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Narrative comprehension and production in children with SLI: An eye movement study

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Abstract

This study investigates narrative comprehension and production in children with specific language impairment (SLI). Twelve children with SLI (mean age 5; 8 years) and 12 typically developing children (mean age 5; 6 years) participated in an eye-tracking experiment designed to investigate online narrative comprehension and production in Catalan- and Spanish-speaking children with SLI. The comprehension task involved the recording of eye movements during the visual exploration of successive scenes in a story, while listening to the associated narrative. With regard to production, the children were asked to retell the story, while once again looking at the scenes, as their eye movements were monitored. During narrative production, children with SLI look at the most semantically relevant areas of the scenes fewer times than their age-matched controls, but no differences were found in narrative comprehension. Moreover, the analyses of speech productions revealed that children with SLI retained less information and made more semantic and syntactic errors during retelling. Implications for theories that characterize SLI are discussed.

Introduction

Labov and Waletzky (1967) characterized a narrative as a sequence of temporally related clauses rendered from a particular point of view. That is, narratives include information about the characters and events of the story, as well as comments that express the narrator's perspective on the story. Thus, the production of spoken narratives depends on the integration of multiple linguistic and cognitive skills. Narrators must select and produce a series of linguistic devices that properly explains the details of the story, while maintaining listeners' attention and dealing effectively with presuppositions regarding world knowledge.

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Although children have some notion of 'what a story is' by age 3 (Appleby, 1978) and are generally proficient with the majority of the morphosyntactic structures of their language by age 5 (e.g. Brown, 1973; Slobin, 1985), the acquisition of narrative skills continues to develop well into adolescence. Given the range of skills required to produce a good narrative, the analysis of children's stories allows us to investigate not only the development of complex language in school-aged children, but also the relationship of language development to other cognitive and affective abilities.

Various methods have been used to elicit children's oral narratives, including visual images and conversation techniques. One group of studies has used the Bus Story norm-referenced narrative test (Renfrew, 1969) to examine story retelling with picture support (e.g. Bishop and Edmundson, 1987; Howlin and Kendall, 1991; Paul and Smith, 1993; Stothard, Snowling, Bishop, Chipcase, and Kaplan, 1998; Girolametto, Wiigs, Smyth, Weitzman, and Pearce, 2001; Fey, Catts, Proctor-Williams, Tomblin, and Zhang, 2004; Pankratz, Plante, Vance, and Insalaco, 2007). In this test, the examiner first reads aloud the story of a bus to the child, who follows along with a picture booklet. When the examiner finishes, the child repeats the story to the examiner. This is an interesting test because it involves both comprehension and production tasks: the child first has to understand the story and then retell it as faithfully as possible. Besides linguistic abilities, the child needs to have a good working memory and a good long-term memory.

The aim of this article is to investigate online narrative comprehension and production in children with specific language impairment(SLI) based on the Bus Story test (Renfrew, 1969). SLI is a developmental language disorder that occurs in the absence of clear neurological, sensorimotor, cognitive or emotional deficits that can affect both expressive and receptive language. Children with SLI are characterized by developmental delays in a number of different language domains, including semantic, morphosyntactic, pragmatic and discourse skills in oral and/or written language (Bishop, 1997; Leonard, 1998).

Studies of children with SLI have often shown difficulties in both production and comprehension of narratives (Catts, Fey, Zhang, and Tomblin, 2001; Boudreau, 2007), and in micro (e.g. utterance complexity, lexical diversity) and macro (e.g. story structure) elements of narrative formulation (see Boudreau, 2007 for a review). Some authors have focused on the comprehension of oral narratives in children with SLI. Zaretsky (2004) studied the auditory comprehension of short stories, specifically, the role of verbal working memory in story comprehension. The results suggested that the difficulties of children with SLI in comprehending connected discourse were attributable to capacity limitations in functional working memory. Bishop and Adams (1992) evaluated the difference between literal and inferential meanings in children with SLI and age-matched controls. Children were questioned about a story presented either orally or pictorially. Half the questions were literal and half required making an inference about what had not been directly shown or stated. Children with SLI performed less well on the questions requiring inferences. The effects of mode of presentation and question type were similar for both groups.

As regards the production of oral narrative, research has shown that children with SLI have three primary features identified as problematic: organizational structure, cohesion and information. Children with SLI produce less mature narrative structures than age-matched children (e.g. Olley, 1989; Paul, Hernandez, Taylor, and Johnson, 1996; Miranda, McCabe, and Bliss, 1998; Wagner, Sahlen, and Nettelbladt, 1999; Manhardt and Rescorla, 2002). Moreover, they produce essential plot components less often (Merritt and Liles, 1987; Olley, 1989; Copmann and Griffith 1994) and produce fewer quality and context components than age-matched controls, resulting in reporting of less events and less complete episodes (Liles, 1987; Merritt and Liles, 1987; Olley, 1989; Copmann and Griffith, 1994; Gillam and Carlile, 1997).

These children use fewer story grammar components, form fewer complete episodes and achieve less cohesion adequacy than do their normal developing peers (Liles, 1985a, b; Roth and Spekman, 1986; Merrit and Liles, 1987; Gillam, McFadden, and van Kleeck, 1995). In addition, compared with age-matched controls, they are less fluent (Thordardottir and Weismer, 2002) and have greater difficulty with narrative production, both with respect to the amount of information retained from a story during a retelling task and in terms of their linguistic accuracy. They make more grammatical errors, use simpler structures and make more omissions (e.g. MacLachlan and Chapman, 1988; Gillam and Johnston, 1992; Scott and Windsor, 2000; Greenhalgh and Strong, 2001; Sanz-Torrent, Serrat, Andreu, and Serra, 2008).

There are two major types of explanations for deficits in children with SLI. The first holds that language deficits reflect problems of grammatical competence among children with SLI. This hypothesis holds that the deficit is representational in nature, in that it stems from a malfunctioning of a hypothesized grammatical acquisition device, such that the grammatical representational system never fully matures to a state of recognizing obligatory aspects of tense or syntactic relations (e.g. Rice, Wexler, and Cleave, 1995; van der Lely, 1998; 2005). Specifically, the Extended Optional Infinitive account (Rice and Wexler, 1996) and its last version, the Extended Unique Checking Constraint account (Wexler, 1999), hold that the deficit in children with SLI arises from a developmental delay in the onset of the ability to mark finiteness. As an alternative, van der Lely (1998) proposed the Representation Deficit for Dependent Relationships that was later reformulated as the Computational Grammatical Complexity(CGC) account (van der Lely, 2005). According to these accounts, children with SLI have a general deficit in the computational system, because they always use the most economic linguistic structure.

The second type of explanation holds that the language difficulties of children with SLI arise from cognitive processing deficits (Leonard, 1998; Ellis Weismer, Evans, and Hesketh, 1999; Montgomery, 2000a, b; Miller, Kail, Leonard, and Tomblin, 2001). The most obvious problems that might be cast in terms of processing capacity limitations came from trade-offs between performance and task complexity observed during language processing tasks. This perspective is supported by evidence that processing speed in SLI is slower in the amount of work that can be accomplished in a given unit of time (Generalized Slowing hypothesis; Kail, 1994; Leonard, 1998; Miller et al., 2001) and that children with SLI have limitations in working memory (Montgomery, 1996, 2000a, b, 2003, 2006; Ellis Weismer et al., 1999). This limited processing capacity in children with SLI affects narrative organization adversely (Shapiro and Hudson, 1991; Eaton, Collis, and Lewis, 1999). Episodic memory, which is dependent on processing capacity, is critical for storing and manipulating narrative scripts, information about situations and events, world knowledge and related feelings, motivations and beliefs (Van Dijk and Kintsch, 1983). The task of selecting appropriate lexical forms for describing story elements in a narrative task may also be constrained by limitations in working memory.

The majority of the studies mentioned above were based on offline methodologies. Studies of comprehension are typically based on the analysis of responses to questions, posed after the narrative was presented, about implicit or explicit aspects of the narrative. In studies of production, the analysis focuses on linguistic features, organizational structure, cohesion and quantity of information of children's productions without paying attention to how they select and organize the information from the scene during their retelling.

One paradigm that provides information about online language processing involves the recording of eye movements while the child is viewing the scene and listening to the narrative simultaneously. The use of real-time measures of spoken language processing, particularly the so-called 'visual world paradigm' (Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard, and Sedivy, 1995), may offer a better picture of the linguistic processing abilities of children with SLI. With the advent of head-mounted and remote eye-tracking systems, it is now relatively easy to obtain a moment-by-moment record of where children and adults are looking as they hear sentences that describe their visual referent world (Trueswell, 2008). Studies that have used this paradigm (Tanenhaus et al., 1995; Altmann and Kamide, 1999; Trueswell, Sekerina, Hill, and Logrip, 1999; Griffin and Bock, 2000; Kamide, Altmann, and Haywood, 2003; Nation, Marshal, and Altmann, 2003, among others) have shown that eye movements can be used to understand the mental processes involved in the comprehension of spoken language and provide information about how visual information is gathered in production tasks.

The study presented in this article seeks to use this paradigm to record eye movements during scene viewing accompanied by auditory input and during narrative production. When people are simultaneously presented with spoken language and a visual field containing elements semantically related to the informative items of speech, they tend to spontaneously direct their line of sight to those elements that are most closely related to the meaning of the language currently heard (e.g. fixating a lion upon hearing part or all of the word 'lion'). In language production, when speakers describe actions or events based on a visual image, they focus their visual attention on each element before producing specific language about it (e.g. fixating a zebra upon say the sentence 'The zebra runs away' while watching a scene of African savannah). On this basis the aims of this study are, on the one hand, to analyse in real time how children with SLI and age-matched controls process narrative information while viewing the scenes and listening to the associated text. The time spent looking at the visual referents of the auditory linguistic input provides a useful and plausible measure of narrative comprehension. On the other hand, in the retelling task, we aim to evaluate whether children with SLI can select the relevant areas of the scene to conceptualize the events of the story and construct and utter the correct phrases or sentences to describe it. Then, we compare this visual information with the elements and structure of the narratives produced. In this case, visual information allows us to understand whether they select the appropriate elements of the scene that could lead to a predication. Then, the comparison with the narrations can inform us if the deficits are focused only in linguistic processes involved in language production, in a more general cognitive domain or both.

The processing limitations approach predicts that children with SLI ought to be slower than age-matched controls. This slow down may lead to problems in processing rapid linguistic input, leading to general system overload. As a result, children with SLI may fail to look at the visual referents related to the informative items of speech. If listeners have processing limitations, they may take more time to retrieve the semantic information associated with a picture and more time to look at its visual referent. So when the following word is mentioned, they may be still processing the previous word and will not have time to look at the next visual referent. As a result, the mean proportion of looks to semantically related elements of children with SLI would be lower than that for age-matched controls. In the retelling task, children with SLI may take more time for sentence planning leading to delays in story retelling. As a result, they will omit information due to their limitations in working memory (e.g. Montgomery, 1996, 2000a, b, 2003, 2006; Ellis Weismer et al., 1999) and they may fail to mention important elements of the scene.

Representational deficit accounts such as the Unique Checking Constraint (Wexler, 1999) that focus on overall developmental delay make no such predictions regarding online effects. However, the CGC account (van der Lely, 2005) predicts that children with SLI will have more difficulty in comprehension of sentences that use complex word order. For instance, children with SLI are known to have difficulty comprehending sentences with non-canonical word order such as The boy is pointed at by the man as compared with those with canonical word order such as The man is pointing at the boy (van der Lely and Harris, 1990; van der Lely, 1994). van der Lely suggests that sentence comprehension deficits in SLI are grounded in an underlying syntactic deficit that is only evident when children with SLI must employ knowledge of syntactic constraints and cannot depend on semantics or pragmatics. Because the original version of the Bus Story uses mainly short canonical SVO sentences, it would provide little information regarding the differential processing of complex structures by SLI children. Still, the CGC account would predict that children with SLI should make more grammatical errors than their controls.

Method

Participants

The sample comprised 24 preschool children bilingual in Catalan and Spanish.[1] The children did not need eye glasses to see the computer screen (as glasses sometimes interfere with eye tracking). The SLI group consisted of 12 children (6 boys and 6 girls) with mean age of 65.08 months (SD 1/411.59). The children with SLI were selected according to current criteria for diagnosing SLI (Stark and Tallal, 1981; Watkins, 1994; Leonard, 1998).

[1]This study was carried out in Catalonia when it is very difficult to separate monolingual and bilingual children. It is important to be aware that in Catalonia both Spanish and Catalan are official languages, thus the proficiency of both Spanish and Catalan is if not native, native-like. In view of this situation, we analysed all the children’s productions as if they came from one sole language. This would not interfere with the results, because all groups met the same conditions and all the structures analysed were similar in both languages. For a review of Catalan and Spanish bilingualism and SLI, see the recent study by Sanz-Torrent, Badia, and Serra (2008).

Specifically, children with SLI were tested to assess their non-verbal intelligence and level of language development. Tests included the Wechsler Intelligence Scale for Children, Revised (Spanish version; Wechsler, Cordero, de la Cruz; TEA Editions, 1993) or the Kaufman Brief Intelligence Test (Spanish version; TEA Editions, 1997). Every SLI child obtained a non-verbal IQ standard score above 85 (mean 1/4102, SD 1/47.06). Language ability was assessed by language profiles following the Spanish protocol for evaluation of language delay (AREL, Pérez and Serra, 1998), the Spanish version of Peabody Picture Vocabulary Test III (Dunn, Dunn, and Arribas, 2006) and the child language scale (Evaluaci n del Llenguaje Infantil, ELI; Saborit and Julián, 2005). The ELI test includes several subtests for, among others, articulation, lexical reception and lexical production and provides an equivalent age and a percentile. Children with SLI had scores of at least 1.25 standard deviations below the mean both in Peabody III (standard scores: mean 1/478.66, SD 1/49.17) and in ELI (percentile: mean 1/49.08, SD 1/41.16). Moreover, language profiles based on transcripts of spontaneous conversations provided information about the characteristics of the language production of the children, from which it was found that they showed a delay of at least 1 year (see Bishop, 1997). Each child passed a hearing screening for each ear (25 dB at 500, 100025 dB at 500, 2000 and 4000 Hz). Children that showed some difficulty in hearing one pure tone were not included in this study. With respect to oral structure and motor function, speech and language therapists examined the children to assess the shape, size and motor function of the speech organs, both active (tongue, lips and jaw) and passive (buccal cavity, palate and teeth), as well as respiratory dynamics, exhalation and rhythm. Motor function was assessed according to a protocol that used different practical exercises to verify that mobility was normal. Moreover, children who had a history of frank neurological impairment or psychological/emotional disturbance or attention deficit disorder or who used medications to control seizures (based upon educational psychologist reports) were excluded. In addition, all the children selected for this study had been diagnosed with SLI by the School Educational Psychology Services of Castell and by the Centre for Educational Recourses for Hearing and Language Impairments NarcísMas (Girona) and were receiving language intervention.

The age-control group was equivalent in age (mean 1/465.17 months, SD 1/411.97), sex and mother tongue (three of them had Catalan and nine of them Spanish as mother tongue) to their counterparts in the SLI group. The children selected were classmates of each one of children with SLI and their teacher was asked to confirm that they showed normal language development for their age. Children were not selected if they had a history of speech therapy or psychological therapy. Moreover, teachers were asked to select children with normal academic performance. All of the children selected came from state schools in Catalonia and Valencia. In addition, language ability was assessed by use of a language profile based on transcripts of 15 minutes of spontaneous conversations. Children were excluded from the sample when speech problems were higher than expected for their age as assessed on language profiles.

Stimuli

The experiments were based on use of the Bus Story norm-referenced narrative test (Renfrew, 1969). This test is designed to evaluate children's comprehension and their use of

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words and phrases, and can also determine the ability to produce a consecutive narrative in children aged between 3 and 8. The test comprises 12 pictures distributed in groups of 3 on 4 cards, accompanied by a narrative. Each of the 12 pictures from the Bus was scanned and used as stimulus. Either a Spanish or a Catalan translation of the original narration of the Bus Story was used depending on the native language of each child. The full original narrative of the Bus Story was fragmented so that each of 12 visual images was paired with the sentence or group of sentences to which it refers. The structure of sentences was equivalent in both languages. Sentences were recorded by a male native bilingual speaker and sampled at 44,100 Hz. A digital audio editor was used to adjust each sentence so the duration was equal in both languages.

Procedure and design

Participants were seated at a distance of 22^{00} away from a 15^{00} WXGA monitor, set to 1280 800 pixels, with a refresh rate of 75 Hz. The images typically occupied the centre of the screen. An Iriscom Quick Glance 2SH device from Eye Tech Digital Systems (Mesa, AZ, USA) was used to collect and store eye-tracking data, which consisted of participants' eye position sampled at 25 Hz (40 millisecond intervals). A chinrest was used to ensure a constant distance between subjects and the apparatus. The sounds of stimuli were presented to participants via a mono channel split to two loudspeakers positioned at either side of the viewing monitor.

The procedure consisted of two stages. We began by establishing a conversation with the child and familiarizing them with the process of exploring images with the Eye Tech. During this stage, which lasted 5 minutes, the eye tracker was calibrated and children carried out a short exercise involving visual exploration of a scene of animals.

The test stage involved administration of the Bus Story Test using a laptop to present the pictures and the eye tracker to record the look pattern. The 12 test pictures were always presented in the same order and with the same exposure times.

In the comprehension task each of the 12 images was presented for 12 seconds with its associated narrative soundtrack to evaluate their comprehension. Image and audio started at the same time. Between each picture, participants were first presented for approximately 2000 milliseconds with a crosshair (which they had been instructed to fixate) so that the direction of gaze on each trial would start from the same point (the centre of the screen). Before beginning this stage, children were given the following instructions: 'Now we're going to see the bus story. Watch it closely, because when it's finished you'll have to tell me the story.'

The same pictures were then presented again for 12 seconds but without the accompanying sound, and the children were then required to retell the story themselves. This time the instructions were: 'Now we're going to see the story pictures again and you're going to tell me what's happening, OK?' While the children were retelling the story and while the crosshair was being presented, they were also given prompts such as 'And what else?' The child's retelling of the Bus Story, made with the visual help of the 12 pictures, was then recorded on audio and video and transcribed.

Apart from the experimenter, children with SLI were always accompanied by their usual speech therapist, and the age-matched controls by their teacher, with the aim of facilitating communication. This second stage of the experiment lasted approximately 15–20 minutes.

Data analysis

For each picture, we selected different areas of interest that we call semantically relevant areas (SRAs). The specific SRAs for each picture were selected according to the judgement of eight language experts from the Department of Basic Psychology, University of Barcelona. The judges were asked to identify the most visually salient features that were fundamental for the development of the story. Figure 1 illustrates the SRAs identified for one of the pictures from the Bus Story. From the horizontal and vertical eye position data obtained from the Iriscom Quick Glance 2SH equipment, we selected the pixels that occupied every SRA. A value of 1 was given to every eye tracking sample that fell within every SRA; otherwise it was given a 0 We rejected trials where there was more than 33% loss of eye position data. We calculated the proportion of looks made by the participants to these SRAs for the comprehension and production tasks. These data provided a measure of what people were thinking on a millisecond timescale, without breaking up the input or interfering with their normal processing.

We used the digital video recording of the story-retelling production task to calculate the onset and offset of speech for every trial for each child. We also used these recordings to transcribe each subject’s retelling of the bus story using the Child Language Data Exchange System (CHAT) of the transcription and coding format (CHILDES) project (MacWhinney, 2000). The analytic categories used in the CHAT transcriptions were based on the category system used in a previous analysis of speech samples of children with SLI (Serra, Aguilar, and Sanz-Torrent, 2002). In this study, a simpler system based on broader and non-exhaustive categories was employed, because the aim of this study was not to analyse speech samples in fine detail but rather to assess linguistic correctness together with data about the visual exploration of stimuli while telling a story. This analysis included the following data: totally correct statements, morphosyntactic errors of commission, morphosyntactic errors of omission and semantic lexical errors. We considered a statement to be complete when the retelling included all of the important relevant elements of a scene.

We first carried out a multivariate approach using the mean and the standard deviation of the proportion of looks to the SRAs as dependent variables. The application of Mauchly’s test for each task yielded a non-significant result and, therefore, we analysed all the data using several univariate ANOVAs for each task. The analysis of the production data used the non-parametric Mann–Whitney U-test for comparing means.

Results

Eye movements

We calculated the proportion of looks over time to the SRAs of every picture. The goal was to determine if there were differences in the proportion of looks to the SRAs between children with SLI and their age-matched controls in the comprehension and production tasks. Finally, we compared the looking patterns made for every group in the comprehension and production tasks.

Comprehension task

Figure 2 shows the proportion of looks over time to the SRAs in the comprehension task. The average duration of the narrations across the 12 images was 7760 milliseconds (194 samples after the image onset), which is marked with the vertical dashed line in Figure 2.

We calculated the mean and standard deviation of the proportion of looks to the SRAs during the temporal window for each child for each image. Table I shows the significance of the different sources analysed, the effect size (ε^2) and power of contrast (1–β) for each source and dependent measure (mean or standard deviation). There are highly significant effects for items for both the mean and the standard deviation. The greatest difference is found with image 12, which presents significant difference in relation to the other images, in particular images 5, 6, 7, 10 and 11 (F 1/419.699; df 1/41; p<0.001; ε^2 1/40.472 until F 1/4111.660; df 1/41; p< 0.001; ε^2 1/40.835). Neither the main effect of group nor the interaction effect was significant.

Production task

For each child on each item, we calculated the time from speech onset to offset, using the digital video recording of the production task. As we can see in Table II, age controls were faster at beginning the narration. This means that, during story retelling, children with SLI devote more time to the apprehension of the scene than their age controls (,457 milliseconds more). Regarding linguistic formulation, children in the SLI group took, on average, 3426 milliseconds speaking whereas age controls took 3872 milliseconds, on average. So, children with SLI spent slightly less time on each production–an average of 446 milliseconds. Table III shows the results of a univariate analysis of total speech time in which none of the effects were significant.

Figure 3 shows the proportion of looks at the SRAs for 200 milliseconds time slices from picture onset to speech onset in the production task.

Table IV presents the results of univariate ANOVAs for the mean and standard deviation of the proportion of SRA looks from picture onset to speech offset during the production task. As we can see in the Table IV and Figure 3, the age-control children showed more looks to the SRAs than did the SLI group. This effect is especially important due to the high value of effect size (ε^2 1/40.972 for the mean of all responses for each image and ε^2 1/40.961 for the mean of standard deviation for each experimental condition). In addition, there are no effect of image item and no interaction effect. The two groups show different responses irrespective of the image presented.

The comparison between comprehension and production tasks

Figure 4 displays the proportion of looks over time to the SRAs for both groups in comprehension and production tasks.

Table V presents the results of ANOVAs on the differences in the number of looks to the SRAs in comprehension and production tasks. The control children made more looks during the comprehension task than in the production task (t 1/423.21; p< 0.001; r 1/40.61). The SLI group did so as well although not in a very clear manner or consistently throughout the whole stimulus programme. On top of that, the SLI group made fewer looks at the relevant areas in comparison with the controls (t 1/418.21; p< 0.001; r 1/40.48).

Speech production

Finally, we consider the data regarding the correctness of the language used in retelling the story. Here, age-matched controls produced a significantly higher percentage of complete statements and made fewer syntactic and semantic errors than did the SLI group (see Table VI). Moreover, differences in syntactic omissions and semantic substitutions were found between children with SLI and age-matched controls. Table VII presents examples of syntactic and semantic errors occurring during the retelling of the story by children with SLI.

Discussion

The purpose of this study was to investigate the online narrative comprehension and production in children with SLI. For this purpose, we used the Visual World Paradigm based on the recording of eye movements during the visual exploration of scenes to comprehend or produce different language structures. The narrative comprehension task involved the recording of eye movements during the visual exploration of successive scenes of Bus Story norm-referenced narrative test (Renfrew, 1969) while listening to the associated narrative. In the production task, children were asked to retell the Bus Story, while once again looking at the scenes as their eyes were monitored. We analysed the speech productions of the story-retelling task to compare the onset and offset of speech and the correctness of the language between the two groups of children. Eye movements revealed that children with SLI look at the most SRAs of the scene fewer times than the age-matched controls during language production task. However, no differences were found in the comprehension task. The analyses of speech productions revealed that children with SLI retained less information and made more semantic and syntactic errors in the retelling but no differences were found in the latencies and time spent to retell each scene.

Despite their linguistic deficits, children with SLI performed well in real-time narrative comprehension that required linking perceived speech to a visual referent world. However, the results of this study show clearly that children with SLI perform worst in the production task, both in terms of the completeness and accuracy of their narrative production and with respect to the specificity of their visual scanning of semantically relevant elements to support their picture descriptions.

It is unlikely that a single root cause of SLI will be identified given the heterogeneity of SLI symptoms. Indeed, even leading figures in the study of SLI now acknowledge that none of the current theories of SLI adequately account for the deficit patterns (Leonard and Deevy, 2006). However, it is still instructive to consider the results of this study in view of the predictions of different accounts of SLI.

As regards the limited processing capacity account, the Generalized Slowing hypothesis (Kail, 1994; Leonard, 1998; Miller et al., 2001) predicted very few anticipatory eye movements for children with SLI in narrative comprehension relative to age-matched controls. In addition, from this hypothesis we expected that children with SLI would take more time for sentence planning and then spend more latency time to start the retelling of each scene narration than age-matched controls. However, none of these predictions were supported in terms of either looks to SRAs in narrative comprehension or latency times in narrative production.

With regard to latencies, although the SLI children were slower in absolute terms at initiating descriptions, these differences were not significant. Therefore, although many studies have shown that SLI children are generally slower in naming (e.g. Wiig, Semel, and Nystrom, 1982; Leonard, Nippold, Kale, and Hale, 1983; Lahely and Edwards, 1996, 1999) any slowdown observed here could be a result of generally slower lexical access, rather than slowness specific to syntactic processes.

The limited processing capacity account also predicted that children with SLI should omit more information and make less looks to SRAs in narrative production due to their limitations in working memory. In this case, the predictions were supported. Children with SLI produced a significantly fewer percentage of complete statements than age-matched controls. This may happen because children with SLI make fewer looks to SRAs and do not mention some important elements of the narration. As previous studies have shown, children with SLI exhibit processing limitations in working memory capacity (Gathercole and Baddeley, 1990; Ellis Weismer et al., 1999; Montgomery, 2000a; Marton and Schwartz, 2003; Archibald and Gathercole, 2006; Montgomery and Evans, 2009). Ellis Weismer (1996) showed that children with SLI have difficulty maintaining the novel phonological information in short-term memory long enough to process its meaning. This is reinforced by the studies of Montgomery (1995, 2000a, b) that found that children with SLI showed comparable comprehension of short sentences but encountered special problems in comprehending long sentences compared with control groups.

Further evidence for a processing capacity limitation comes from the comparison of the eye movements of the two groups of subjects on the comprehension and production tasks. The most straightforward account for these findings holds that the greater difficulty of the production task resulted from the fact that it placed greater demands on processing capacity. Both groups had a greater proportion of looks to SRAs on the comprehension task than on the production task. We believe that the overall processing load was lower in the comprehension task, thereby allowing subjects to focus more clearly on the SRAs. Control children did this more effectively than children with SLI, but for both groups, focusing on SRAs was easier in the less demanding comprehension task than in the resource-intensive production task.

The data on the correctness of the SLI children's speech are also compatible with a processing deficit account for the production task. We found that children with SLI made more grammatical and semantic errors than did the control children. Similar findings have been reported in narrative production (e.g. Gillam and Johnston, 1992; Scott and Windsor, 2000; Greenhalgh and Strong, 2001; Sanz-Torrent et al., 2008, and many others). Although this finding has been obtained in several previous studies in Catalan and Spanish (Serra et al., 2002; Sanz-Torrent et al., 2008), it differs from the findings of studies with English-speaking SLI children, where morphological errors predominate (Ingram, 1972; Steckol and Leonard, 1979; Fletcher and Peters, 1984; Clahsen, 1989; Fletcher, 1992; Clahsen and Hasen, 1993; Rice and Oetting, 1993; Marchman, Wulfeck, and Weismer, 1999; Rice and Wexler, 1996; Leonard, Eyer, Bedore, and Grela, 1997). The typological characteristics of these languages (rich vs. poor morphology, importance of word order and so on) may be the cause of these differences (Sanz-Torrent, et al., 2008).

The fact that our results found that syntactic errors were mainly errors of omission further supports the processing deficit account, because omissions often arise from capacity overload (Yoshimura and MacWhinney, 2007). However, production problems with grammar can be also accounted for by a deficient knowledge of particular linguistic rules, principles or constraints.

To conclude, we believe that this study provides further evidence that children with SLI are bumping up against a processing capacity and limitations in working memory in the narrative production task. We believe that these limitations can explain, to a large extent, the seriousness of the language delays shown by these children. Of course, a more precise characterization of the bases of this ceiling will require further experimentation, using both behavioural and neuroscientific methods.

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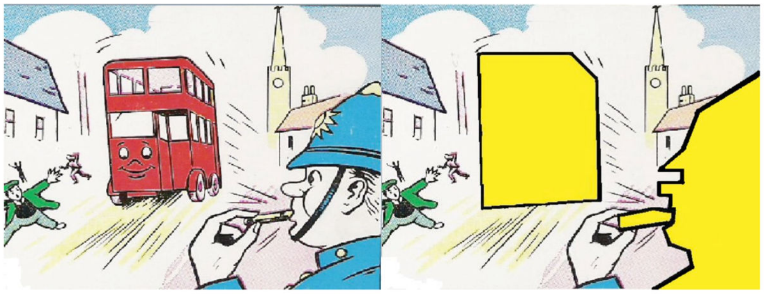

Figure 1.

Scene showing the semantically relevant areas (SRAs). The narrative associated was: ‘Elautobúsllego corriendo a una ciudad, donde se encontr con unpolicíaque hizo sonar susilbatoy le grito: Párateautobús!’ [‘The-Bushurried into the city, where it met a policeman who blew his whistle and shouted, “Stop, bus”’].

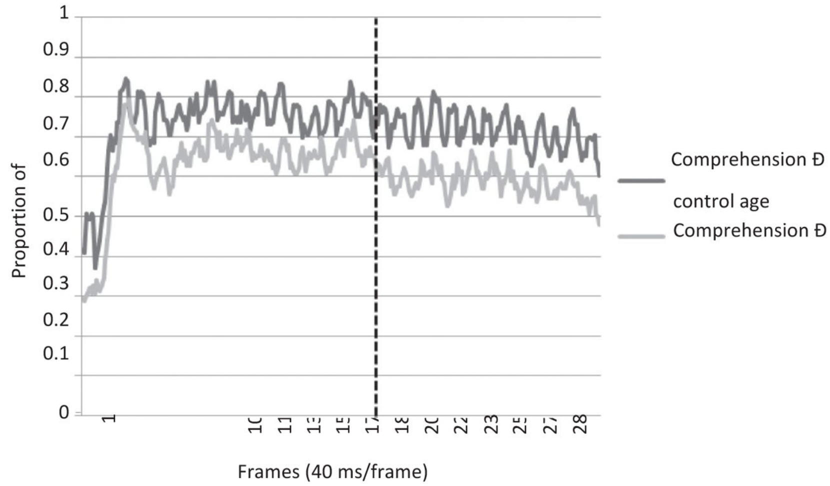

Figure 2.

Proportion of looks at SRAs by samples from pictures onset in the comprehension task. The discontinuous line is the average duration of the oral narration.

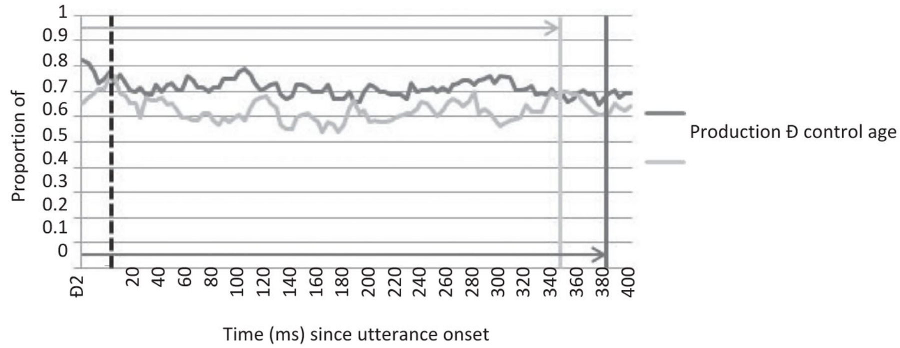

Figure 3.
Proportion of SRA looks during 200 milliseconds time slices from mean speech onset.

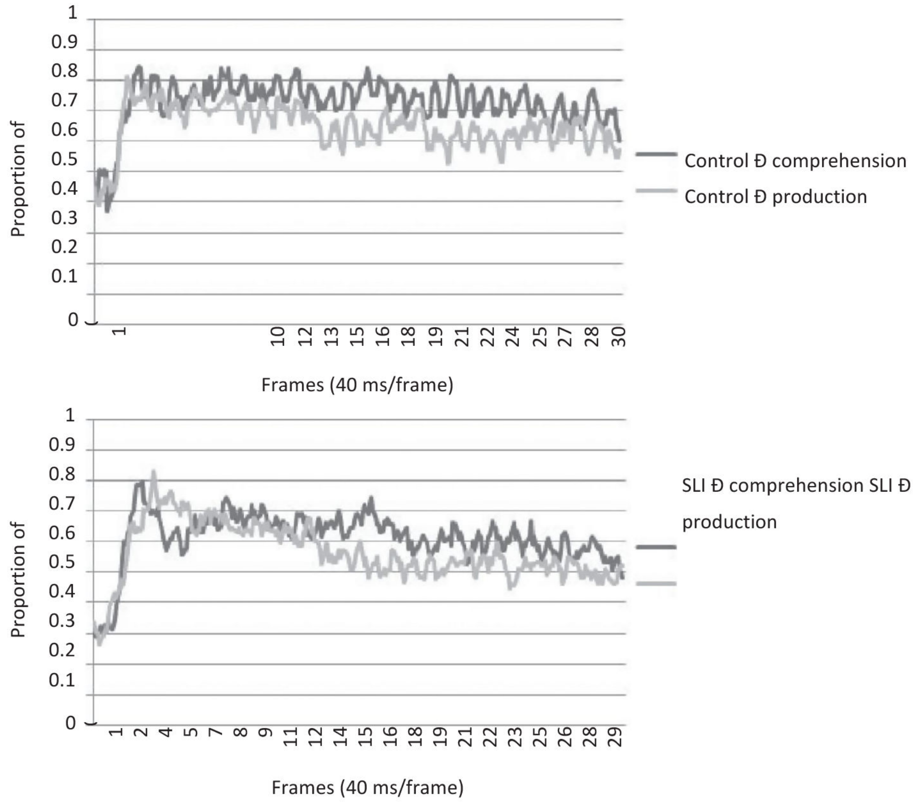

Figure 4.
Proportion of looks at SRAs by samples from pictures onset in both comprehension and production tasks.

Table I

Univariate ANOVA of mixed factorial design with repeated measures for comprehension phase.

	Mean of observed times as a dependent variable					Standard deviation of observed times as a dependent variable				
Source	**F**	**df**	**P value**	ε^2	**(1–β)**	**F**	**df**	**P value**	ε^2	**(1–β)**
Group	3.627	1	0.07	–	–	3.721	1	0.08	–	–
Items	20.429	11	<0.001	0.48	0.984	9.268	1	<0.001	0.296	0.998
Interaction	1.056	11	0.398	–	–	0.863	11	0.577	–	–

Note: ε^2 is the effect size and (1–β) is the power of the statistical contrast.

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Table II

Mean times for speech onset and offset.

	Speech onset	Speech offset
Age controls	2514.53 milliseconds (1536.98)	6386.74 milliseconds (2506.87)
SLI	2971.65 milliseconds (1344.04)	6397.81 milliseconds (2511.76)

Note: The data are represented as means of time (standard deviation).

Table III

Mean of total times as dependent variables.

Source	F	df	P value	ε^2	(1–β)
Group	1.651	1	0.235	–	–
Images	0.769	11	0.670	–	–
Interaction	1.457	11	0.162	–	–

Notes: All the significances obtained from α1/40.05. ε^2 is the effect size and (1–β) is the powerful of statistical contrast

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Table IV

Univariate ANOVA of mixed factorial design with repeated measures for production phase.

Mean of observed times as a dependent variable						Standard deviation of observed time as a dependent variable				
Source	**F**	**df**	**P value**	**ε^2**	**(1–β)**	**F**	**df**	**P value**	**ε^2**	**(1–β)**
Group	121.861	1	<0.001	0.93	0.972	197.404	1	<0.001	0.961	0.997
Images	6.037	11	<0.001	0.43	0.984	1.505	1	0.144	–	–
Interaction	0.902	11	0.902	–	–	0.514	11	0.889	–	–

Notes: All the significances obtained from α1/40.05. ε^2 is the effect size and (1–β) is the powerful of statistical contrast

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Table V

Proportion of looks at SRAs in comprehension while they were listening to the narration and production task while they were speaking.

	Control age group	SLI group
Comprehension–mean of proportion of looks	0.74 (0.42)	0.62 (0.41)
Production–mean of proportion of looks	0.66 (0.40)	0.59 (0.35)

Note: The data are represented as means of proportions (standard deviation).

Table VI

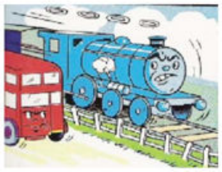
Percentage of complete statements, syntactic errors and semantic errors (percentages over the number of the scenes).

	Control age group	SLI group	Significant difference
Complete statements	90.85 (13.97)	61.36 (28.50)	$p < 0.05$
Syntactic errors	16.92 (10.68)	42.81 (27.66)	$p < 0.05$
Semantic errors	7.70 (10.34)	24.68 (21.98)	$p < 0.05$

Note: The data are represented as means of percentages (standard deviation).

Table VII

Examples of syntactic and semantic errors committed in retelling the story by children with SLI.

	Omission of determinant: ‘està fent carrera amb(el/un)tren’[he’s racing with (the/a) train]
	Omission of preposition: ‘iva passar(per)un túnel’. [and he went (through) a tunnel]
	Semantic substitution: ‘ese“talaycia”(policia) y para atren’[that‘taliceman’ (policeman) and stop the train] (substitution of bus by train).