Truth* × *Group* interaction, F (1, 32) = .012, p = .914, indicating that this variable is not significant for both groups.

For what concerns reaction times, a t-test was conducted for each condition, showing that latencies were always longer for dyslexics. In fact, they displayed significantly longer response times in Condition A “Nessuno_T” (t(32), = 7.362, p = .000), in Condition B “Nessuno_F” (t(32) = 7,362, p = .000), in Condition C “Niente_T” (t(32) = 6.177, p = .000) and in Condition D “Niente_F” (t(32) = 6.200, p = .000).

Therefore, the results show that dyslexic children are significantly more impaired in the comprehension of Negative Concord in comparison to control children in all conditions, as evidenced both by higher error rates and slower response times. However, in this case the truth-value of the target sentences did not affect performance.

As predicted, the presence of a supportive context has an impact on the performance, as demonstrated by two facts: first, by the fact that the error rates were lower in this experiment in comparison to the error rates reported in Experiments 1 and 2. Second, the slower response times shown by dyslexics in this experiment can be interpreted as evidence for the fact that dyslexics perceive the task as easier in comparison to the previous experiments and try to provide an answer. The faster response time reported in Experiments 1 and 2, instead, can be read as an incapacity to cope with the test, leading them to guess.

3.4.4. *Discussion*

As in the previous experiments, dyslexic children experience significantly more difficulties in comparison to control children when asked to evaluate sentences containing Negative Concord against pictures. In particular, they underperform in all conditions, needing more time than control children to provide the answer.

However, the presence of a supportive context enhances performance: in fact, both dyslexics’ and controls’ error rates are lower in this experiment, in comparison to the error rates found in Exp. 1 and Exp. 2. Moreover, the slower response times shown by dyslexics seem to suggest that they perceive the task as easier, concentrating more on the task in order to provide the correct answer. As expected, the type of concord is not a significant variable.

In contrast with Experiment 1 and Experiment 2, the truth-value of the target sentence does not affect performance in this case. However, note that this result does not entail that true sentences are not problematic for dyslexic children, but rather it indicates that they have difficulties with both kinds of sentences. Moreover, the absence of a truth effect may be a consequence of the supportive context, which weakens the general complexity of the task.

In sum, the results are consistent with the Two-Step Simulation Hypothesis, showing that negative sentences are more difficult when they are presented out of an appropriate context.

3.5. General discussion and conclusion

This experimental protocol was designed to test how dyslexic children interpret negative sentences in comparison to age-matched typically developing children.

The protocol comprised four different experiments, testing respectively the computation of negative sentences (Exp. 1), the computation of negative passive sentences (Exp. 2), the computation of sentences with negative quantifiers (Exp. 3) and the computation of sentences with Negative Concord (Exp. 4). The method used in all these experiments was a sentence-picture verification tasks, in which subjects were asked to evaluate the sentences uttered by a puppet that had the task to describe what was represented in a picture. Both error rates and response times were considered, showing that dyslexic children are remarkably more impaired than control children in all tasks.

In Experiment 1, in particular, dyslexics display a poorer performance in comparison to controls in all conditions, namely when asked to interpret true and false sentences with internal negation (Conditions A and B), and true and false sentences with external negation (Conditions C and D). True sentences were significantly more difficult than false sentences for dyslexic children, whereas the type of negation (internal vs. external negation) did not affect the performance.

Similar results have been obtained in Experiment 2, which tested the interpretation of negative passive sentences. Also in this case dyslexics manifested significantly more difficulties than controls in all conditions, i.e. in true and false passive sentences with internal negation (Conditions A and B) and external negation (Conditions C and D), as shown by higher error rates. In this experiment, the truth of the target sentences affected the performance of both groups of subjects, whereas the type of negation had no impact. This fact has been considered to be a consequence of the higher complexity of the task due to the presence of a passive construction.

No difference in response times between the groups has been found either in Experiment 1 or in Experiment 2.

In Experiment 3, the interpretation of sentences with negative quantifiers has been tested in supportive contexts; the results show that dyslexics experience more difficulties than control children, as shown by significantly higher response times, both when the quantifier *nessuno* ‘nobody’ was used in true sentences (Condition A) and in false sentences (Condition B). However, the statistical analysis revealed that error rates were significantly greater for dyslexics only in true sentences.

Finally, in Experiment 4, the interpretation of Negative Concord in supportive contexts has been tested. Two types of Negative Concord were tested, namely the Negative Concord constructed with the neg-word *nessuno* ‘nobody’ in true and false sentences (Conditions A and B) and the Negative Concord constructed with the neg-word *niente* ‘nothing’ in true and false sentences (Conditions C and D).

Also in this experiment, dyslexics displayed a significantly poor performance in comparison to control children, as shown both by higher error rates and slower response times. However, in this case the statistical analysis showed that neither the type of concord nor the truth of the target sentence affected performance.

In both Experiment 3 and Experiment 4 a lower error rate has been observed, in comparison to the very high error rate found in Experiment 1 and 2, arguably due to the presence of a supportive context that enhanced performance.

In order to interpret these results, we adopt the framework of the Two-Step Simulation Hypothesis developed by Kaup, Zwaan & Lüdtke, claiming that negation is implicitly encoded in the sequencing of two distinct mental simulations, namely the simulation of the expected state of affairs, representing the affirmative counterpart of the negative sentence, and the simulation of the actual state of affairs, representing the negative sentence.

According to this hypothesis, two cases can be distinguished: when the negated state of affairs is already present in the discourse context before encountering the negative sentence, all that subjects have to do is to correct the expectations by simulating the actual state of affairs. When the negated state of affairs is absent from the discourse context, the comprehenders have to construct first a simulation of the expected state of affairs and then a simulation of the actual state of affairs. Consequently, when negative sentences are not uttered in a felicitous supportive context, the comprehenders' task is more complex. This hypothesis is consistent with the results reported in this experimental protocol. In Exp. 1 and 2, the target sentences were not presented in a supportive context and the error rates displayed by dyslexic children were significantly high, approaching chance level in the true conditions. In Exp. 3 and 4, in contrast, the sentences were presented in a supportive context and the subjects' task was facilitated, as shown by lower error rates.

The data concerning response times reported in the four experiments can also be read as related to the presence or absence of a felicitous discourse context. In Exp. 1 and 2, both dyslexics and controls display similar response times, whereas in Exp. 3 and Exp. 4 latencies were significantly longer for dyslexic children.

This fact has been explained arguing that in Exp. 3 and 4 dyslexics seem to perceive the task as easier, trying to concentrate more on the task in order to provide the correct answer, as confirmed both by higher reaction times and slower error rates. Conversely, the absence of a felicitous context in Exp. 1 and 2 further complicates the tasks: this complication has a significant impact especially on dyslexics, who seem to get stuck and to resort to guessing, committing many errors.

To explain the greatest difficulty reported in true conditions in comparison to false conditions, we refer to the Model of Sentence-Picture Match Processing for Negative sentences illustrated in section 2.4.

According to this model, when the picture does not provide the subject with a representation of what the sentence is about, she has to correct this mismatch, creating a representation of the sentence which can be compared against the picture. This is the case for negative true sentences, which in fact were experienced as the most difficult, as demonstrated by higher error rates in Exp. 1, 2 and 3. Conversely, when the picture and the sentence match, as in the "false" conditions, the subject's task was facilitated.

To sum up, the results of this experimental protocol show that dyslexic children are significantly more impaired than age-matched typically developing children when they are asked to interpret negative sentences. Their difficulty is due to the fact that negative sentences are remarkably demanding in terms of processing resources and that their working memory is not efficient enough to cope with this task.

4. APPENDIX: SOME NOTES ON HORN'S CONJECTURE

In this section, we intend to suggest that some of the conceptual ingredients of a pragmatics of negation (such as the notion of "plausible denial" and the relationship between "expected state of affairs" and "asserted state of affairs"), which we have held as responsible for the kind of impairment manifested by dyslexic subjects in the comprehension of negative sentences, may also be useful in the analysis of some long-standing issues concerning the lexicalization of quantificational phrases. More particularly, we argue that the processing models of negation illustrated above may be directly relevant for the analysis of the lexicalization phenomena falling under the scope of what we would like to dub – following Moeschler 2007 – "Horn's conjecture", essentially concerning the non-existence of lexical items lexicalizing negative particulars in human language – a tentative semantic universal. In this way, we intend to illustrate the advantages of a perspective on negation inspired from the principles of neo-Gricean formal pragmatics.

Given Aristotle's square of oppositions, illustrated in (1) below, a system of relations emerges according to which A/O and I/E are pairs of contradictories (in any state of affairs one member must necessarily be true and the other false), whilst A and E are contraries (they cannot be true together) and I and O subcontraries (they cannot be false together):

(1) A ($\forall$) universal affirmative: e.g., every student solved the problem.
E ($\neg\exists$) universal negative: e.g., no student solved the problem.
I ($\exists$) particular affirmative: e.g., some students solved the problem.
O ($\neg\forall$) particular negative: e.g., not every student solved the problem.

The issue at stake is why negative particulars (O) cannot be lexicalized, to a significant crosslinguistic extent, contrary to what happens in the case of negative universals (E). This is shown in (2) and (3) below (the linguistic expression of O requires a pair of complex values (*some* and *not* in (2a) and *not* and *all* in (2b)), whereas the expression of E involves a lexicalized single value (*no* in (3)):

(2) a. Some students are not ill.
b. Not all students are ill.

(3) No students are ill.

The problem with Horn's conjecture, formulated in (4) (cf. Moeschler 2007), is that there is no satisfactory definition of what counts as a complex value, and, in particular, there is no principled explanation for why lexicalization is blocked for O and admitted for E.

(4) *Horn's conjecture*: Natural languages tend not to lexicalize complex values, since these need not be lexicalized.

Let us thus see if any progress can be made at this level, capitalizing on the processing conditions on negation discussed in this contribution. Let us start with negative particulars (O), whose two potential logical forms are given in (5a/b):

(5) a. $\exists x \neg Fx$
b. $\neg \forall x Fx$

Since O is a negative sentence, Plausible Denial (PD) requires that it be uttered in a context where its affirmative counterpart (the contradictory of O, i.e. A) is somehow presupposed or could at least be uttered felicitously. More precisely, let us suppose that the processing of O necessarily involves the processing of A as an intermediate processing step (cf. the Two-Step Simulation Hypothesis, Kaup et al. 2007). This clearly entails that the sentence that has to be presupposed in order for O to be uttered felicitously is (6) (as an instantiation of A):

(6) All students are ill.

If we ask now the question how O can be realized linguistically, we are led to the conclusion that neither internal nor external negation are suitable tools. Internal negation provides us with (7), which is not the contradictory of (6), whereas external negation can only be realized metalinguistically, as shown in (8):

(7) All students are not ill.

(8) It is not the case that all students are ill.

From this perspective, the obvious question that arises is whether there is any way to linguistically realize the contradictory of (6) clause-internally. A direct answer to this puzzle is provided by constituent-negation, exemplified in (9):

(9) [Not all students] are ill.

The logical form of (9) is provided by (10a), which is of course equivalent to (10b) and (10c):

(10) a. At most |A-1| of the students are ill.
b. At least one student is not ill.
c. Some students are not ill.

This reasoning, based on the role of A as the presupposed contradictory of O, is arguably correct, since both (9) and (10c) can be used as negative particulars in contexts of plausible denial where A is presupposed. We conclude that there is no objection to using complex values for the expression of O.

Let us now consider negative universals (E), whose two potential logical forms are given in (11a/b):

(11) a. $\forall x \neg Fx$
b. $\neg \exists x Fx$

Since the contradictory of E is I (positive particular), a context of plausible denial for (11a/b) is a context where we need to presuppose I, exemplified in (12):

(12) Some students are ill.

Again, once we have adopted this perspective, the obvious question is why the contradictory of (12) is linguistically expressed as it is, that is, in a form involving the lexicalization of the complex values in (11) (*no student is ill*). As above, neither internal nor external negation provide us with suitable means, since (13a) is not the contradictory of (12) and (13b) involves metalinguistic negation:

(13) a. Some students are not ill.
b. It is not the case that some students are ill.

However, notice that in this case we cannot resort to constituent-negation, since (14) is ungrammatical in English:

(14) * [Not some students] are ill.

Why is (14) ungrammatical? Given a lexical scale triggering implicature computation, we know that (cf. Moeschler 2007):

(15) An upper-bound term F *truth-conditionally implies a lower-bound term* f *:* $F \rightarrow f$*.*
A lower-bound term f *Q-implicates the negation of the upper-bound term F:* $f \rightarrow \neg F$

By application of the second clause of (15), (12) becomes (16):

(16) Some students are ill and not all students are ill.

At this point, there is a striking fact to be noticed. When we apply constituent-negation to build (14), we trigger a kind of downward monotonicity ([not some students] = zero students). This downward monotonicity effect is in conflict with the kind of upward monotonicity triggered, as just noted, by implicature computation (*some student* implicates *not all students*). We propose that it is these conflicting monotonicity properties (tied to the pragmatic properties of *some*) that make *not some students* ungrammatical. Conceptual confirmation is provided by the observation that lexical scales are well-known as obeying strict monotonicity requirements. Empirical confirmation is provided by the possibility of generalizing the ungrammaticality of constituent-negation to **not most*, **not three*, etc. (the exception constituted by *not many* will not be discussed here, for space reasons).

The hypothesis that we intend to put forward is that, since *not some students* is not admitted, lexicalization is a last resort to create the semantic value roughly corresponding to *zero* (*no* can be regarded as a lexicalization of *zero*), while resolving the monotonicity conflict proper to *not some students*.

Horn's insight is thus partially confirmed: lexicalization of complex values involving negation is indeed a last resort strategy, that applies to E and does not apply to O for the principled reasons we have discussed. The proposed strategy of elucidation of Horn's conjecture makes it clear that the study of the conditions on the pragmatics and processing of negation is not orthogonal to the theory of (lexical) meaning.

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