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The formulation of argument structure in SLI: an eye-movement study

LLORENÇ ANDREU[1], MÒNICA SANZ-TORRENT[2], JOAN GUÀRDIA OLMOS[3] & BRIAN MACWHINNEY[4]

[1]*Cognitive Neuroscience and Information Technologies Research Program, IN3, Universitat Oberta de Catalunya, Barcelona, Catalunya,* [2]*Departament de Psicologia Bàsica, Universitat de Barcelona, Barcelona, Catalunya,* [3]*Departament de Metodologia de les Ciències del Comportament, Universitat de Barcelona, Barcelona, Catalunya, and* [4]*Department of Psychology, Carnegie Mellon University, Pittsburgh, PA, USA*

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Abstract
This study investigated the formulation of verb argument structure in Catalan- and Spanish-speaking children with specific language impairment (SLI) and typically developing age-matched controls. We compared how language production can be guided by conceptual factors, such as the organization of the entities participating in an event and knowledge regarding argument structure. Eleven children with SLI (aged 3;8 to 6;6) and eleven control children participated in an eye-tracking experiment in which participants had to describe events with different argument structure in the presence of visual scenes. Picture descriptions, latency time and eye movements were recorded and analyzed. The picture description results showed that the percentage of responses in which children with SLI substituted a non-target verb for the target verb was significantly different from that for the control group. Children with SLI made more omissions of obligatory arguments, especially of themes, as the verb argument complexity increased. Moreover, when the number of arguments of the verb increased, the children took more time to begin their descriptions, but no differences between groups were found. For verb type latency, all children were significantly faster to start describing one-argument events than two- and three-argument events. No differences in latency time were found between two- and three-argument events. There were no significant differences between the groups. Eye-movement showed that children with SLI looked less at the event zone than the age-matched controls during the first two seconds. These differences between the groups were significant for three-argument verbs, and only marginally significant for one- and two-argument verbs. Children with SLI also spent significantly less time looking at the theme zones than their age-matched controls. We suggest that both processing limitations and deficits in the semantic representation of verbs may play a role in these difficulties.

Keywords: *language development*, *specific language impairment*, *eye movements*, *language production*, *verb and argument structure*

Correspondence: Mònica Sanz-Torrent, Departament de Psicologia Bàsica, Universitat de Barcelona, Barcelona, Vall d'Hebrón 171, 08035 Barcelona, Spain. Tel: +34 933125150. Fax: +34 934021363. E-mail: monicasanz@ub.edu

Introduction

Within linguistic theory, argument structure is a construct that specifies the relation between the semantics of a lexical item and its syntactic expression (Grimshaw, 2005; Jackendoff, 2002; Levin & Rappaport, 1995). The argument structure of a verb specifies the number and type of possible semantic arguments (often referred to as thematic roles) and determines how these arguments should be expressed syntactically. Jackendoff (2002) notes that argument structure is particularly important in determining the syntactic properties of verbs. Each verb specifies a particular number of arguments, and determines which of these arguments must be obligatorily expressed. For example, the verb *shoot* must have two arguments. In the sentence *The hunter shot the rabbit* – the agent is *the hunter* who executes the action and the patient is *the rabbit* who is affected by the action. In contrast, the verb *give* has three arguments – an agent, a theme and a recipient. Arguments can be obligatory or optional. The number and types of arguments required or allowed are determined by the verb's meaning (Thordardottir & Ellis Weismer, 2002) and this meaning then determines its syntactic argument structure (Levelt, Roelofs, & Meyer, 1999; McRae, Ferretti, & Amyote, 1997; Pickering & Branigan, 1998; Roelofs, 1993). The semantics of arguments are often constrained by the detailed semantics of the verb. For example, we can drink coffee or juice, but we cannot drink wood.

During sentence comprehension, constraints deriving from verb argument structure can help listeners anticipate the shape of incoming information (Altmann & Steedman, 1988; MacDonald, Pearlmutter, & Seidenberg, 1994) and guide sentence comprehension in general (Boland, Tanenhaus, & Garnsey, 1990; Boland, Tanenhaus, Garnsey, & Carlson, 1995; Ferreira & McClure, 1997; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Konieczny, Hemforth, Scheepers, & Strube, 1997; Trueswell, Tanenhaus, & Garnsey, 1994; Trueswell, Tanenhaus, & Kello, 1993). During production, constraints deriving from verb argument structure can guide the speaker to produce a sentence that contains all the obligatory constituents for a particular verb in a particular context. If young language learners do not have a complete knowledge of the semantics of the verb, they may produce a variety of errors in terms of omission of obligatory arguments and substitution of incorrect arguments (Bowerman & Brown, 2007; Gropen, Pinker, Hollander, & Goldberg, 1991).

There is evidence that children with specific language impairment (SLI) have problems with verb morphology and semantics (Aguilar, Sanz-Torrent, & Serra, 2007; Bishop, 1997; Conti-Ramsden & Jones, 1997; Paradis & Crago, 2001; Sanz-Torrent, Serrat, Andreu, & Serra, 2008; Verhoeven & Van Balkom, 2004). Various studies (Grela & Leonard, 1997; de Jong, 1999; Loeb & Leonard, 1988; Schelletter, Sinka, Fletcher, & Ingham, 1999) have indicated that children with SLI have difficulties utilizing verb argument structure. A recent study of Catalan and Spanish children with SLI (Sanz-Torrent, Andreu, Badia, & Sidera, 2011) showed that Catalan- and Spanish-speaking children with SLI have special difficulties in producing verbs with a highly complex argument structure and make more mistakes in specifying obligatory arguments.

There are two major types of accounts for these problems. The first type of account (Eyer & Leonard, 1995; Gopnik, 1990, Gopnik & Crago, 1991; Ingram & Carr, 1994; Van der Lely, 1994) attributes these problems to deficits in either syntactic or semantic representations. A study by Thordardottir & Ellis Weismer (2002) provided evidence for the presence of deficits in syntactic representations. They analyzed speech samples from 50 children with SLI and observed that these children used significantly fewer argument types, fewer argument structure types and fewer verb alternations than age-matched normally developing children. It is also possible that the representational deficit found in children with SLI may involve not syntactic structure, but semantic structure. This hypothesis is based on the idea that the quality of semantic knowledge represented in children's lexicon makes words more or less vulnerable to retrieval failure. Children with SLI exhibit slower lexical processing and more naming errors, as compared with their peers, in picture naming

(Andreu, Sanz-Torrent, Buil, & MacWhinney, 2012; Lahey & Edwards, 1996; Leonard, Nippold, Kail, & Hale, 1983) and word recognition (Edwards & Lahey, 1996). Moreover, they show slower mean latencies and lower accuracy rates than controls in auditory verb recognition (Royle, Jarema, & Kehayia, 2002), as a result of impoverished semantic representations (Capone & McGregor, 2005; McGregor & Appel, 2002; McGregor, Newman, Reilly, & Capone; 2002; Sabisch, Hahne, Glass, von Suchodoletz, & Friederici, 2006). For example, McGregor et al. (2002) demonstrated an impoverished semantic representation in the child's lexicon in three tasks (naming, drawing and defining) and argued that limited semantic knowledge contributes to the frequent naming errors of children with SLI.

The second type of account attributes deficits in SLI children to processing limitations (Ellis Weismer, Evans, & Hesketh, 1999; Leonard, 1998; Miller, Kail, Leonard, & Tomblin, 2001; Montgomery, 2000a, 2000b). 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 (Ellis Weismer et al., 1999; Montgomery, 1996, 2000a, 2000b, 2003, 2006; Montgomery & Evans, 2009). These limitations can involve either slower processing, as seen in increased latency in picture naming (Lahey & Edwards, 1996; Leonard et al., 1983) or reduced capacity, as reflected in reduced ability to deal with words/sentences of increased complexity (for example, capacity limitations can produce increased levels of word omission, when there are increases in sentence complexity). In support of this account, several studies have emphasized that children with SLI are slower in the amount of work that can be accomplished in a given unit of time. In particular, they are slower than typically developing children on simple picture naming tasks (Katz, Curtiss, & Tallal, 1992; Lahey & Edwards, 1996; Leonard et al., 1983). Oetting (1999) found that children with SLI could use argument structure cues to process novel verbs in a story viewing task, but were unable to retain this information across trials. Grela (2003) analyzed the omission of subject arguments in children with SLI. The participants were asked to produce sentences of varied argument-structure complexity using a story completion task. The results indicated that both the children with SLI and their mean length of utterance (MLU)-matched controls omitted more subject arguments in the ditransitive sentences than in sentences with intransitive and transitive verbs. In addition, children with SLI omitted more subject arguments as linguistic complexity increased. This effect was not found for the age-matched control children who never omitted subjects, regardless of increases in argument-structure complexity. Grela argued that these results supported the notion that grammatical errors in children with SLI and their MLU-matched controls may be due to problems with processing complex linguistic information, rather than with limitations in linguistic representations. Similarly, Pizzioli and Schelstraete (2008) studied the effect of argument-structure complexity in French children with SLI. They showed that more complex argument structures elicited the highest number of grammatical morpheme omissions and that this effect was independent of sentence length. The authors suggested these data support the hypothesis that the grammatical morpheme deficit in SLI is caused by limited processing capacities.

These various studies have provided evidence that difficulties in argument structure control in SLI are linked to both representational and processing difficulties. At this point, we need to explore in greater detail the specific mechanics of the processes involved in order to determine which of these barriers are operative in particular cases. To do this, we will use the visual world paradigm (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), which tracks eye movements to understand the detailed incremental nature of language processing. This task relies on the fact that people tend to look at the referents of the words they are listening to (Cooper, 1974). The paradigm has been applied to the study of word recognition (Allopena, Magnuson, & Tanenhaus, 1998; Dahan, Magnuson, & Tanenhaus, 2001), lexical and syntactic ambiguity resolution (Dahan & Tanenhaus, 2004; Spivey, Tanenhaus, Eberhard, & Sedivy, 2002; Trueswell, Sekerina, Hill, & Logrip, 1999), and language comprehension (Altman & Kamide, 1999; Arnold, Eisenband, Brown-Schmidt, & Trueswell, 2000; Kamide, Altmann, & Haywood, 2003).

Studies of language production using this paradigm have often looked at the production of short phrases or lists of objects (Belke & Meyer, 2002; Meyer, Sleiderink, & Levelt, 1998; Van der Meulen, 2001, 2003). However, we are more interested here in those studies that have used this method to study the production of entire utterances with verbs. In this regard, a study by Griffin and Bock (2000) is of particular interest. These authors studied eye movements in tasks that involved describing events in pictures. In this picture description task, they found that 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 in a picture of the African savannah, as they begin to say *the zebra runs away*). In the first 300 ms, speakers focus on understanding the action and identifying the agent and the patient. Gleitman, January, Nappa, and Trueswell (2007) demonstrated that the first glance at the represented object influences the participants' form of production. In addition, the objects that are focused on during this first glance tend to be grammaticalized as the subjects of the sentence. The influence of first glances varies according to the type of stimulus and the task that is to be carried out. Bock (2004) stated that the elements that are taken as a starting point (MacWhinney, 1977) are not the most prominent aspects of a scene. Instead, they are the elements that could lead to a predication. Similarly, eye position may not be related to the choice of order, but to the result of a more general semantic analysis of the scene. In other words, the eye does not look at the most significant element of the scene. Instead it gazes at the element that is the easiest to use to start the sentence (Bock, Irwin, Davidson, & Levelt, 2003; Griffin & Bock, 2000). Griffin and Bock (2000) argued that sentence formulation takes 1600 ms after the onset of the pictures before articulation began.

Based on this research, we hypothesize that the knowledge of a verb's semantics and its argument structure can play an important role in how we describe information in the visual world. In order to describe an event, people must scan the visual scene to extract information to construct a sequential linguistic formulation. If the semantics of a verb are accurate, when children activate a verb, they will also activate its accompanying arguments. This activation then guides the selection of additional visual information needed to fully describe the event. In other words, knowledge of the argument structure of a verb may be a determining factor in guiding attention (Boland, 2005). If the semantics of a verb are accurate, children will be able to select visual zones corresponding to each obligatory argument. If children have a poor representation of verb semantics, they will be less accurate in selecting appropriate zones for eye fixation during this planning phase. So they will show less proportion of looks to the relevant areas of the event. If they are inaccurate in directing their gaze, the information they extract will be less complete and the resulting syntactic production will also be less accurate. Moreover, the incomplete semantic representations approach predicts that latency time and errors in children with SLI depend not so much on the number of arguments of the verb, but rather on the precision of the semantic representation that these children have for each particular verb.

In contrast, the processing limitations approach predicts that children with SLI ought to be slower than age-matched controls. According to this account, complex linguistic operations such as the formulation of complex sentences may overwhelm the system's capacity, resulting in competition for resources between different stages of language processing and thus generating a computational trade-off that would benefit early stages of language processing and burden later ones. Then, although children with SLI will be able to select the more important visual zones of the event, they will take more time looking at them. As a result, children with SLI will take more time for sentence planning and this slowness will increase as the argument complexity increases. Moreover, we can expect the verb argument omissions to be higher when the number of arguments of the event increases.

Method

Participants

The sample included 22 children who were bilingual in Catalan and Spanish[1] (11 children with SLI and 11 age-matched controls) with a mean age of 63.30 months (SD = 10.91) and age range 3;8 and 6;6 years. Although this age range is quite large, this is very common in the studies carried out on children with SLI. The prevalence of this disorder – about 7% of the population in English speakers (Tomblin et al., 1997) – is the main reason for the use of this range. Although the linguistic development that takes place between these ages is quite significant, the task used in this study (i.e. describe simple events) is as suitable for the youngest children as for the oldest ones. The sample was selected in accord with established criteria for diagnosing of children with SLI (Leonard, 1998; Stark & Tallal, 1981; Watkins, 1994). SLI is defined as a developmental language disorder in the absence of clear neurological, sensorimotor, non-verbal cognitive or social emotional deficits that can affect both expressive and receptive language. Children with SLI are characterized by developmental delays in verbal abilities that are not accompanied by non-verbal cognitive deficits (Bishop, 1997; Leonard, 1998). To ensure that these criteria were met, we assessed the children's intelligence and level of language development. Cognitive ability was tested with the Wechsler Intelligence Scale for Children (WISC-R; Spanish version; Wechsler, Cordero, & de la Cruz, 1993). Each of the children obtained a standard score above 85. For this group, the mean non-verbal intelligence quotient (IQ) was 103.3 (SD = 8.5, range = 86–115).

Following the established Spanish/Catalan protocol for the evaluation of language delay (Anàlisi del Retard del Llenguatge, AREL, Pérez & Serra, 1998), the children's language ability was assessed with the Spanish version of the Peabody Picture Vocabulary Test III (PPVT-III, Dunn, Dunn, & Arribas, 2006) and the Avaluació del Llenguatge Infantil (ELI, Saborit & Julián, 2005) for children younger than 6 years. The ELI scale includes several subtests for phonetics, lexical reception, lexical production and pragmatics. The children with SLI had scores of at least a −1.25 standard deviation below the mean, on both the PPVT-III and the ELI. Language profiles based on transcripts of spontaneous conversations provided further information about the characteristics of the language production of the children. Based on these transcripts, we calculated the MLU in words of the two groups. Children with SLI showed 3.89 (SD = 1.39) mean words for production and control age 6.86 (SD = 1.76). Moreover, children with SLI produced significantly more morphosyntactic and semantic errors such as omissions of auxiliary verbs and verb markers (person, number and tense), and semantic substitutions (*train* for *bus*). These analyses showed that these children had a delay of at least 1 year (see Bishop, 1997) in language production.

The children with SLI also received a test for auditory attention, overall discrimination, recognition of sound stimuli (background sounds, sound qualities, etc.), phoneme discrimination, phoneme recognition within words, phoneme order discrimination and word pair discrimination. For Spanish, we used the Análisis del Retraso del Habla (AREHA, Aguilar & Serra, 2003); for Catalan, we used the Anàlisi del Retard del Llenguatge (AREPA, Aguilar & Serra, 2005). Based on these tests, all of the children had age-appropriate phonemic processing abilities. Children also passed a hearing screening test at 25 dB for each ear at 500, 1000, 2000 and 4000 Hz.

School psychologists examined the case histories of all the children for any evidence of seizures, cerebral palsy or brain damage. With respect to oral structure and motor functions, speech therapists examined the children to assess the shape, size and motor functions 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 the mobility was normal.

With respect to physical and social interactions, the school psychologists drew up a report containing information about each child's family background and aspects of his/her personality such as self-esteem, sense of self confidence, confidence in others, level of socialization, social abilities and degree of anxiety. This information was used to verify that the child had no symptoms of impaired reciprocal social interaction or any restriction of activities. In addition, the children selected for the study had been diagnosed with SLI by the School Educational Psychology Service (Servei Psicoepdagògic Escolar, SPE) of Castelló C-04 and by the Center for Educational Recourses for Hearing Impairments (Centres de Recursos per a Deficients Auditius, CREDA) Narcís Masó of Girona and were receiving speech and language intervention.

The control group was paired in age, sex and language dominance to their matches in the SLI group. The sample was selected from the classmates of each child with SLI. Teachers were asked to verify that the control subjects' language development was normal for their age. Children were not selected for the control group if they had a history of speech therapy or psychological therapy. In addition, teachers were asked to select children with normal academic performance. Their intelligence were tested and the mean non-verbal IQ was $M = 106.2$, SD = 5.9, range = 99–114. Moreover, language ability was assessed by use of the Spanish version of the PPVT-III (Dunn et al., 2006) and a language profile based on transcripts of 15 min of spontaneous conversations. Children were excluded from the sample when their test-equivalent age on the PPVT-III was either 6 months lower or 6 months higher than their chronological age or when speech problems were higher than expected for their age, as assessed on language profiles. All of the children selected came from state schools in Catalonia and Valencia. A summary of descriptive data for the two groups of children is presented in Table I.

Stimuli

The stimuli included 39 verbs (13 one-argument, 13 two-argument and 13 three-argument verbs). The verbs were chosen to be equivalent in Spanish and Catalan. All the target verbs had similar imageability from published rating norms (Valle-Arroyo, 1999) and had high and similar frequency in

Table I. Characteristics of the specific language impairment group and the control group.

	SLI group		Control age group	
	6 females, 5 males		6 females, 5 males	
Gender	Mean	SD	Mean	SD
Age	63.3	10.91	66.36	12.32
PPVT-III	78.2	7.28	112.07	14.37
NVIQ	103.3	8.5	106.2	5.9
ELI-phonetics*	6.37	4.27	2.12	2.23
ELI-receptive vocabulary*	36.27	18.84	73.07	17.97
ELI-expressive vocabulary*	8.62	1.8	60.38	15.06
ELI-pragmatics*	53.64	25.99	80.38	15.60

Notes: Chronological age is given in months; SD, standard deviation; NVIQ is the WISC-R non-verbal IQ; PPVT-III is the Peabody Picture Vocabulary Test III. Spanish version. The ELI-phonetics score is the mean number of errors; the ELI-receptive vocabulary. ELI-expressive vocabulary and ELI-pragmatics are all percentile scores.
*Values only calculated with the children younger than 6 years old.

Figure 1. Examples of images of events with one (to run), two (to hear) and three arguments (to tie).

the two languages as assessed in the LEXESP corpus (Sebastián, Martí, Carreiras, & Cuetos, 2000) of written Spanish and with "Diccionari de frequencies" (Rafel, 1996) of written Catalan. Moreover, all the verbs had the same argument structure both in Spanish and Catalan. We also made sure that the stimuli were age-appropriate for the children. All verbs had similar ages of acquisition, as assessed in the Serra-Solé corpus (Serra, Serrat, Solé, Bel, & Aparici, 2000). This was determined by using the FREQ program (MacWhinney, 2000) to find the frequency of each target word in the Serra-Solé corpus of transcripts of 10 children recorded monthly from 12 to 48 months.

Forty-six simple color drawings were created to depict each event. They included 39 images for the experimental picture and 7 filler images. Figure 1 presents examples of events that have one, two and three arguments. Fillers were designed as complex scenes with undefined events. All 39 images were appropriate for children, had the same style and colors and were located in the center of the screen with the background in white. The experimental verbs and target sentences are given in the Appendix.

To determine how well the images depicted the intended action, a group of 32 adults rated the appropriateness of each word for the corresponding picture. This was done for each item by showing the picture with the word printed next to it in the infinitive form. Participants then answered the following question: On a scale from 1 to 7 how good is this as a one-word name for this picture? Label appropriateness did not differ significantly among the three verb classes.

Procedure and design

Participants sat at a distance of 22″ away from a 15″ monitor, set to 1280×800 pixels, with a refresh rate of 75 Hz. The images occupied the center of the screen. 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 min, the eye tracker was calibrated and children carried out a short exercise involving visual exploration of a scene of animals. The test stage consisted of the presentation of the 39 test images (plus 7 filler images) in the same order to all of the participants. The images were placed in a random order to avoid breaking up sequences of trials with the same number of arguments. Each image was presented to the subjects for 10 s. After each trial, participants were asked to fixate for 2000 ms on a crosshair at the center of the screen, so that the direction of gaze on each trial would start from the same point.

The children were instructed to "tell us what is happening here". The exposure duration time was the same for all of the children. The total length of the experiment (pre-test and test stages) was approximately 30 min. To facilitate communication, children with SLI were always accompanied during the experiment by their regular speech and language therapist and children with typical language development with their teacher.

An Iriscom QuickGlance 2SH eye-tracker from Eyetech Digital Systems was used to collect and store eye-tracking data, which consisted of participants' eye position sampled at 25 Hz (40 ms

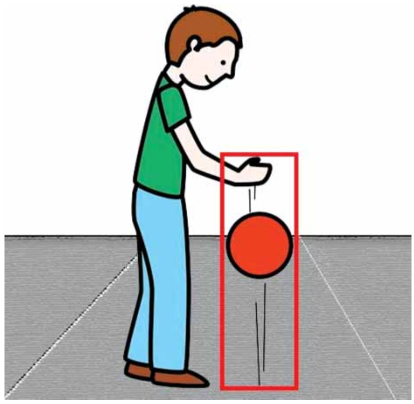

Figure 2. Example of the nucleus of the event zone for the verb *bounce* (The boy bounces the ball).

intervals). A chinrest was used to ensure a constant distance between subjects and the apparatus. The children's productions were recorded on audio and video and transcribed.

Coding and analyses

We analyzed both speech and eye-movement data. A trained transcriber created transcripts from the videotapes, using the CHAT format of the CHILDES project (MacWhinney, 2000). The transcriptions were reviewed by the second author and compared with the recordings. Any discrepancies were discussed at weekly meetings by the members of the GRECIL research team during the transcription phase. This same procedure was then repeated during the coding phase. Only intelligible sentences were analyzed. Interjections, stereotypes and unintelligible productions were excluded. The transcribed productions were categorized as conceptually correct or incorrect without regard to possible grammatical errors. We calculated argument omission scores as the number of times that the argument category was produced divided by the number of times it was required. Moreover, using a digital sound editor, we calculated latencies as the time from the start of the presentation of the target image display to the onset of the production. Latencies were only calculated for correct responses. The time spent in false starts and pre-response vocalizations (e.g. *eeh*, *mm*) was excluded.

For the eye-movement data, the horizontal and vertical eye position coordinates obtained from the QuickGlance 2SH Software were used to assess gaze fixation. For each picture, we selected a specific region of interest that we called the event zone (see Figure 2). This was defined as the

Figure 3. Examples of argument zones for the sentence *El niño regala un regalo a la niña/El nen regala un regal a la nena* [The boy gives a present to the girl].

zone where the main action was carried out. The determination of the nucleus of each image was based on judgments from eight language experts in the Department of Basic Psychology, University of Barcelona. Working alone, each judge marked in a printed image of each stimulus the zone where he/she considered the main action was carried out. We then selected those zones that the majority of the judges considered important. Within these zones, we selected the most restrictive zone of intersection of judgments. Disagreements were resolved by discussion between the judges and the first and the second author.

To analyze visual exploration linked to the arguments of the verb, we delineated agent, theme and recipient zones depending on whether the event was a one-, two- or three-argument verb (see Figure 3).

A value of one was given to each eye-tracking sample that fell within a specified region of interest (event, agent, theme or recipient zones); otherwise it was given a value of zero. Using these data, we then calculated the proportion of gazes and the percentage of total time devoted to every zone.

As in Trueswell et al. (1999), we rejected trials on which there was more than 33% loss of eye position data. The mean percent of tracking loss for the age-control group was 8.48%, which led to the dropping of only 11 trials. The SLI group had an 8.32% level of tracking loss, resulting in only 15 trials being dropped. Thus, both groups showed similar values in terms of track loss, and only a small number of trials had to be dropped.

Results

Speech data

We recorded the percentage of correct responses across conditions and groups. Responses were judged as correct, regardless of any grammatical errors, as long as the children used the target verb or a verb synonymous with the target and with the same argument structure. For example, synonyms, such as *launch* for *throw*, were coded as correct responses. Figure 4 shows the percentage of verb omissions, target verb productions and non-target verb productions.

The children with SLI responded in a way that was often not in keeping with the target verb. They produced significantly more non-target verbs (Mann–Whitney = 62.56, $p < 0.05$). Children with SLI produced fewer target verbs than children with typical language; however, this difference just fell short of statistical significance (Mann–Whitney = 12.33, $p < 0.06$). Here are some examples of responses made by children with SLI:

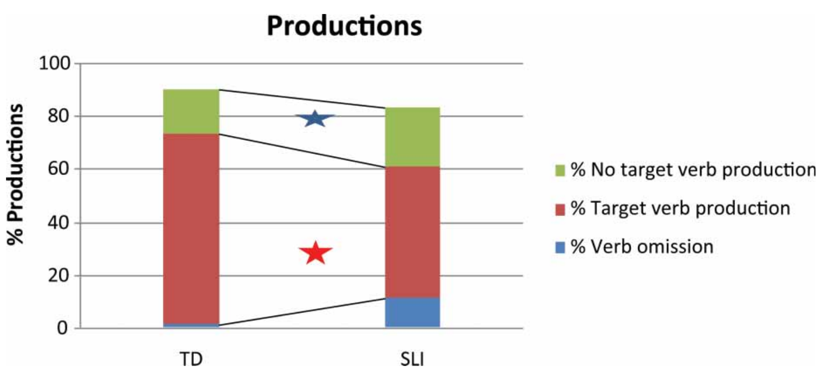

Figure 4. Percentages of verb omission, target verb production and non-target verb production.
Note: Asterisk in blue: $p < 0.05$; Asterix in red: $p < 0.06$.

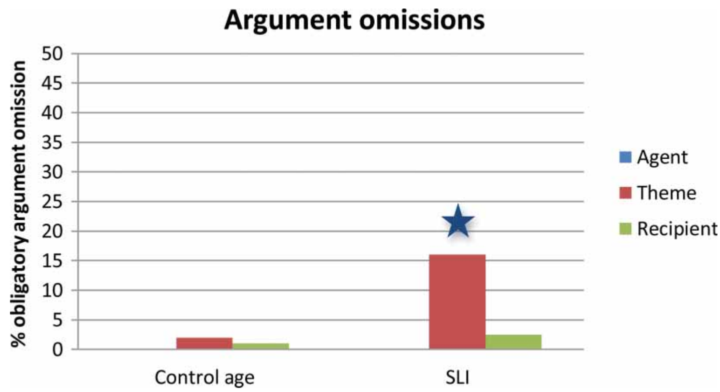

Figure 5. Percentage of utterances with argument omission.
Note: Asterisk in blue: significant differences $p < 0.05$.

- Non-target verb production: *El perro coge la pelota* [The dog catches the ball] instead of *El hombre lanza una pelota al perro* [The man throws a ball to the dog] or *El perro muerde* [The dog bites] instead of *El perro ladra* [The dog barks].
- Verb omission: *Un regal* [A present] instead of *El niño regala un regalo a la niña* [The boy gives a present to the girl].

Children with SLI also made more omissions of obligatory arguments, especially for theme, Mann–Whitney = 6.43, $p < 0.05$ (Figure 5). In both Spanish and Catalan, the omission of subjects is not a grammatical error, but an optional syntactic process. Because of this, it is not meaningful to talk about agent omission as an error. For example, some children with SLI, when describing the event depicted in Figure 2 (*The boy gives a present to the girl*), say (*Da un regalo a la niña/ Dóna un regal a la nena* [Gives a present to the girl]) or simply *Da un regalo/Dóna un regal* [Gives a present].

Moreover, we also analyzed the differences in argument omissions according to verb complexity. Figure 6 shows the data displayed for each verb type. In particular, the SLI group's responses differed from those of the control group in events with two or three arguments ($p < 0.05$).

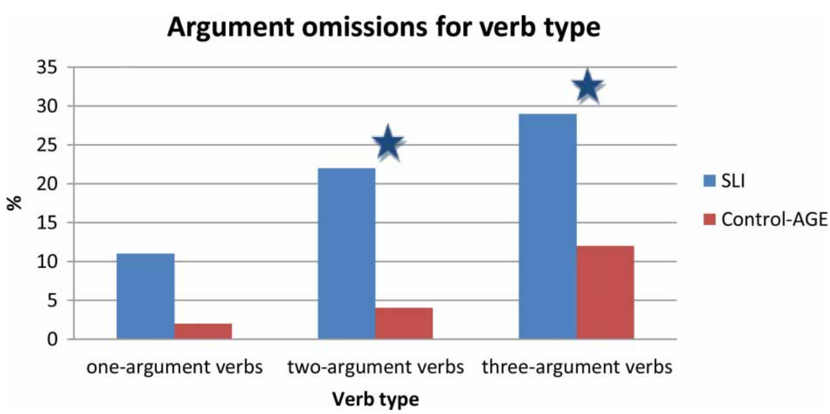

Figure 6. Percentage of utterances with argument omission.
Note: Asterisk in blue: significant differences $p < 0.05$.

Table II. Mean times for speech onset.

	All events together	One argument	Two argument	Three argument
Control age	1912.39 (225.02)	1624.82 (221.49)	1984.80 (305.89)	2127.54 (283.04)
SLI	2317.41 (740.99)	2049.71 (580.55)	2353.95 (843.10)	2548.58 (1170.85)

Notes: The data are mean times in milliseconds. In parentheses: standard deviation.

Using a digital sound editor, we calculated the response latencies from the start of the presentation of the target image to the onset of sentence production. The time spent in false starts and pre-response vocalizations (e.g. *eeh*, *mm*) was excluded, so that the response was considered to begin with the word that actually described the picture. Table II shows the mean times for speech onset for control children and children with SLI for the three verb types. An ANOVA with the factors of group (control and SLI) and verb type (one, two or three arguments) revealed significant main effects for verb type [$F(2,19) = 11{,}508$; $p < 0.01$; $\eta^2 = 0.548$]. Paired comparisons for verbs showed that all children were significantly faster to start speaking in one-argument events than in two- and three-argument events. No differences in latency time were found between two- and three- argument events. There were no significant differences in group, $F(1,20) = 2.586$; $p =$ 0.123 ($\eta^2 = 0.115$), and no interaction effect between group and verb type, $F(2,19) = 0.044$; $p =$ 0.957 ($\eta^2 = 0.056$).

Eye movements

The language production results showed that children with SLI substituted a non-target verb for the target verb significantly more than did the age-matched control group. This suggests that children with SLI might have problems selecting the relevant zone of an event needed to identify the main action. Based on the finding from Griffin and Bock (2000) that adult speakers take around 1600 ms after picture onset to begin articulation, we reasoned that, with child subjects, we should use a window of 2000 ms to study this process. We analyzed the proportion of gazes to the target zone during this two-second window using hierarchical (multilevel) linear models. The models were provided with crossed random intercepts for the factors of group and argument number (see Baayen, Davidson, & Bates, 2008). Prior to entering the data into the models, the gaze time proportions were transformed using an empirical logit function (see Barr, 2008). The mean proportions of gazes during the first two seconds are given in Table III. It can be seen in that table that children with SLI spent less time gazing at the event zone for all three types of verbs.

Figure 7 plots the proportion of gazes to the event zone over time for all event types together. Figure 8 plots this separately for one-, two- and three-argument events. These proportions were

Table III. Mean of proportion of gazes to the event zone 0–2000 ms after image onset.

	Group	Mean	Standard deviation
One-argument events	SLI	0.3752	0.1437
	Control age	0.4483	0.1713
Two-argument events	SLI	0.1876	0.0928
	Control age	0.2226	0.0604
Three-argument events	SLI	0.1816	0.0569
	Control age	0.2488	0.0347

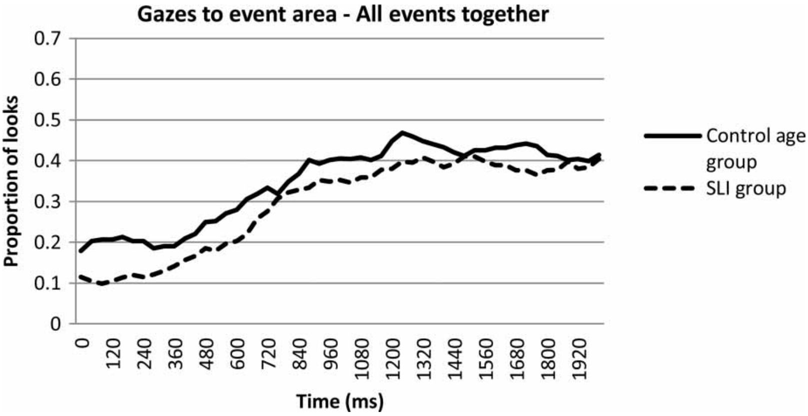

Figure 7. Proportion of gazes to the event zone for all event types together.

obtained by determining the proportion of gazes to the event zone at a given time slice (40 ms) for every participant and image to show how gaze patterns change over time.

The effect of argument number (1, 2 and 3) was highly significant, $F_{(2,97)} = 414.518$; $p < 0.001$ ($\varepsilon^2 = 0.895$). The effect of group (SLI *vs.* control) was also highly significant, $F_{(1,98)} = 10.357$; $p < 0.002$ ($\varepsilon^2 = 0.095$). Finally, the interaction between group and argument number was also highly significant, $F_{(2,97)} = 17.931$; $p < 0.001$ ($\varepsilon^2 = 0.270$) with a moderate effect size. Figures 7 and 8 show the effect of statistically significant main effects and interaction. The differences between the groups were significant for three-argument verbs; however, this difference just fell short of statistical significance for one- and two-argument verbs.

The language production results showed that the children with SLI made more omissions of obligatory arguments, especially for theme. To further explore this issue, we examined looking times at the various argument zones across the whole period of sentence production. Specifically, we selected the proportion of gazes during the first six seconds from picture onset (that was the mean time the participants took to describe the events). We only use two- and three-argument events for the analysis because one-argument events only have the thematic role of agent and given the null-subject nature of Catalan and Spanish there is high subject elision. Again, the analysis used mixed linear models with crossed random effects on empirical logit values. The mean of proportion of gazes are given in Table IV. The factors in the analysis were Group and Argument type (thematic role). There was a main effect of zone of argument [$F_{(2,297)} = 515.388$; $p < 0.001$, $\varepsilon^2 = 0.776$] and also a main effect of Group [$F_{(1,298)} = 36.470$; $p < 0.00$, $\varepsilon^2 = 0.109$]. Figure 9 plots the proportion of gazes to the agent and theme zones over time for two-argument verbs and Figure 10 shows the proportion of gazes to agent, theme and recipient zones for three-argument verbs.

On two-argument events, all of the children preferred to look first at the agent. After looking at the agent, the control group children then looked most at the theme. However, after first looking at the agent, the children with SLI do not move on clearly to look at the theme. After 3 s, their gaze shifts without any clear preference.

On three-argument events, all the groups showed a preference for looking first at the animate entities (that represent the roles of agent and recipient). The control age group looked at the two animate entities during the first second. Then, they focused on the agent. The children with SLI, however, continued looking at both candidates for the agent role with no clear preference (Mann–Whitney = 67.45, $p < 0.05$).

Finally, we also examined the total looking time spend looking at thematic role zones during the first six seconds after image onset (Figure 11). Here, the SLI group looked especially at the agent

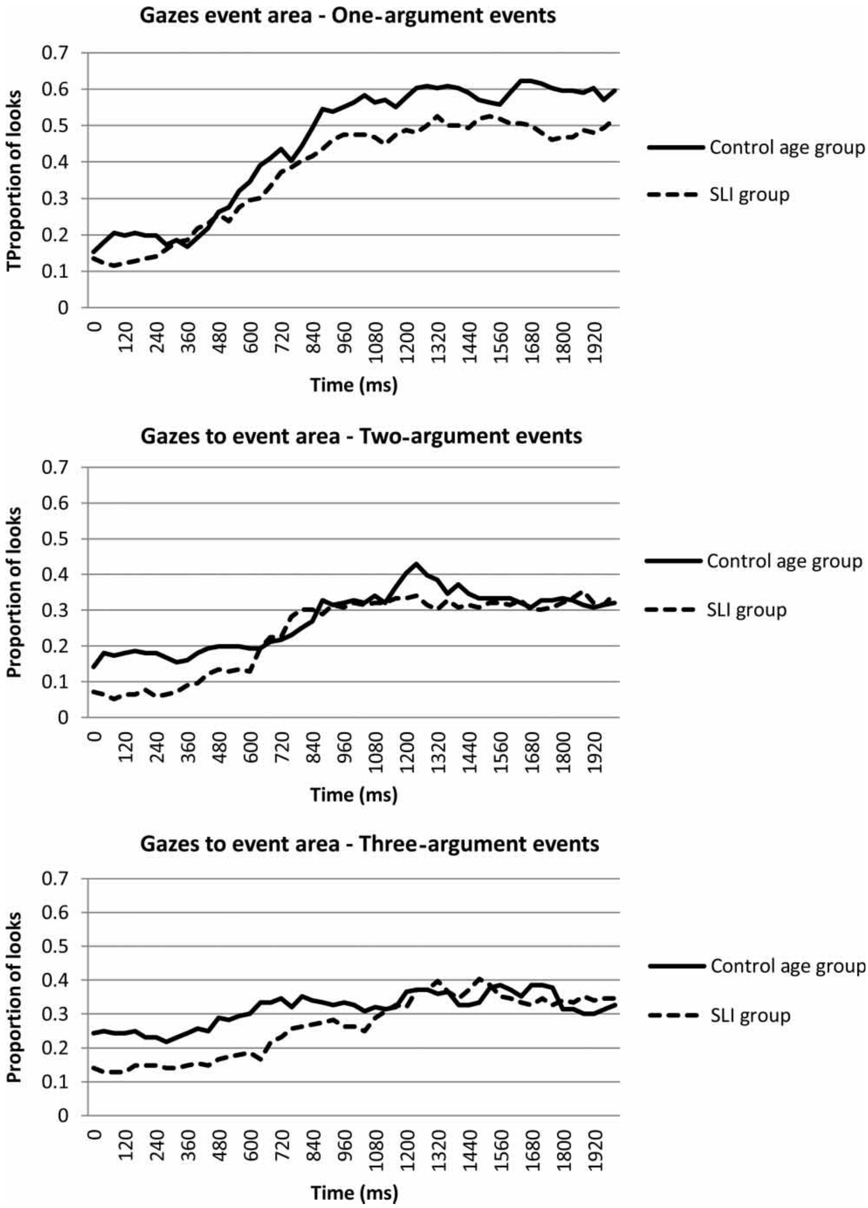

Figure 8. Proportion of gazes to the event as a function of argument number.

and the recipient and, to a lesser extent, at the theme. In comparison to the control age group, the difference in looking at the theme was significant (Mann–Whitney = 72.33, $p < 0.05$). This thematic role was also omitted significantly more by children with SLI in the language production analyses.

Discussion

The purpose of this study was to investigate the formulation of argument structure in children with SLI. To evaluate this issue, we recorded language productions and eye movements as children

Table IV. Mean of proportion of gazes to the thematic roles zones 0–6000 ms after image onset.

	Group	Mean	Standard deviation
Proportion of gazes to agent – two–argument events	SLI	0.3591	0.0759
	Control age	0.3946	0.0981
Proportion of gazes to theme – two–argument events	SLI	0.2561	0.0667
	Control age	0.3290	0.1018
Proportion of gazes to agent – three–argument events	SLI	0.2533	0.0469
	Control age	0.2980	0.0952
Proportion of gazes to theme – three–argument events	SLI	0.1515	0.0572
	Control age	0.1810	0.0638
Proportion of gazes to recipient – three-argument events	SLI	0.2603	0.0574
	Control age	0.2743	0.0672

described events with different argument structure based on visual images. Language production results showed that children with SLI substituted a non-target verb for the target verb significantly more than typically developing children. Moreover, they made more omissions of obligatory arguments, especially for theme, as the verb argument complexity increased. Results of production latency showed that all children were significantly faster to start describing one-argument events than two- and three-argument events. No differences in latency time were found between two-

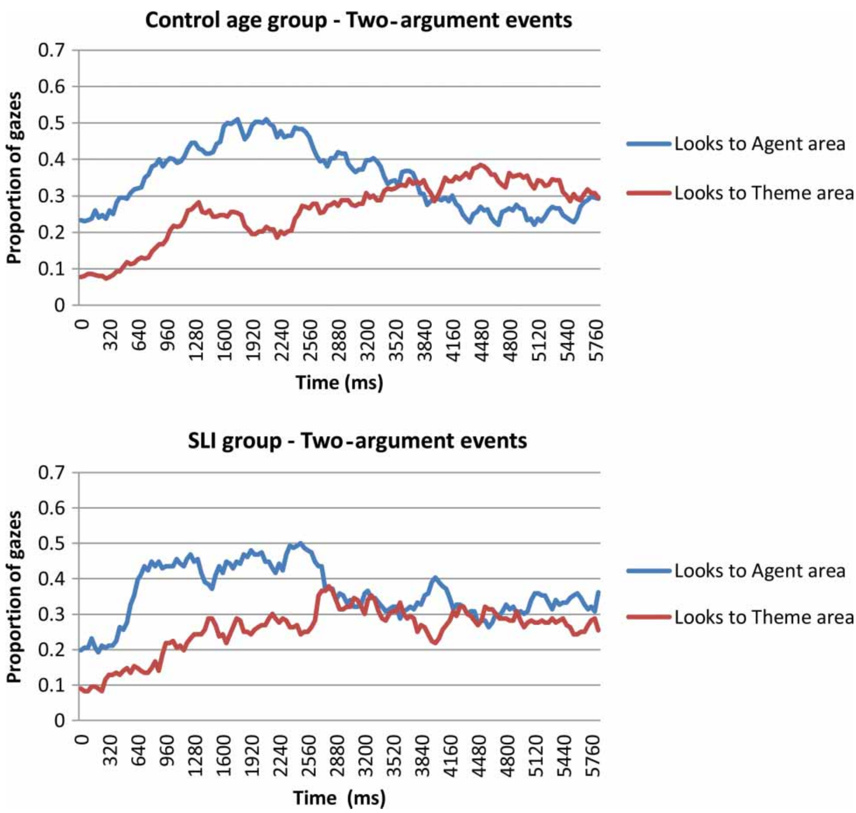

Figure 9. Proportion of gazes by time samples from picture onset for two-argument verbs.

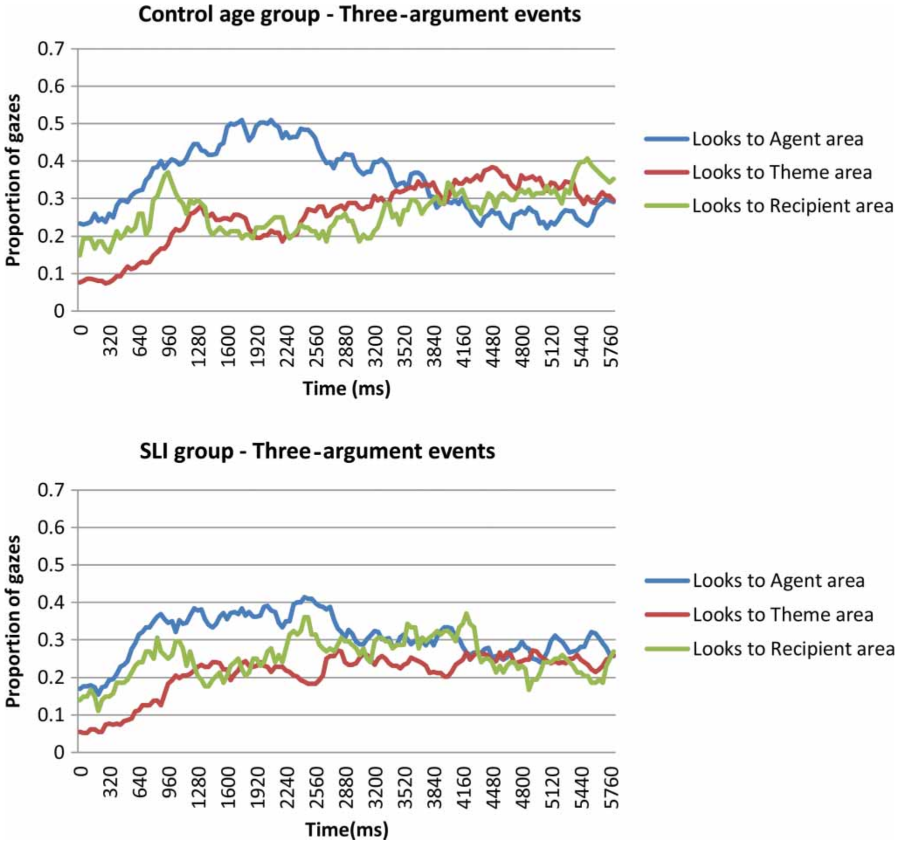

Figure 10. Proportion of gazes by samples from pictures onset for three-argument events.

and three- argument events. There were no significant differences in group. Eye-movement data showed that children with SLI looked less at the event zone than the age-matched controls during the first two seconds (when speakers focus on understanding the action and planning the sentence). These differences between the groups were significant for three-argument verbs, and only marginally

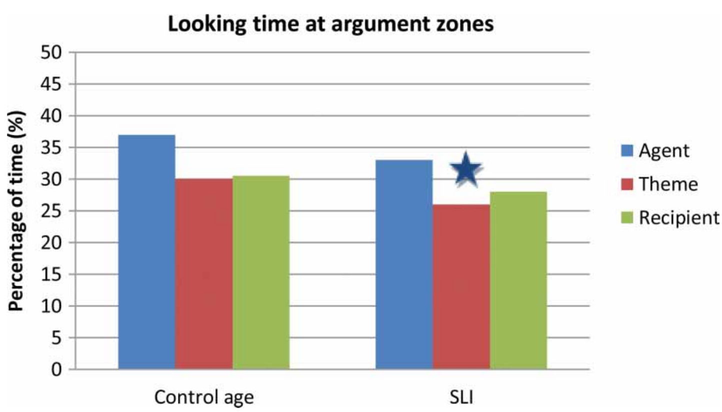

Figure 11. Percentage of looking time at obligatory argument zones.
Note: Asterisk in blue: significant differences $p < 0.05$.

significant for one- and two-argument verbs. Children with SLI also spent significantly less time looking at the theme zones than their age-matched controls.

These results show how the argument structure of the verb can guide both visual attention and sentence production. Speakers use the first few seconds to recognize the event and plan the sentence. Once an event is recognized, a specific verb is accessed along with the argument structure information needed to produce a sentence. As speakers focus their visual attention on each element just before producing specific language about it (Griffin & Bock, 2000), the knowledge of a verb's semantics and its argument structure can guide the gaze to those zones that correspond with the elements that are being lexicalized.

In this study, children with typical language development described events by identifying the verb and the arguments needed to give meaning and a unified structure to the event. However, children with SLI showed a different pattern. They spent less time gazing at focal picture zones during the planning phase. Moreover, during sentence formulation, children with SLI also spent less time looking at the argument zones. This different pattern of gazes was reflected with more problems in event description than the control group. The percentage of correct responses in the SLI group was significantly lower that in the control group. Children with SLI substituted non-target verbs for the target verb significantly more than the control age group and omitted more verbs and obligatory arguments.

In sum, eye-movement data showed that children with SLI spent less time looking at the picture zones related to the arguments (agent, theme and recipient). They differed particularly from the control group in the duration of the gazes at the theme zone which was also the argument for which they had significantly more omissions in language production. This suggests that they are not trying to encode thematic arguments and failing, instead they are often not trying to lexically encode thematic arguments at all.

We attribute the differences in visual patterns and the problems in sentence description showed by children with SLI to deficits in semantic representations in the lexicon (Capone & McGregor, 2005; McGregor & Appel, 2002; McGregor et al., 2002; Sabisch et al., 2006), as suggested by the limited linguistic representations account. In language production, the semantics of a verb play a crucial role because the activation of a verb lemma depends on the retrieval of other information necessary for sentence production. In this sense, information regarding argument structure will help children produce a sentence that contains all the obligatory constituents for that particular verb in that particular context. We suggest that children with SLI do not have a knowledge of the verb's semantics that is sufficiently clear to guide them in processing these pictures. Consequently, they looked less at the event zone and were less accurate selecting the areas that represent the arguments of the event. This was reflected in language production because children with SLI substituted more a non-target verb for the target verb and made more omissions of obligatory arguments than the control group.

In experiments involving elicited sentences, Sanz-Torrent et al. (2011) report similar patterns for Spanish–Catalin bilingual children with SLI. This type of error has also been found for other languages (Fletcher & Garman, 1988; de Jong, 1999; Schelletter et al., 1999). Pinker (1990) suggested that many argument structure errors are related to projecting verb semantics onto the syntax. The simplification of the productions (omission of arguments, elisions of subject, etc.) of the children with SLI suggests that children with SLI use a simplification strategy and have a weak pragmatic understanding of the information that has to be transmitted. Similar results have also been reported for English (Grela & Leonard, 1997).

The limited processing capacity accounts predicted that children with SLI should be slower in verbal production and comprehension than age-matched controls. Although children with SLI would be able to select the more important visual zones of the event, they would take more time planning the message and thus more time looking at relevant zones in the pictures. The eye-movement data showed that children with SLI looked less than control children at specific event zones for events with three arguments. As we suggested previously, these differences can be attributed to representational deficits. Because their representations are imprecise, children with SLI may fail to trigger quick eye movements, leaving them unsure about when and where to look during sentence planning and formulation. It is true that this effect appears most clearly for pictures with three-argument verbs that are also more complex visually. However, neither of the accounts being considered here envisions SLI as involving problems with visual processing. Thus, it seems most reasonable to view the lack of precision in picture processing as arising from a lack of guidance of visual search from a clear understanding of the semantics of the verb.

Children with SLI also made more omissions of obligatory arguments, especially of themes, as the verb argument complexity increased. This effect is consistent with the representational deficit account, but it is also consistent with the processing deficit account.

In contrast to previous research that have observed slower response time in children with SLI (Leonard et al., 2007; Montgomery, 2000a, 2000b, 2006), we did not find differences in production latency between children with SLI and their controls. However, most previous studies of sentence processing or picture naming only controlled for stimulus frequency and did not take into account other variables that determine speed and accuracy in lexical access. The fact that we controlled stimuli for imageability, frequency, age of acquisition and label appropriateness may explain these differences.

It is unlikely that a single root cause of SLI will be identified given the heterogeneity of SLI symptoms. We suggest deficits in the semantic representation of verbs may play a role in sentences production difficulties. Moreover, we suggest that processing limitations affect the ability to process complex information but not the speed of the processing this information. 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 & Deevy, 2006).

These results have important implications for clinical practice with children with SLI. The problems children with SLI have in forming sentences may stem from representational problems involving semantic representations of the verbs in these sentences. Theories of lexical representation assume that verbs encode combinatory syntactic information (e.g. the number and types of syntactic complements the verb assigns), combinatory semantic information (the number and types of semantic entities or arguments/roles) and lexical–conceptual information (we can drink coffee or juice, but we cannot drink wood). Given this, language intervention should focus on providing experiences with verbs that will help children enrich the knowledge represented in child's semantic lexicon. In this regard, Ebbels, Van der Lely, and Dockrell (2007) considered whether syntactic–semantic and semantic therapies could improve the use of verb argument structure in pupils with persistent SLI. The results showed that pupils receiving the syntactic–semantic and semantic therapies made significant progress, which was maintained at follow-up and generalized to control verbs. Both therapies improved linking of arguments to syntax, and the syntactic–semantic therapy tended to increase use of optional arguments. Pupils receiving the control therapy made no progress.

Future research should continue to explore the extent to which children with SLI evidence processing deficits or deficits in the semantic representations of verbs. Moreover, they should explore the possibility that different tasks will demonstrate differential contributions of these factors.

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Note

1. In Catalonia, it is practically impossible to analyze the use of Catalan separately from that of Spanish in small children, since they mix both languages. In view of this situation, we analyzed all the children's productions as if they came from one sole language. This would not interfere with the results, since all groups met the same conditions and all the structures analyzed were similar in both languages.

References

Aguilar, E., Sanz-Torrent, M., & Serra, M. (2007). Influence of phonology on morpho-syntax in Romance languages in children with specific language impairment (SLI). *International Journal of Language & Communication Disorders*, *42*(3), 325–347.

Aguilar, E., & Serra, M. (2003). *AREHA: Análisis del retraso del habla*. Barcelona: Editorial Universitat de Barcelona.

Aguilar, E., & Serra, M. (2005). *AREPA: Anàlisis del retard de la parla*. Barcelona: Editorial Universitat de Barcelona.

Allopena, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory and Language*, *38*, 419–439.

Altmann, G. T. M., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, *73*, 247–264.

Altmann, G. T. M., & Steedman, M. J. (1988). Interaction with context during human sentence processing. *Cognition*, *30*, 191–238.

Andreu, L., Sanz-Torrent, M., Buil, L., & MacWhinney, B. (2012). Effect of verb argument structure on picture naming in children with and without specific language impairment (SLI). *International Journal of Language & Communication Disorders*, *47*(6), 637–653.

Arnold, J. E., Eisenband, J., Brown-Schmidt, S., & Trueswell, J. C. (2000). The rapid use of gender information: Evidence of the time course of pronoun resolution from eyetracking. *Cognition*, *76*, B13–B26.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*, 390–412.

Barr, D. (2008). Analyzing "visual world" eyetracking data using multilevel logistic regression. *Journal of Memory and Language*, *59*, 457–474.

Belke, E., & Meyer, A. (2002). Tracking the time course of multidimensional stimulus discrimination: Analysis of viewing patterns and processing times during same-different decisions. *European Journal of Cognitive Psychology*, *14*, 237–266.

Bishop, D. (1997). *Uncommon understanding*. London: Psychology Press.

Bock, J. K. (2004). Psycholinguistically speaking: Some matters of meaning, marking, and morphing. In B. H. Ross (Ed.), *The psychology of learning and motivation* (Vol. 44, pp. 109–144). San Diego, CA: Elsevier.

Bock, K., Irwin, D. E., Davidson, D. J., & Levelt, W. J. M. (2003). Minding the clock. *Journal of Memory and Language*, *48*, 653–685.

Boland, J. E. (2005). Visual arguments. *Cognition*, *95*, 237–274.

Boland, J. E., Tanenhaus, M. K., & Garnsey, S. M. (1990). Evidence for the immediate use of verb control information in sentence processing. *Journal of Memory and Language*, *29*, 413–432.

Boland, J. E., Tanenhaus, M. K., Garnsey, S. M., & Carlson, G. N. (1995). Verb argument structure in parsing and interpretation: Evidence from wh-questions. *Journal of Memory and Language*, *34*, 774–806.

Bowerman, M., & Brown, P. (2007). *Crosslinguistic perspectives on argument structure: Implications for learnability*. Hillsdale, NJ: Lawrence Erlbaum.

Capone, N., & McGregor, K. K. (2005). The effect of semantic representation on toddlers' word retrieval. *Journal of Speech, Language, and Hearing Research*, *48*, 1468–1480.

Conti-Ramsden, G., & Jones, M. (1997). Verb use in specific language impairment. *Journal of Speech, Language and Hearing Research*, *40*, 1298–1313.

Cooper, R. M. (1974). The control of eye fixation by meaning of spoken language: A new methodology for the real time investigation of speech perception, memory and language processing. *Cognitive Psychology*, *6*, 84–107.

Dahan, D., Magnuson, J. S., & Tanenhaus, M. K. (2001). Time course of frequency effects in spoken-word recognition: Evidence from eye movements. *Cognitive Psychology*, *42*, 317–367.

Dahan, D., & Tanenhaus, M. K. (2004). Continuous mapping from sound to meaning in spoken-language comprehension: Immediate effects of verb-based thematic constraints. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 498–513.

Dunn, L. M., Dunn, L. M., & Arribas, D. (2006). *PPVT-III Peabody, Test de Vocabulario en Imágenes*. Madrid: TEA Ediciones.

Ebbels, S. H., Van der Lely, H. K. J., & Dockrell, J. E. (2007). Intervention for verb argument structure in children with persistent SLI: A randomized control trial. *Journal of Speech Language and Hearing Research*, *50*, 1330–1349.

Edwards, J., & Lahey, M. (1996). Auditory lexical decisions of children with specific language impairment. *Journal of Speech and Hearing Research*, *39*, 1263–1273.

Ellis Weismer, S., Evans, J., & Hesketh, L. (1999). An examination of verbal working memory capacity in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, *42*, 1249–1260.

Eyer, J., & Leonard, L. (1995). Functional categories and specific language impairment: A case study. *Language Acquisition*, *4*, 177–203.

Ferreira, F., & McClure, K. (1997). Parsing of garden-path sentences with reciprocal verbs. *Language and Cognitive Processes*, *12*, 273–306.

Fletcher, P., & Garman, M. (1988). Normal language development and language impairment: Syntax and beyond. *Clinical Linguistics & Phonetics*, *2*, 97–113.

Garnsey, S. M., Pearlmutter, N. J., Myers, E., & Lotocky, M. A. (1997). The contributions of verb bias and plausibility to the comprehension of temporarily ambiguous sentences. *Journal of Memory and Language*, *37*(1), 58–93.

Gleitman, L. R., January, D., Nappa, R., & Trueswell, J. C. (2007). On the give and take between event apprehension and utterance formulation. *Journal of Memory and Language*, *57*(4), 544–569.

Gopnik, M. (1990). Feature-blind grammar and dysphasia. *Nature*, *344*, 715.

Gopnik, M., & Crago, M. B. (1991). Familial aggregation of a developmental language disorder. *Cognition*, *39*, 1–50.

Grela, B. G. (2003). The omission of subject arguments in children with specific language impairment. *Clinical Linguistics & Phonetics*, *17*, 153–169.

Grela, B. G., & Leonard, L. B. (1997). The use of subject arguments by children with specific language impairment. *Clinical Linguistics & Phonetics*, *11*, 443–453.

Griffin, Z. M., & Bock, J. K. (2000). What the eyes say about speaking. *Psychological Science*, *11*, 274–279.

Grimshaw, J. (2005). Semantic structure and semantic content in lexical representation. In J. Grimshaw (Ed.), *Words and structure* (pp. 75–89). Stanford, CA: CSLI Publications.

Gropen, J., Pinker, S., Hollander, M., & Goldberg, R. (1991). Affectedness and direct objects: The role of lexical semantics in the acquisition of verb argument structure. In B. Levin, & S. Pinker (Eds.), *Lexical and conceptual semantics* (pp. 153–195). Oxford: Blackwell.

Ingram, D., & Carr, L. (1994). *When morphological ability exceeds syntactic ability: A case study.* Poster presented at the Annual Convention of the American Speech-Language-Hearing Association, New Orleans, LA.

Jackendoff, R. (2002). *Foundations of language: Brain, meaning, grammar, evolution.* Oxford: Oxford University Press.

de Jong, J.. (1999). *Specific language impairment in Dutch: Inflectional morphology and argument structure*. Enxchede, NL: Print Partners Ipskamp.

Kail, R. (1994). A method for studying the generalized slowing hypothesis in children with specific language impairment. *Journal of Speech and Hearing Research*, *37*, 418–421.

Kamide, Y., Altmann, G. T., & Haywood, S. L. (2003). The time-course of prediction in information in incremental sentence processing: Evidence from anticipatory eye-movements. *Journal of Memory and Language*, *49*, 133–156.

Katz, W., Curtiss, S., & Tallal, P. (1992). Rapid automatized naming and gesture by normal and language impaired children. *Brain and Language*, *43*, 623–641.

Konieczny, L., Hemforth, B., Scheepers, C., & Strube, G. (1997). The role of lexical heads in parsing: Evidence from German. *Language and Cognitive Processes*, *12*(2/3), 307–348.

Lahey, M., & Edwards, J. (1996). Why do children with specific language impairment name pictures more slowly than their peers? *Journal of Speech and Hearing Research*, *39*(5), 1081–1097.

Leonard, L. (1998). *Specific language impairment*. Cambridge, MA: MIT Press.

Leonard, L. B., & Deevy, P. (2006). Cognitive and linguistic issues in the study of children with specific language disorders. In M. Traxler, & M. Gernsbacher (Eds.), *Handbook of psycholinguistics* (2nd ed., pp. 1143–1171). Boston, MA: Elsevier.

Leonard, L., Nippold, M., Kail, R., & Hale, C. (1983). Picture naming in language-impaired children. *Journal of Speech and Hearing Research*, *26*, 609–615.

Leonard, L. B., Ellis Weismer, S., Miller, C. A., Francis, D. J., Tomblin, J. B., & Kail, R. V. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech, Language, and Hearing Research*, *50*, 408–428.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1–75.

Levin, B., & Rappaport, H. M. (1995). *Unaccusativity: At the syntax-lexical semantics interface*. Cambridge, MA: MIT Press.
Loeb, D. F., & Leonard, L. B. (1988). Specific language impairment and parameter theory. *Clinical Linguistics & Phonetics*, *2*, 317–327.
MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review*, *101*(4), 676–703.
MacWhinney, B. (1977). Starting points. *Language*, *53*, 152–168.
MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk*. Hillsdale, NJ: Lawrence Erlbaum.
McGregor, K. K., & Appel, A. (2002). On the relation between mental representation and naming in a child with specific language impairment. *Clinical Linguistics & Phonetics*, *16*, 1–20.
McGregor, K. K., Newman, R. M., Reilly, R. M., & Capone, N. C. (2002). Semantic representation and naming in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *45*, 998–1014.
McRae, K., Ferretti, T., & Amyote, L. (1997). Thematic roles as verb-specific concepts. *Language and Cognitive Processes*, *12*(2–3), 137–176.
Meyer, A. S., Sleiderink, A. M., & Levelt, W. J. M. (1998). Viewing and naming objectes: Eye movements during noun phrase production. *Cognition*, *66*, B25–B33.
Miller, C., Kail, R., Leonard, L., & Tomblin, B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *44*(2), 416–433.
Montgomery, J. (2000a). Relation of working memory to off-line and real-time sentence processing in children with specific language impairment. *Applied Psycholinguistics*, *21*, 117–148.
Montgomery, J. (2000b). Verbal working memory and sentence comprehension in children with specific language impairment. *Journal of Speech Language and Hearing Research*, *43*, 293–308.
Montgomery, J. W. (1996). Sentence comprehension and working memory in children with specific language impairment. *Topics in Language Disorders*, *17*, 19–32.
Montgomery, J. W. (2003). Working memory and comprehension in children with specific language impairment: What we know so far. *Journal of Communication Disorders*, *36*, 221–231.
Montgomery, J. W. (2006). Real-time language processing in school-age children with specific language impairment. *International Journal of Language & Communication Disorders*, *41*, 275–291.
Montgomery, J., & Evans, J. (2009). Complex sentence comprehension in children with specific language impairment: Influence of working memory. *Journal of Speech, Language, and Hearing Research*, *52*, 269–288.
Oetting, J. B. (1999). Children with SLI use argument structure cues to learn verbs. *Journal of Speech and Hearing Research*, *42*(5), 1261–1274.
Paradis, J., & Crago, M. (2001). The morphosyntax of specific language impairment in French: An extended optional default account. *Language Acquisition*, *9*(4), 269–300.
Pérez, E., & Serra, M. (1998). AREL. *Análisis del retraso del lenguaje*. Barcelona: Ariel.
Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic persistence in written language production. *Journal of Memory and Language*, *39*, 633–651.
Pinker, S. (1990). Language acquisition. In D. N. Osherson, & H. Lasnik (Eds.), *An invitation to cognitive science* (Vol. 1, pp. 107–133). Cambridge, MA: MIT Press.
Pizzioli, F., & Schelstraete, M. A. (2008). The argument-structure complexity effect in children with specific language impairment: Evidence from the use of grammatical morphemes in French. *Journal of Speech, Language, and Hearing Research*, *51*, 706–721.
Rafel, J. (1996). *Diccionari de frequencies.* Barcelona: Institut d'estudis Catalans.
Roelofs, A. (1993). Testing a non-decompositional theory of lemma retrieval in speaking: Retrieval of verbs. *Cognition*, *47*, 59–87.
Royle, P., Jarema, G., & Kehayia, E. (2002). Frequency effects on visual word access in developmental language impairment. *Journal of Neurolinguistics*, *15*, 11–41.
Sabisch, B., Hahne, A., Glass, E., von Suchodoletz, W., & Friederici, A. D. (2006). Lexical-semantic processes in children with specific language impairment. *Developmental Neuroscience*, *17*, 1511–1514.
Saborit, C., & Julián, J. P. (2005). *ELI – L'Avaluació del Llenguatge Infantil.* Castelló de la Plana: Universitat Jaume I.
Sanz-Torrent, M., Andreu, L., Badia, I., & Sidera, F. (2011). Argument omissions in preschool Catalan and Spanish speaking children with SLI. *Infancia y Aprendizaje*, *34*, 49–66.
Sanz-Torrent, M., Serrat, E., Andreu, L., & Serra, M. (2008). Verb morphology in Catalan and Spanish in children with specific language impairment: A developmental study. *Clinical Linguistics & Phonetics*, *22*, 459–474.
Schelletter, C., Sinka, I., Fletcher, P., & Ingham, R. (1999). English speaking SLI children's use of locative/contact and causative alternations. In M. Garman, C. Letts, B. Richards, C. Schelletter, & S. Edwards (Eds.), *Issues in normal and disordered child language: From phonology to narrative* (pp. 106–117). Reading: The New Bulmershe Papers, University of Reading.

Sebastián, N., Martí, M. A., Carreiras, M., & Cuetos, F. (2000). *LEXESP. Léxico informatizado del español*. Barcelona: Edicions Universitat de Barcelona.

Serra, M., Serrat, E., Solé, R., Bel, A., & Aparici, M. (2000). *La adquisición del lenguaje*. Barcelona: Ariel.

Spivey, M. J., Tanenhaus, M. K., Eberhard, K. M., & Sedivy, J. C. (2002). Eye movements and spoken language comprehension: Effects of visual context on syntactic ambiguity resolution. *Cognitive Psychology*, *45*, 447–481.

Stark, R. E., & Tallal, P. (1981). Selection of children with specific language deficits. *Journal of Speech and Hearing Disorders*, *46*, 114–122.

Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J. C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*, 1632–1634.

Thordardottir, E. T., & Ellis Weismer, S. (2002). Verb argument structure weakness in SLI in relation to age and utterance length. *Clinical Linguistics & Phonetics*, *16*, 233–250.

Tomblin, J. B., Records, N. L., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech and Hearing Research*, *40*(6), 1245–1260.

Trueswell, J. C., Sekerina, I., Hill, N. M., & Logrip, M. L. (1999). The Kindergarten path effect: Studying on-line sentence processing in young children. *Cognition*, *73*, 89–134.

Trueswell, J. C., Tanenhaus, M., & Garnsey, S. (1994). Semantic influences on parsing: Use of thematic role information in syntactic disambiguation. *Journal of Memory and Language*, *33*, 285–318.

Trueswell, J. C., Tanenhaus, M., & Kello, C. (1993). Verb-specific constraints in sentence processing: Separating effects of lexical preference from garden-paths. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *19*, 528–553.

Valle-Arroyo, F. (1999). *Normas de Imaginabilidad*. Oviedo: Servicio de Publicaciones Universidad de Oviedo.

Van der Lely, H. (1994). Cannonical linking rules: Forward versus reverse linking in normally developing and specifically language-impaired children. *Cognition*, *51*, 29–72.

Van der Meulen, F. F. (2001). *Moving eyes and naming objects*. Nijmegen: MPI series in Psycholinguistics.

Van der Meulen, F. F. (2003). Coordination of eye gaze and speech in sentence production. In H. Härtl, & H. Tappe (Eds.), *Mediating between concepts and grammar* (pp. 39–63). Berlin: Mouton de Gruyter.

Verhoeven, A. L., & Van Balkom, J. (2004). *Classification of developmental language disorders*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Watkins, R. (1994). Specific language impairments in children: An introduction. In A. R. Watkins, & M. L. Rice (Eds.), *Specific language impairments in children* (pp. 1–15). Baltimore, MD: Paul H. Brookes Publishing.

Wechsler, D., Cordero, A., & de la Cruz, M. V. (1993). *Wechsler Intelligence Scale for Children, Revised (WISC-R, Spanish version)*. Madrid: TEA Editions.

Appendix. List of verbs and target sentence used as stimuli

Target verb (Spanish/Catalan [English])	Target sentence (Spanish/Catalan [English])
One-argument verbs	
Aullar/Udolar [to howl]	*El lobo aulla/El llop udola* [The wolf howls]
Bucear/Bussejar [to dive]	*El hombre bucea/L'home busseja* [The man dives]
Correr/Córrer [to run]	*La mujer corre/La dona corre* [The woman runs]
Dormir/Dormir [to sleep]	*El hombre duerme/L'home dorm* [The man sleeps]
Ladrar/Bordar [to bark]	*El perro ladra/El gos borda* [The dog barks]
Llorar/Plorar [to cry]	*La niña llora/La nena plora* [The girl cries]
Nadar/Nedar [to swim]	*El niño nada/El nen neda* [The child swims]
Patinar/Patinar [to skate]	*La niña patina/La nena patina* [The girl skates]
Reír/Riure [to laugh]	*El niño rie/El nen riu* [The child laughs]
Resbalar/Relliscar [to slip]	*El hombre resbala/L'home rellisca* [The man slips]
Rezar/Pregar [to pray]	*La mujer reza/La dona prega* [The woman prays]
Soplar/Bufar [to blow]	*El hombre sopla/L'home bufa* [The man blows]
Volar/Volar [to fly]	*El pájaro vuela/L'ocell vola* [The bird flyes]
Two-argument verbs	
Abrir/Obrir [to open]	*El hombre abre la puerta/L'home obre la porta* [The man opens the door]
Arreglar/Arreglar [to fix]	*El fontanero arregla el grifo/El lampista arregla l'aixeta* [The plumber fixes the tap]
Borrar/Esborrar [to erase]	*El maestro borra la pizarra/El mestre esborra la pissarra* [The teacher erases the blackboard]
Botar/Botar [to bounce]	*El niño bota la pelota/El nen bota la pilota* [The child drops the ball]
Cerrar/Tancar [to close]	*El hombre cierra la ventana/L'home tanca la finestra* [The man closes the window]
Empujar/Empènyer [to push]	*El hombre empuja el coche/L'home empeny el cotxe* [The man pushes the car]
Encender/Encendre [to turn on]	*La mujer enciende la luz/La dona encén la llum* [The women turns on the light]
Escuchar/Escoltar [to listen to]	*El perro escucha la radio/El gos escolta la ràdio* [The dog listens to the radio]
Leer/Llegir [to read]	*El hombre lee el periódico/L'home llegeix el diari* [The man reads the newspaper]
Pelar/Pelar [to peel]	*La niña pela una mandarina/La nena pela una mandarina* [She peels a tangerine]
Pisar/Trepitjar [to steps on]	*El hombre pisa un plátano/L'home trepitja un plàtan* [The man steps on a banana]
Romper/Trencar [to break]	*El niño rompe un jarrón/El nen trenca un gerro* [The child breaks a base]
Tocar/Tocar [to play]	*La mujer toca el piano/La dona toca el piano* [The women plays the piano]
Abrochar/Cordar [to clasp]	*La madre abrocha el botón al hijo/La mare corda el botó al fill* [The mother clasps the button to the the child]
Three-argument verbs	
Arrancar/Arrencar [to start]	*El niño arranca el pelo a la niña/El nen arrenca els cabells a la nena* [The child starts the hair to the girl]
Atar/Lligar [to tie]	*La abuela ata los cordones al niño/L'àvia lliga els cordons al nen* [The grandmother tied the shoelaces to the boy]
Contar/Contar [to tell]	*La abuela cuenta una cuento a la niña/L'àvia explica una conte a la nena* [The grandmother tells a story to the girl]
Dar/Donar [to give]	*La madre da caramelos al niño/La mare dóna caramels al nen* [The mother gives candies to the boy]
Entregar/Lliurar [to deliver]	*El cartero entrega la carta al hombre/El carter lliura la carta a l'home* [The postman delivered the letter to the man]
Lanzar/Llançar [to throw]	*El hombre lanza una pelota al perro/ L'home llança una pilota al gos* [The man throws a ball to the dog]
Pedir/Demanar [to beg]	*El mendigo pide limosna a la mujer/El captaire demana almoina a la dona* [The beggar begs alms to the woman]
Quitar/Treure [to remove]	*El niño quita la piruleta a la niña/El nen treu la piruleta a la nena* [The boy removes the lollipop to the girl]
Regalar/Regalar [to give (a gift)]	*El niño regala un regalo a la niña/El nen regala un regal a la nena* [The child gives a gift to the girl]

Robar/Robar [to steal]	*El ladrón roba la cartera al hombre/ El lladre roba la cartera a l'home* [The thief steals the wallet to the man]
Sacar/Treure [to pull out]	*El árbitro saca tarjeta roja al jugador/L'àrbitre treu una targeta vermella al jugador* [The referee pulls out red card to player]
Secar/Secar [to dry]	*La peluquera seca el pelo a la señora/La perruquera seca el pèl a la senyora* [The hairdresser dry the hair to the woman]