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How do children with developmental language disorder extend novel nouns?

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ABSTRACT

In this study, we investigated the ability of children with developmental language disorder (DLD) to extend nouns referring to different categories of novel objects. In a word extension task, we used several types of object entities (solid, animate, nonsolid, functional, and spatial relations) for which children needed to attend to diverse properties (shape, texture, role, or spatial relation) to decide category membership. We compared 15 school-aged children with DLD with typically developing (TD) children matched on either age or vocabulary. Our results indicate that children with DLD were impaired in extending novel words for nonsolid substances and relational objects, whereas age-matched TD children performed well for all object classes. Similar to children with DLD, TD children matched on language had difficulty in extending spatial relation categories. We also show that children with DLD needed more learning exemplars and relied more on shape-based information than TD children, especially for spatial configuration objects. Overall, our findings suggest that children are able to learn regularities between object properties and category organization and to focus on diverse features according to the object presented when extending novel nouns. They also provide clear evidence

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linking DLD to deficits in novel name generalization and word learning.

Introduction

Vocabulary is the set of words of a language known by an individual. Whereas vocabulary size grows quickly in typically developing (TD) children (Bloom, 2002), children with developmental language disorder (DLD) seem to struggle to expand their lexicon. DLD is a neurodevelopmental disorder characterized by impairments in language development and learning, including difficulties in novel word learning, and it is not due to a biomedical condition linked to genetic or neurological causes (Bishop, Snowling, Thompson, Greenhalgh, & CATALISE-2 Consortium, 2017). These language impairments persist until middle school and beyond, and they have an arguably deleterious impact on children's everyday life.

Previous research has shown that children with DLD produce their first words later than their peers (Trauner, Wulfeck, Tallal, & Hesselink, 2000). Furthermore, as reported by McGregor, Oleson, Bahnsen, and Duff (2013), their vocabulary is characterized by not only limited breadth (i.e., the number of words they know) but also limited depth (i.e., how well they comprehend the meanings of the words they know). In a word definition task, McGregor et al. showed that children with DLD produce significantly fewer informative definitions than TD children even when the analyses included only children who manifested a real ability to provide definitions. These findings suggest that children with DLD may learn novel words but that the meanings of words remain less detailed than in TD children.

Word learning is a complex multidimensional process that encompasses several components such as phonological encoding, form–meaning mapping, lexical access, word retention, and semantic knowledge and organization as well as working memory (Kan & Windsor, 2010, p. 740). Several studies have reported that children with DLD perform worse than their age-matched peers but similar to their language-matched peers in learning novel words (for a review, see Kan & Windsor, 2010). In addition, they are slow to learn new words, have difficulty in retaining new word labels, encode fewer semantic features of newly learned items, and require more exposure to novel words in order to learn them (Alt, Plante, & Creusere, 2004; Jackson, Leitao, & Claessen, 2016; Nation, 2013). It should be noted that these studies have focused mainly on the initial stage of lexical learning (form–meaning mapping) and not on all aspects of lexical development (Kan & Windsor, 2010). The authors considered broad variables such as the number of novel word exposures, types of words (e.g., nouns or verbs), types of tasks or output formats (e.g., identification or production of words), and presentation format (e.g., fast or slow). These factors tell us what children learned easily (e.g., nouns better than verbs) and/or the best way in which to discriminate children with or without DLD (e.g., testing after high exposure or with comprehension and recognition tasks), but they tell us nothing about the underlying causes of these difficulties.

A promising line of research aiming at understanding word learning difficulties in children with DLD has been to investigate the cognitive processes known to support typical lexical acquisition such as novel word generalization (i.e., word extension). When young children learn a novel word, they need to understand the set (category) of instances to which this word refers to be able to extend or generalize it to new instances in various contexts (Gentner & Namy, 1999; Kan & Windsor, 2010). For example, if children encounter an animal and are told that it is called *poodle,* they must understand the features characterizing poodles in order to *extend* it accurately later while restricting the word *poodle* to poodles only. Furthermore, novel name extensions are not constrained in the same way across noun types. It has been argued that children learn very early that names for *solid* objects apply to objects that share the same shape. To illustrate, when children learn the word *cup,* they need to specifically attend to the object shape because shape is a relevant property when deciding whether or not an object can be included in the *cup* category (Smith, Jones, Landau, Gershkoff-Stowe, &

Samuelson, 2002). This shape bias favors shape over other properties such as size and color (Gershkoff-Stowe & Smith, 2004; Jones & Smith, 1998). The shape bias has been consistently observed in 2- and 3-year-old children (Gershkoff-Stowe & Smith, 2004; Jones & Smith, 1998; Samuelson & Smith, 2000). Smith et al. (2002) showed that teaching 17-month-old infants nouns for categories well organized by shape resulted in these children developing a shape bias not only for these categories but also for other novel solid object categories. Interestingly, infants who developed the shape bias increased their vocabulary for solid objects outside the laboratory during the course of the study. Therefore, this bias is an important tool for learning in young children.

Other categories are organized by perceptual features other than shape, and other word extension biases are at play. For example, when objects are identified as animates, the shape bias is weakened and texture becomes a critical feature to extend new words. Jones, Smith, and Landau (1991) showed that 2- and 3-year-old children extended new words by shape when objects had no eyes but did so by shape and texture when eyes were added to the same objects. Jones and Smith (1998) found that 3-year-olds extended novel nouns by shape for objects without shoes and by texture for objects with shoes. In this context, children over 2 years of age extend nonsolid object names by texture and not by shape (Soja, Carey, & Spelke, 1991). However, such a texture bias seems to be more fragile (Samuelson & Horst, 2007) or more context dependent (Perry, Samuelson, & Burdinie, 2014) than the shape bias.

Another category of nouns, relational nouns, has also received much attention. One feature of relational nouns is that they are defined not by perceptual features but rather by extrinsic properties. "Their meanings include relations between other concepts" (Gentner, 2005, p. 248). Nouns such as *predator, robbery,* and *neighbor* are relational because they refer to a relational structure between entities (e.g., between two animals or between an individual and an object), whereas their referents are often visually dissimilar or have no common intrinsic property (Gentner, 2005). It is worth noting that relational nouns are acquired later than solid object names. In fact, there are few relational nouns in the MacArthur Communicative Developmental Inventory until 30 months of age (Gentner, 2005). Moreover, when relational nouns are acquired, they are often understood as object names defined by concrete features. Contrary to school-aged children, preschoolers tend to define relational nouns in terms of objects' perceptual properties. For example, children find it hard to believe that a 2-year-old infant could be an uncle because uncles need to be about 24 or 25 years old (Keil & Batterman, 1984).

Regarding novel word learning, it has been argued that children are able to use different kinds of properties to extend novel nouns referring to various object classes, depending on the object with which they are confronted (Jones & Smith, 1998; Jones et al., 1991; Snape & Krott, 2018). Thus, children seem to be sensitive to regularities between object properties and category organization. This sensitivity is important because of its impact on the size of the lexicon. For example, Thom and Sandhofer (2009) found that 20-month-old infants who were trained with more color words were better able to extend new color words than children who were trained with fewer words, suggesting that word extension is facilitated in domains for which children have a labeling experience. Thus, as children learn more words, they develop attentional biases toward properties that are relevant to category membership (Jones & Smith, 1998). Because object names are the most frequent in young children's daily life, it is not surprising that the shape bias is their first and most robust attentional bias (Samuelson, Horst, Schutte, & Dobbertin, 2008; but see Bloom, 2002, for a different interpretation).

Most of the evidence regarding the above attentional biases has been obtained with a single training exemplar design in which participants are shown a training stimulus and then are asked to select, among a set of options, the one that has the same name. However, in many learning situations, two or more stimuli are introduced simultaneously with the same word, giving children the opportunity to compare these stimuli before generalizing their names to novel instances. There is now ample evidence that a comparison format leads to more conceptually based generalizations in novel noun learning tasks than single stimulus formats (see Augier & Thibaut, 2013; Namy & Gentner, 2002). A general explanation is that comparisons lead participants to first focus on salient similarities between training exemplars (e.g., shape) and to later search for deeper commonalities, even though less salient (Namy & Gentner, 2002). This is especially the case for relational nouns for which comparisons support the identification of relational features over perceptual features in young children (Christie & Gentner, 2010; Gentner, Anggoro, & Klibanoff, 2011; Thibaut & Witt, 2015, 2017). For example, Christie and Gentner (2010) found that 3- and 4-year-old were able to extend a novel noun for a spatial relation when two learning exemplars were provided, but not when only one learning exemplar was presented. Multiple object presentation favors generalization in word extension tasks, although it can give rise to generalizations based on salient but irrelevant properties (see Augier & Thibaut, 2013).

Novel noun extension in children with DLD

Only a few studies have systematically investigated novel noun extension in children with DLD. Schwartz, Leonard, Messick, and Chapman (1987) found that these children apply a new noun to unnamed exemplars less than their language-matched peers. Gray (1998) also found that children with DLD do not perform as well as age-matched peers when they need to extend words to new contexts (i.e., color photographs or black line drawings). More recently, Collisson, Grela, Spaulding, Rueckl, and Magnuson (2015) found that, contrary to their age-matched peers, preschool-aged children with DLD did not exhibit a shape bias. They did not preferentially extend solid object names by shape given that they relied equally on shape, color, and texture. Therefore, DLD seems to be associated with word extension impairment in addition to deficits in other aspects of word learning such as semantic representation and form–meaning mapping (Kan & Windsor, 2010; McGregor et al., 2013).

However, although other classes of nouns have received much attention in TD children, to our knowledge no studies have investigated word extension for words other than solid object names in children with DLD. Pandolfe, Wittke, and Spaulding (2016) showed that adolescents with DLD were impaired in their knowledge of words related to driving, which are abstract words and, for many of them, relational words. Moreover, previous studies with children with DLD have shown that learning other types of relational words, such as verbs, is problematic for this population (Windfuhr, Faragher, & Conti-Ramsden, 2002). This is interesting because the difficulties of children with DLD in learning verbs suggest that learning other types of words such as relational nouns may also be hampered in this population.

Although being exposed to two learning instances facilitates relational noun extension in TD children (Christie & Gentner, 2010; Gentner et al., 2011), such an experimental setup might not benefit children with DLD because DLD is associated with difficulty in using comparisons and structural alignment (Leroy, Maillart, & Parisse, 2014; Leroy, Parisse, & Maillart, 2012). These children also have difficulty in identifying relational similarities when they are not supported by perceptual features (Leroy et al., 2012, 2014). In analogical reasoning tasks, Leroy et al. (2014) showed that children with DLD had poorer performance in a linguistic task (composed of syllables) and a nonlinguistic analogical reasoning task (composed of pictures) in which they needed to complete a sequence sharing the same relational structure as previously presented sequences. Interestingly, in the linguistic task, the performance of children with DLD was poorer for relational items that were not backed up by perceptual cues (e.g., /na-ba-ba/ and /ty-sy-sy/) than for relational items that were backed up by perceptual cues (e.g., /my-ly-ly/ and /me-le-le/). This suggests that relational terms themselves may be difficult to learn and generalize by children with DLD when different instances of a relation do not share any perceptual cue (e.g., different classes of objects can be connected by the "neighbor of" relational noun).

In sum, children with DLD have difficulty in learning and extending new words (Gray, 1998; Kan & Windsor, 2010; Schwartz et al., 1987). They do not develop a shape bias at the same age as their TD peers (Collisson et al., 2015), and they have difficulty in learning abstract and relational words (Pandolfe et al., 2016; Windfuhr et al., 2002). Moreover, children with DLD are impaired in using comparison, and they have difficulty in focusing on relational features rather than perceptual features (Leroy et al., 2012, 2014). In contrast, TD children can identify regularities across objects in order to extend novel names for different classes of entities. TD children also develop attentional biases toward features that are relevant to category membership (Jones & Smith, 1998; Jones et al., 1991; Soja et al., 1991). In this context, within-category comparisons seem to contribute to the abstraction of conceptually relevant properties, especially for words that are not defined by perceptually based features such as relational nouns (Christie & Gentner, 2010; Gentner et al., 2011; Thibaut & Witt, 2015).

The current study

The main purpose of this study was to examine generalization abilities in school-aged children with DLD using a word extension task. During the experiment, children first were introduced to an unfamiliar object together with its name (a nonword), and then they were asked to indicate the other stimulus to which they would generalize the novel noun.

This study had four objectives. First, we evaluated the ability of children with DLD to extend nouns associated with different kinds of entities and to identify the relevant properties to category membership according to the object that has been introduced. Indeed, novel noun generalization abilities have not been compared for nouns referring to various types of entities. Thus, comparing how novel words for various types of entities are acquired remains an open question. We compared extensions of novel nouns for five object classes: solid objects, animate objects, nonsolid substances, functional role categories, and spatial configuration categories. These object classes have already been examined separately (Christie & Gentner, 2010; Gentner et al., 2011; Jones & Smith, 1998; Smith et al., 2002; Soja et al., 1991) or in comparison (e.g., solid and nonsolid objects; see Kucker et al., 2019, for a recent review) in various studies in TD children, but to our knowledge these five classes have never been compared in the same study in children with DLD or in TD children.

Second, we have seen that these abilities are related to the size of the lexicon (Smith et al., 2002; Thom & Sandhofer, 2009). Therefore, it is possible that children with DLD are impaired relative to age-matched peers but perform similarly to children matched on a vocabulary measure. Thus, we included two TD matched groups: one younger (the language-matched group) and one older (the age-matched group). This double-matching procedure would allow us to disentangle language-level issues from age-related issues.

Third, we contrasted single-object and multiple-object presentations. Indeed, it has been repeatedly shown that the opportunity to compare multiple instances of the same category leads to more accurate generalizations (Christie & Gentner, 2010; Gentner & Namy, 1999). Given the limited size of our available sample of participants with DLD, we could not run the comparison and single-object conditions as a between-participants factor. Thus, we decided to first start with a single occurrence and, in case of failure, multiple exemplars of the same category were presented. Note that this new methodological within-participants approach corresponds to what may happen in real-world situations. Children sometimes encounter one stimulus of a category and later encounter two (or more) specimens of the same category.

Fourth, we analyzed a possible generalization bias of children with DLD to focus on salient perceptual features even in relational categories. Indeed, as mentioned above, younger children sometimes generalize novel relational nouns based on perceptual similarities (Christie & Gentner, 2010; Keil & Batterman, 1984). This may also happen with children with language deficits given that these children have already been found to favor perceptual similarities over relational features (Leroy et al., 2012, 2014).

Method

Participants

Of the 49 children recruited for this study, 19 were identified as having DLD and 30 were TD children. Children were recruited in the French-speaking region of Belgium. Informed consent was obtained from parents through schools, as was information about children's medical and developmental history. Children were recruited if parents did not report any hearing impairment or neurological disorder. Because bilingualism could have affected language assessment, all children were monolinguals. The study received the approval of the local ethics committee.

Children with DLD, aged 7;3 (years;months) to 12;4, were recruited through schools for children with special needs. All children with DLD had been diagnosed before their enrollment in this study. We performed a language assessment protocol that confirmed their current diagnosis. Receptive abilities were assessed with a picture-pointing task involving words for vocabulary (Evaluation du

Vocabulaire en Images Peabody [EVIP]; Dunn, Thériault-Whalen, & Dunn, 1993) and a picture-pointing task involving sentences for the morphosyntax domain (Epreuve de Compréhension Syntaxico-Semantique [ECOSSE], French adaptation of the Test for Reception of Grammar; Lecocq, 1996). Expressive abilities were evaluated with the Evaluation du Langage Oral (ELO) battery (Khomsi, 2001), which includes a word repetition task in phonology, a picture-naming task in vocabulary, and a sentence completion task in morphosyntax. Children were selected if they scored below the 10th percentile in at least two language components and thus matched Leonard's (2014) criteria for specific language impairment, that is, the previous designation of DLD. The most frequently impaired language components were phonology and morphosyntax. Finally, all children had a nonverbal intellectual quotient (NVIQ) of at least 80 (Echelle non Verbale d'Intelligence de Wechsler; Wechsler & Naglieri, 2009).

Regarding TD children (n = 30), none had repeated a year in school and none had a history of language or other developmental disorder. We conducted the same language evaluation protocol with TD children; all performed above the 10th percentile in every language component. A total of 15 TD children (age range = 7;0–11;11) were individually matched with children with DLD on chronological age (±6 months) and on NVIQ (±8 points). However, 4 children with DLD could not be matched to a TD child due to low NVIQ scores. Overall, TD and DLD age-matched groups did not differ in age, gender, or NVIQ but differed in all language measures (Table 1). An additional 15 TD children (age range = 5;9–10;11) were individually matched to children with DLD according to a vocabulary comprehension measure (EVIP, ±8 points; Dunn et al., 1993). A vocabulary comprehension measure was chosen because vocabulary has been related to the ability to extend new words (Jones & Smith, 1998; Thom & Sandhofer, 2009). As previously mentioned, 4 children with DLD could not be matched to TD children due to low scores on the vocabulary measure. The group of children with DLD and their TD language-matched group did not differ in gender, NVIQ, vocabulary comprehension, or sentence comprehension, but they differed in age and all other language measures (Table 2).

Materials

This study aimed at evaluating the abilities of children with DLD and TD children to extend novel names to other instances of novel categories of objects. We used the word extension task paradigm in which children are presented with a nonword, such as *padi*, associated with an object (Gentner & Namy, 1999). We constructed 30 nonwords that followed the consonant–vowel–consonant–vowel

Table 1
Characteristics of the age-matched groups.

	Children with DLD (n = 15)	Age-matched children (n = 15)	Statistic
Gender	7 girls and 8 boys	9 girls and 6 boys	$\chi^2(1) = 0.13$
Age [years;months (*SD*)]	10;0 (1;6)	10;1 (1;7)	$t(28) = 0.18$
NVIQ [mean (*SD*)]	96.5 (9.8)	97.1 (10.5)	$t(28) = 0.16$
Word repetition [raw score—mean (*SD*)]	24.3 (7.3)	31.9 (0.3)	$W = 225.00^{***}$
Picture-pointing task (word) [raw score—mean (*SD*)]	90.9 (16.5)	117.0 (12.6)	$t(28) = 4.87^{***}$
Picture-naming task [raw score—mean (*SD*)]	29.5 (3.4)	35.2 (2.6)	$t(28) = 5.15^{***}$
Picture-pointing task (sentence) [error score—mean (*SD*)]	12.4 (4.3)	6.08 (3.0)	$t(28) = -4.64^{***}$
Sentence completion [raw score—mean (*SD*)]	13.9 (3.3)	20.9 (2.5)	$W = 213.00^{***}$

Note. DLD, developmental language disorder; NVIQ, nonverbal intellectual quotient.
*** $p < .001$.

Table 2
Characteristics of the language-matched groups.

	Children with DLD (n = 15)	Language-matched children (n = 15)	Statistic
Gender	9 girls and 6 boys	9 girls and 6 boys	$\chi^2(1) = 0.00$
Age			
[years;months (*SD*)]	10;5 (1;7)	8;1 (1;7)	$t(28) = -3.88^{***}$
NVIQ			
[mean (*SD*)]	96.8 (12.4)	100.2 (12.9)	$t(28) = 0.74$
Word repetition			
[raw score—mean (*SD*)]	24.2 (8.5)	31.3 (1.1)	$W = 210.00^{***}$
Picture-pointing task (word)			
[raw score—mean (*SD*)]	94.6 (15.9)	95.6 (17.6)	$t(28) = 0.16$
Picture-naming task			
[raw score—mean (*SD*)]	29.9 (3.8)	33.6 (4.3)	$W = 185.00^{**}$
Picture-pointing task (sentence)			
[error score—mean (*SD*)]	12.3 (5.2)	9.2 (4.2)	$t(28) = -1.78$
Sentence completion			
[raw score—mean (*SD*)]	14.1 (3.6)	18.8 (3.9)	$t(28) = 3.42^{**}$

Note. DLD, developmental language disorder; NVIQ, nonverbal intellectual quotient.
** $p < .01$.
*** $p < .001$.

(CV–CV) structure typical of the French language (see Appendix). All syllables had a phonotactic frequency higher than 1000 according to the Manulex database (Lété, Sprenger-Charolles, & Colé, 2004).

Visual stimuli consisted of colored pictures presented on a white background. Pictures depicted different objects belonging to one of five categories of objects: solid, nonsolid, animate, spatial configuration, or functional relational objects. As detailed below, category membership was determined by specific critical properties.

First, solid objects referred to a category of shape-based objects. As mentioned above, solid objects have been related to a shape bias in TD children, meaning that children should attend to shape when generalizing solid object names (Gershkoff-Stowe & Smith, 2004; Smith et al., 2002). Five different sets of solid objects were created. Each set comprised six objects that shared similar shapes but had different textures and colors (see Fig. 1). Two types of distractor stimuli were used: one including pictures of novel objects that resembled the learning exemplar in color only (i.e., color match) and one including pictures of novel objects that resembled the learning exemplar in texture only (i.e., texture match).

Second, nonsolid objects were textured shapes designed to illustrate existing substances such as cream, water, and jam (Perry, Samuelson, Malloy, & Schiffer, 2010; Soja et al., 1991). Five sets of nonsolid objects were created. Each set comprised six objects that shared similar textures but had different shapes and colors (see Fig. 1). Two types of distractor stimuli were selected: one including pictures of novel objects that resembled the learning exemplar in shape only (i.e., shape match) and one including pictures of novel objects that resembled the learning exemplar in color only (i.e., color match).

Third, we also used a category of animate objects. Animate objects were similar to solid objects except that they had eyes. Eyes have been consistently regarded as being a cue for animacy (Jones et al., 1991), and animacy has been shown to draw children's attention to shape and texture (Jones & Smith, 1998; Jones et al., 1991). Five sets of animate objects were created. Each set comprised six objects that shared similar shapes and textures but had different colors (see Fig. 1). Two types of distractor stimuli were assembled: one including pictures of novel animate objects whose shape and color matched those of the learning exemplar (i.e., shape & color match) and one whose color and texture matched those of the learning exemplar (i.e., color & texture match).

The fourth category of objects used in our experiment referred to the spatial configuration category. For these objects, category membership relied on the relational pattern of its constituent parts.

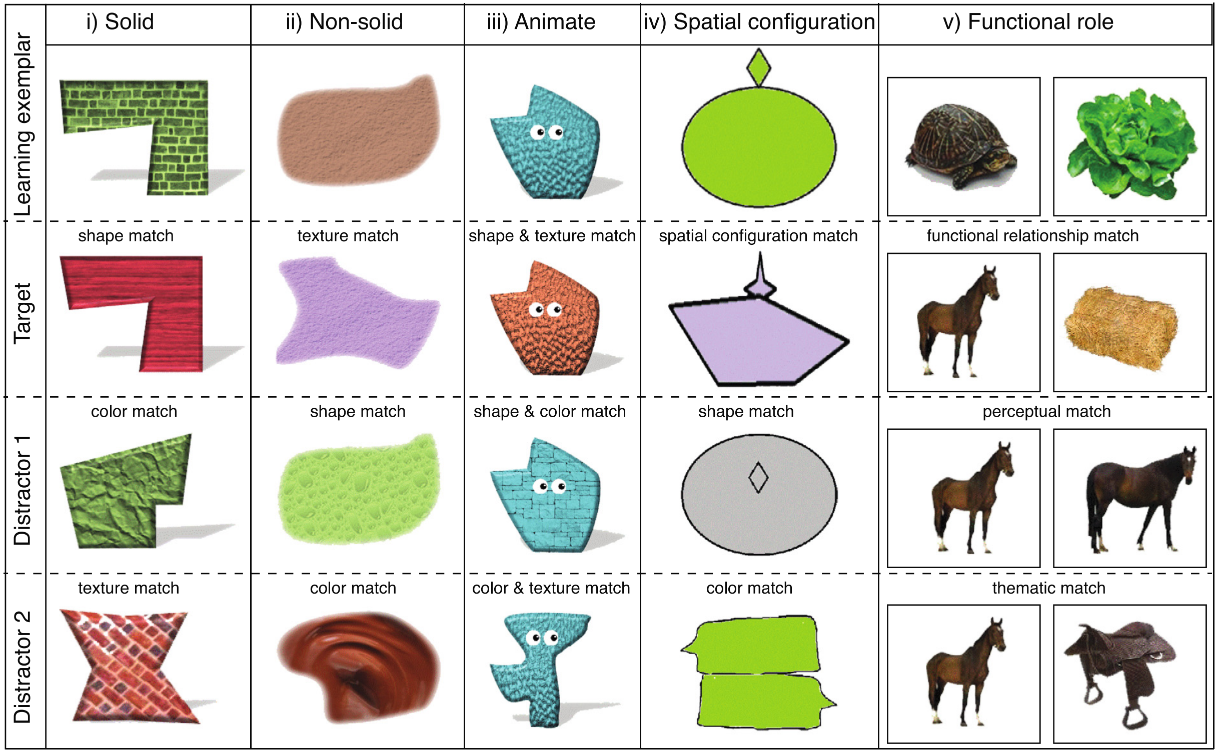

Fig. 1. Examples of stimuli used for each category of objects: (i) solid, (ii) nonsolid, (iii) animate, (iv) spatial configuration, and (v) functional role. For each category of objects, the first and second rows display a learning exemplar and the corresponding generalization target object, respectively, and the last two rows show related distractor stimuli (Distractor 1 and Distractor 2).

As shown in Fig. 1, the learning exemplar and target stimulus shared the same spatial configuration in that they depicted an object composed of a small element placed on top of a bigger element. Given that spatial configuration is not relevant to object categorization in the real world, children cannot use their knowledge of existing categories to learn the rule underlying object categorization for such a category of objects. Moreover, Christie and Gentner (2010) found that preschool-aged children extended a novel noun for a spatial relation when they were presented with two learning exemplars. The spatial configuration is a property for which children can learn to decide category membership, albeit through within-category comparison. Learning the driving rule for this category of objects would require that participants be exposed to more experimental materials and thus more trials. Therefore, we created 10 different sets of spatial configuration objects. Each set comprised six objects that shared similar spatial relational configurations but had different shapes and colors. Two types of distractor stimuli were selected: one including pictures of novel objects that resembled the learning exemplars in shape only (i.e., shape match) and one including pictures of novel objects that resembled the learning exemplars in color only (i.e., color match).

Finally, following Thibaut and Witt's (2015) study, we also used a category of objects defined by functional relationship. For this latter category, all stimuli were photographs of real objects such as *horse, duck,* and *pencil* (see Fig. 1). To illustrate category membership, stimuli were always presented in pairs. In fact, presenting two objects side by side better highlighted the specific functional role that describes the nature of the relationship between these two objects. Five sets of pairs of real objects were created. Each set comprised six pairs of objects that shared a similar functional relational role but had different object entities. As shown in Fig. 1, the learning exemplar and target stimulus of the functional role category shared the same thematic relationship; that is, the turtle eats the lettuce as the horse eats the hay. Two types of distractor stimuli were assembled: one including a pair of objects whose relationship was perceptually based (i.e., two different horses) and one pair displaying a thematic relationship that is different from the one depicted by the learning exemplar (i.e., horse and its saddle).

Procedure

Children were tested individually in a quiet room at their home or at their school during a session of about 30 min. The experiment was run on a PC laptop computer using OpenSesame software (Mathôt, Schreij, & Theeuwes, 2012). The task was introduced to each child in an entertaining context in which a friendly alien asked children to learn words of his language.

The experimental session began with two familiarization trials during which children were shown a novel object associated with a novel word. In the first trial, a learning exemplar of a category of objects appeared at the center of the upper half of the screen monitor as the experimenter labeled it with a nonword: "You see this object—this is a *dufan* in the alien language." Three pictures of test objects, or *response* stimuli, were then presented below the learning exemplar. One of the response stimuli belonged to the same category as the learning exemplar (i.e., the target object), and the other two were distractors. The experimenter then asked, "Now, can you show me another *dufan* among these objects?" Children were instructed to indicate their choice by pressing one of three keyboard buttons. The spatial arrangement of the three response buttons mapped the spatial position of the three response stimuli on the screen: left, center, and right. The second trial proceeded in a similar fashion but exhibited two learning exemplars rather than one exemplar belonging to the same category. The correct response was never provided (to facilitate the reading, we use *correct response* for the expected response given the attentional biases observed in previous studies [see "Materials" section], whereas *incorrect response* refers to the distractors).

After the familiarization phase, children received five experimental blocks. In each block, they were exposed to one of the five categories of objects (solid, nonsolid, animate, spatial configuration, or functional relational objects). The order of presentation of these sets was counterbalanced across participants except for the spatial relation category, which was always performed as the last experimental block. Given that spatial configuration is not a common criterion for object categorization (Christie & Gentner, 2010), we speculated that children's understanding of category relationship for this

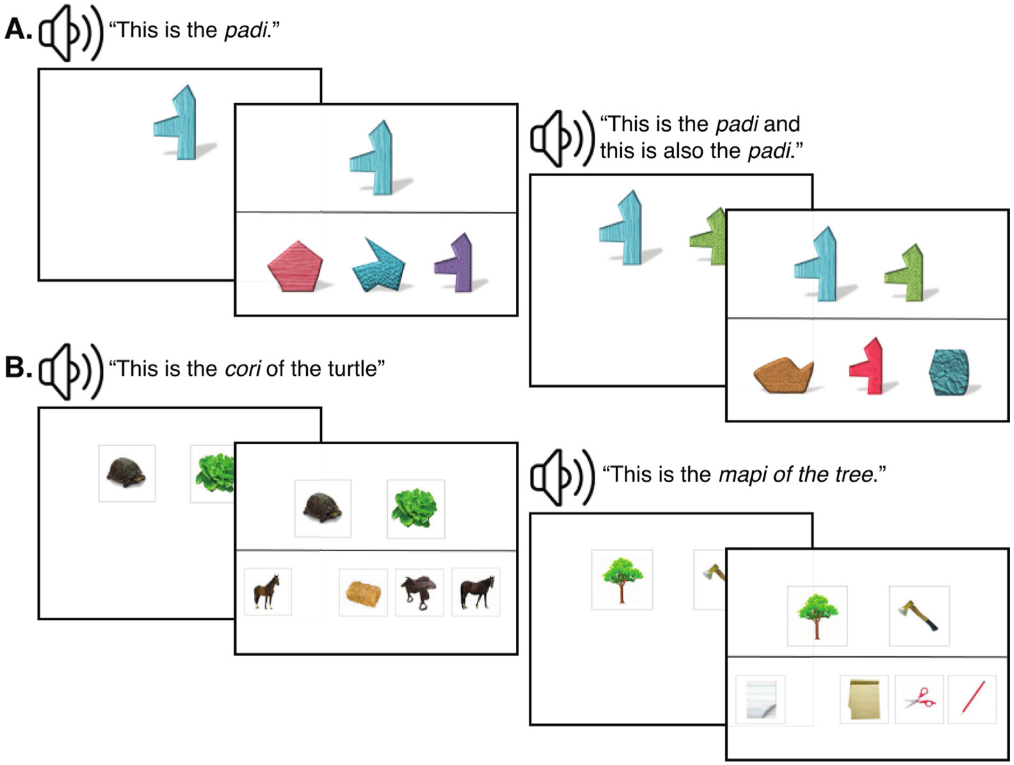

Fig. 2. (A) Schematic representation of a test trial involving nonword labels associated with a solid object. When participants failed to choose the correct response (i.e., the target stimulus), the following trial presented the same nonword along with two learning exemplars, and participants were asked again to find a similar object among the three response stimuli. (B) Schematic representation of a test trial involving nonwords associated with a functional role category of objects. When participants chose the correct response stimulus, as illustrated here, the following trial presented another set of objects.

category of objects may differ from that of the other categories of objects used in this study that would rely on more common object properties (and shape, texture, thematic relations).

In each block except the spatial relation category block, children were exposed to five different nonwords associated with a specific target object category. The nonword labels were randomly assigned to target objects. For the spatial relation category block, children were exposed to 10 different nonwords. To evaluate the facilitatory effect of within-category comparison on new word extension (Christie & Gentner, 2010; Gentner et al., 2011; Thibaut & Witt, 2015), every novel noun was presented with one learning exemplar. In case of failure in this first trial, the same noun was introduced with two learning exemplars. If children failed again, the same noun was presented with three learning exemplars. This means that the number of attempts to identify the correct object among the response stimuli could vary across children, being 5 at its minimum and 15 at its maximum. For the spatial relation block, the number of attempts ranged from 10 to 30 trials.

Fig. 2 illustrates the unfolding of a test trial for the experimental blocks involving solid, nonsolid, animate, and spatial configuration objects (Fig. 2A) and for the experimental block involving the functional role category of objects (Fig. 2B). As shown in Fig. 2A, the test trial for each nonword started with the presentation of one learning exemplar of one specific category of objects. The experimenter pointed to the object's picture and labeled it by saying to participants, "This is the *padi.* Look carefully at the *padi.*" All nonwords were introduced by saying "This is *the* . . ." rather than "This is *a* . . ." (Imai & Gentner, 1997). While the learning exemplar remained on the screen, three different pictures of objects (the target object/correct response and two distractors/incorrect responses) appeared below the learning exemplar; and the experimenter said, ‘‘Show me the other *padi*.” The position of the individual response stimuli (left, middle, or center) was randomly determined. In case children chose the target object (i.e., the correct response), the subsequent trial involved learning another nonword associated with another object of the same object category. In case of failure (see Fig. 2A), no feedback was provided, but the same nonword was presented again with two learning exemplars: the same learning exemplar as in the previous trial and another one (see Fig. 2A). The experimenter said, ‘‘This is the *padi*, and this is also the *padi*,” and added, ‘‘Look at the reason why they are both *padi*.” Some authors have indeed found that comparison must be explicitly encouraged to be beneficial in word extension tasks (Christie & Gentner, 2010). Then, children were presented with three response stimuli and were asked to show ‘‘the other *padi*.” If children failed to make the correct choice, the same nonword was again presented with three learning exemplars, and the procedure was repeated. If children failed again, no other exemplar was presented for this nonword and the next trial moved to the presentation of another nonword that began with no feedback other than neutral encouragement. Finally, after every object class, children were given a reward to encourage motivation.

As depicted in Fig. 2B, test trials for the functional relation categories were slightly different from the other blocks. The test trials started with the presentation of a pair of real objects (e.g., a turtle and lettuce), and the experimenter said ‘‘This is the *cori* of the turtle” while pointing to the two pictures. Then, children were presented with a picture of a horse and needed to select ‘‘the *cori* of the horse” among three possibilities. This syntactic structure has been found to orient 4-year-old children to extend new words by role even with only one learning exemplar (Gentner et al., 2011). Thus, children should select the object that has the same role as the learning exemplar (Gentner et al., 2011; Thibaut & Witt, 2015).

Results

First, we evaluated children’s success rate at identifying the relevant property for category membership after being exposed to only one learning exemplar. Therefore, we conducted analyses of variance (ANOVAs) comparing the performance of a group of children with DLD with an age-matched group, on the one hand, and with a language-matched group, on the other, when one learning exemplar was provided as a function of the object class (ezANOVA of the ez package in R; Lawrence, 2011). The scores of age-matched and language-matched groups were computed in two separate analyses because a subset of children with DLD could not be matched to a TD child on age (in the age-matched case) or on language (in the language-matched case). Thus, the two subgroups of children with DLD cannot be considered as one homogeneous group that would be equivalent to *both* control groups. Then, to further evaluate the impact of vocabulary on novel noun extension, we added the vocabulary measures to the models. We also verified that the percentages differed from chance level using one-sample *t*/Wilcoxon tests. In a second analysis, we examined the impact of within-category comparisons (i.e., comparison trials) on novel word extension. We performed ANOVAs on the mean number of exemplars used by age-matched groups and language-matched groups to extend novel words as a function of the object class. Thus, we examined the number of learning exemplars that children needed to successfully extend each novel noun, and we computed the mean for every object class. Finally, we investigated the role of the salient stimuli features by analyzing the type of distractor children selected in case of errors. We conducted ANOVAs to compare the number of incorrect responses as a function of the group and distractor for nonsolid substances, functional role categories, and spatial configuration categories. The trials involving one, two, and three learning exemplars were computed together for these last analyses.

Percentage of correct responses following one learning exemplar

Age-matched groups

We conducted a 2×5 ANOVA on the percentage of correct responses in the one learning exemplar case with group (DLD vs. age-matched) as a between-participants factor and category of objects (solid objects vs. animate objects vs. nonsolid substances vs. functional role categories vs. spatial

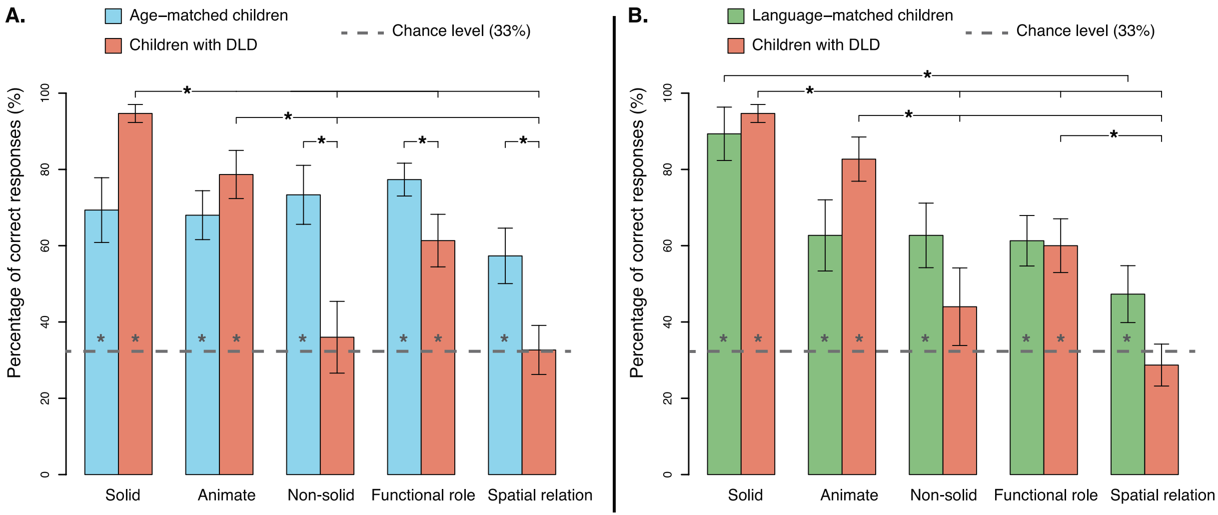

Fig. 3. Mean percentages of correct responses following one learning exemplar are displayed as a function of category of objects and as a function of group. Panel A compares children with developmental language disorder (DLD) and age-matched typically developing (TD) children. Panel B compares children with DLD and language-matched TD children. The gray dashed line marks the chance level, and the gray asterisk indicates significant above-chance performance. Bars represent the standard error of the mean. *$p < .05$.

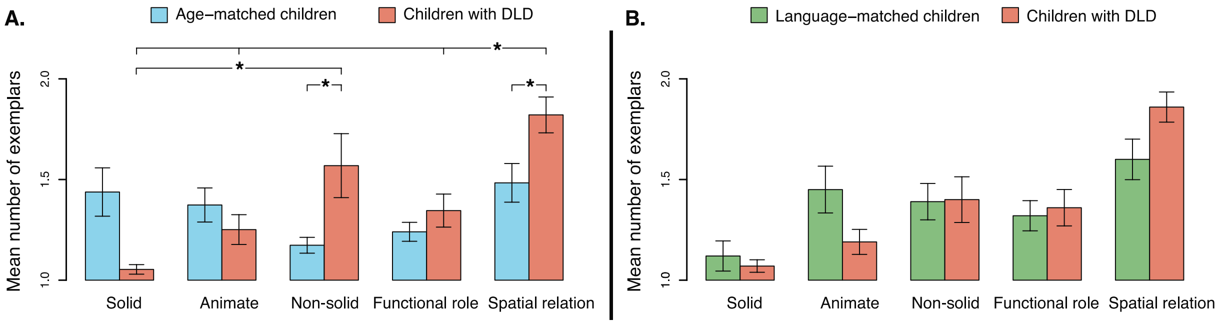

Fig. 4. Mean numbers of learning exemplars needed for successful word extension as a function of category of objects and as a function of group. Panel A compares children with developmental language disorder (DLD) and age-matched typically developing (TD) children. Panel B compares children with DLD and language-matched TD children. Bars represent the standard error of the mean. $^*p < .05$.

configuration categories) as a within-participants factor. The main effect of group was not significant, $F(1, 28) = 3.21$, $p = .084$, $\eta_p^2 = .10$. Moreover, the analysis yielded a significant effect of object category, $F(4, 112) = 9.90$, $p < .001$, $\eta_p^2 = .26$, and, more important, a significant interaction between group and object category, $F(4, 112) = 7.45$, $p < .001$, $\eta_p^2 = .21$. Post hoc analyses (Tukey HSD [honestly significant difference]) revealed that whereas the two groups performed similarly on trials with solid and animate objects ($p > .10$), age-matched children outperformed children with DLD on trials with nonsolid substances ($p < .001$), functional role categories ($p = .020$), and spatial configuration categories ($p = .002$). Furthermore, whereas the performance of age-matched children did not differ significantly across the five categories of objects (all *ps* > .05), the performance of children with DLD varied significantly as a function of object category (see Fig. 3A). Follow-up post hoc analyses showed that children with DLD performed better on trials with solid and animate objects than on trials with nonsolid substances and spatial configuration categories ($p < .001$) and performed better on trials with solid objects than on trials with role categories ($p = .021$). These results are presented in Fig. 3A.

To further investigate the relationships between vocabulary and noun extension, we added the vocabulary measures to the model. Therefore, we conducted an analysis of covariance (ANCOVA) on the percentage of correct responses when one learning exemplar was provided with group as a between-participants factor, the object category as a within-participants factor, and receptive and expressive vocabulary measures as covariates. The main effect of group was not significant, $F(1, 26) = 4.11$, $p = .053$, $\eta_p^2 = .14$. The effect of object category, $F(4, 112) = 9.90$, $p < .001$, $\eta_p^2 = .26$, and the interaction, $F(4, 112) = 7.45$, $p < .001$, $\eta_p^2 = .21$, still reached significance. Interestingly, the effect of receptive vocabulary was also significant, $F(1, 26) = 5.89$, $p = .022$, $\eta_p^2 = .18$, contrary to the effect of expressive vocabulary, $F(1, 26) = 3.90$, $p = .059$, $\eta_p^2 = .13$.

To assess whether the observed patterns of results were due to chance responding, we compared each group's performance in each object category condition with chance level (i.e., 33%). The analyses showed that age-matched children performed above chance level in all object category blocks (all *ps* < .01). Children with DLD performed above chance level for solid objects, animate objects, and functional role categories (all *ps* < .01), but their performance was at chance level for nonsolid substances, $t(14) = 0.29$, $p = .78$, and spatial configuration categories, $t(14) = -0.098$, $p = .92$.

Language-matched groups

We conducted a 2 $\times$ 5 ANOVA on the percentage of correct responses when one learning exemplar was provided with group (DLD vs. language-matched) as a between-participants factor and object category (solid objects vs. animate objects vs. nonsolid substances vs. functional role categories vs. spatial configuration categories) as a within-participants factor. Data are reported in Fig. 3B. The analysis did not reveal any group effect, $F(1, 28) = 0.22$, $p = .64$, $\eta_p^2 = .003$. The effect of object category reached significance, $F(4, 112) = 18.10$, $p < .001$, $\eta_p^2 = .39$, and so did the interaction between group and object category, $F(4, 112) = 2.97$, $p = .022$, $\eta_p^2 = .096$. Post hoc analyses using the Tukey method revealed that children with DLD performed similarly to TD children for all object categories (all *ps* > .64). The significant group by object category interaction indicated, however, that the performances of children with DLD varied more as a function of object category. Language-matched children performed better on trials with solid objects than on trials with spatial configuration categories ($p = .001$). In contrast, children with DLD performed better on trials with solid objects than on trials with nonsolid sub-

Table 3
Numbers of incorrect responses as a function of group (age-matched vs. DLD), distractor, and object class.

	Nonsolid substances		Functional role categories		Spatial configuration categories	
	Shape	Color	Visual	Thematic	Shape	Color
Children with DLD (n = 15)	6.80 (4.87)	0.60 (0.91)	1.87 (1.68)	1.87 (1.88)	11.93 (2.59)	1.13 (2.59)
AM children (n = 15)	2.60 (4.34)	0.07 (0.26)	0.53 (0.83)	1.40 (1.35)	6.07 (1.33)	0.93 (1.33)

Note. DLD, developmental language disorder; AM, age-matched.

stances ($p < .001$), functional role ($p = .016$), and spatial configuration categories ($p < .001$). They also performed better on trials with animate objects than on trials with nonsolid substances ($p = .004$) and spatial configuration categories ($p < .001$). Finally, they performed better on trials with functional role than on trials with spatial configuration categories ($p = .044$).

Furthermore, we also investigated the impact of expressive vocabulary on novel noun extension because the language groups were not matched on this measure. We conducted an ANCOVA with group as a between-participants factor, object category as a within-participants factor, and expressive vocabulary as a covariate. The effect of group was not significant, $F(1, 27) = 0.21$, $p = .64$, $\eta^2_p = .003$. The effect of object category still reached significance, $F(4, 112) = 18.10$, $p < .001$, $\eta^2_p = .39$, and so did the interaction, $F(4, 112) = 2.97$, $p = .022$, $\eta^2_p = .096$. Finally, the effect of the vocabulary did not reach significance, $F(1, 27) = 0.95$, $p = .34$, $\eta^2_p = .015$.

Regarding chance level, language-matched children performed significantly above chance level for all categories of objects (all $ps < .01$) except for the category of spatial configuration, $t(14) = 1.88$, $p = .081$. Children with DLD performed above chance level for solid objects, animate objects, and functional role categories (all $ps < .01$), but their performance was at chance level for nonsolid substances, $t(14) = 1.05$, $p = .31$, and spatial configuration categories, $t(14) = -0.84$, $p = .41$.

Number of learning exemplars required for successful word extension

Age-matched groups

To assess whether within-category comparison was beneficial to noun extension, we examined the number of learning exemplars each participant group needed to correctly extend novel nouns, and we then computed a mean for every object category. Recall that the number of learning exemplars was one in the first trial and was two and three if children failed at the first and second trials, respectively. If children were successful at identifying the correct object with one learning exemplar, it meant that they did not need the comparison procedure. However, if children failed with one learning exemplar but succeeded with two or three, it meant that a comparison was beneficial. We conducted a 2 × 5 ANOVA on the mean number of exemplars needed to correctly extend new words with group (DLD vs. age-matched) as a between-participants factor and object category (solid objects vs. animate objects vs. nonsolid substances vs. role categories vs. spatial configuration categories) as a within-participants factor. The main effect of group did not reach significance, $F(1, 28) = 0.15$, $p = .70$, $\eta^2_p = .005$. Because the Mauchly test indicated a violation of the sphericity assumption ($W = 0.48$, $p = .024$), we corrected degrees of freedom using Greenhouse–Geisser corrections ($\varepsilon = 0.75$) for within-participants factors. The effect of object category reached significance, $F(3, 84) = 7.55$, $p < .001$, $\eta^2_p = .21$. More interesting, the interaction between the two factors group and object category was significant, $F(3, 84) = 5.85$, $p = .001$, $\eta^2_p = .17$. This interaction indicated that whereas the number of exemplars differed as a function of object category in children with DLD, no such category-related differences were observed in age-matched children (all $ps > .05$). As shown in Fig. 4A, children with DLD relied on more learning exemplars in the spatial configuration category block than in the solid, animate (both $ps < .001$), and functional role category blocks ($p = .028$). Children with DLD also needed more exemplars for nonsolid substances than for solid objects ($p = .003$). Finally, children with DLD

Table 4
Numbers of incorrect responses as a function of group (language-matched vs. DLD), distractor, and object class.

	Nonsolid substances		Functional role categories		Spatial configuration categories	
	Shape	Color	Visual	Thematic	Shape	Color
Children with DLD ($n = 15$)	6.00 (5.15)	0.47 (0.92)	1.87 (1.51)	1.93 (1.94)	13.60 (7.59)	0.47 (0.83)
LM children ($n = 15$)	3.27 (4.22)	0.60 (0.91)	1.87 (2.00)	2.20 (2.04)	9.33 (8.13)	0.80 (1.47)

Note. DLD, developmental language disorder; LM, language-matched.

relied more on comparison than their age-matched peers for nonsolid substances (p = .005) and spatial configuration categories (p = .007). These results are presented in Fig. 4A.

Language-matched groups

We conducted the same ANOVA on the mean number of exemplars required to correctly extend novel words with group (DLD vs. language-matched) and object category (solid objects vs. animate objects vs. nonsolid substances vs. role categories vs. spatial configuration categories) as factors. The analysis did not yield a significant effect of group, $F(1, 28) = 0.004$, $p = .95$, $\eta_p^2 < .001$, or a significant group by object category interaction, $F(4, 112) = 2.24$, $p = .069$, $\eta_p^2 = .074$. Moreover, the effect of object category was significant, $F(4, 112) = 18.00$, $p < .001$, $\eta_p^2 = .39$. Post hoc analyses using the Tukey method showed that whereas solid objects required less learning exemplars than the other object categories (p = .047 for animate objects, p = .002 for nonsolid substances, p = .022 for functional role categories, and p < .001 for spatial configuration categories), spatial configuration categories required the most (all ps < .001). These results are presented in Fig. 4B.

Response patterns to distractors' irrelevant features

To examine whether children with DLD and their age-matched and language-matched peers exhibited different patterns of response bias toward irrelevant objects' features, we counted the number of times children picked each of the two distractor objects. When participants failed to choose the correct stimulus response (i.e., on trials with one, two, or three learning exemplars), they selected the distractor whose shape or color (or another attribute) matched that of the target object but was not relevant for category membership. Because solid and animate objects elicited a very low proportion of errors, we analyzed separately the data from nonsolid substances, functional role categories, and spatial configuration categories only.

Age-matched groups

For nonsolid substances, we conducted a 2 $\times$ 2 ANOVA with distractor (shape vs. color) as a within-participants factor and group (age-matched vs. DLD) as a between-participants factor on the number of responses. The effect of group reached significance, $F(1, 28) = 7.58$, $p = .010$, $\eta_p^2 = .21$, as children with DLD produced more incorrect responses than their age-matched peers. The effect of distractor was also significant, $F(1, 28) = 26.90$, $p < .001$, $\eta_p^2 = .49$, with distractors based on shape being selected more than distractors based on color. Finally, the interaction also reached significance, $F(1, 28) = 4.74$, $p = .038$, $\eta_p^2 = .14$. Post hoc analyses (Tukey HSD) revealed that children with DLD were more likely to select the shape distractor than their peers (p = .048). They were also more likely to select the shape distractor than the color distractor (p < .001) (see Table 3).

For functional role categories, we conducted a 2 $\times$ 2 ANOVA with distractor (visual vs. thematic) as a within-participants factor and group (age-matched vs. DLD) as a between-participants factor on the number of responses. The effect of group was significant, $F(1, 28) = 4.54$, $p = .042$, $\eta_p^2 = .14$, as children with DLD produced more incorrect responses than their peers. Neither the effect of distractor, $F(1, 28) = 1.58$, $p = .22$, $\eta_p^2 = .053$, nor the interaction, $F(1, 28) = 1.58$, $p = .22$, $\eta_p^2 = .053$, reached significance (see Table 3).

For spatial configuration categories, we conducted a 2 $\times$ 2 ANOVA with distractor (shape vs. color) as a within-participants factor and group (age-matched vs. DLD) as a between-participants factor on the number of responses. The effect of group reached significance, $F(1, 28) = 6.26$, $p = .018$, $\eta_p^2 = .18$, as children with DLD produced incorrect responses more often than their peers. The effect of distractor was also significant, $F(1, 28) = 50.40$, $p < .001$, $\eta_p^2 = .64$, with distractors based on shape being selected more than distractors based on color. Finally, the most interesting result was the significant interaction, $F(1, 28) = 6.37$, $p = .017$, $\eta_p^2 = .18$. Post hoc analyses (Tukey HSD) revealed that both groups selected significantly more shape distractors than color distractors, but this difference increased for children with DLD (p = .016 for age-matched children and p < .001 for children with DLD).

Language-matched groups

For nonsolid substances, we conducted a 2 × 2 ANOVA with distractor (shape vs. color) as a within-participants factor and group (language-matched vs. DLD) as a between-participants factor on the number of responses. The effect of group was not significant, $F(1, 28) = 1.97$, $p = .17$, $\eta_p^2 = .066$, but the effect of distractor was, $F(1, 28) = 24.90$, $p < .001$, $\eta_p^2 = .47$, as distractors based on shape were selected more than distractors based on color. Finally, the interaction did not reach significance, $F(1, 28) = 3.04$, $p = .092$, $\eta_p^2 = .09$ (see Table 4).

For functional role categories, we conducted a 2 × 2 ANOVA with distractor (visual vs. thematic) as a within-participants factor and group (language-matched vs. DLD) as a between-participants factor on the number of responses. The effect of group did not reach significance, $F(1, 28) = 0.061$, $p = .81$, $\eta_p^2 = .003$, nor did the effect of the distractor, $F(1, 28) = 0.22$, $p = .64$, $\eta_p^2 = .008$, or the interaction, $F(1, 28) = 0.097$, $p = .76$, $\eta_p^2 = .003$.

For spatial configuration categories, we conducted a 2 × 2 ANOVA with distractor (shape vs. color) as a within-participants factor and group (language-matched vs. DLD) as a between-participants factor on the number of responses. The effect of group was not significant, $F(1, 28) = 1.78$, $p = .19$, $\eta_p^2 = .060$, but the effect of distractor was, $F(1, 28) = 57.40$, $p < .001$, $\eta_p^2 = .67$, with distractors based on shape being selected more than distractors based on color. Finally, the interaction did not reach significance, $F(1, 28) = 2.59$, $p = .12$, $\eta_p^2 = .085$ (see Table 4).

Summary

When one exemplar was provided, children with DLD performed worse than age-matched children for nonsolid substances, functional role categories, and spatial configuration categories. Children with DLD also performed better for solid and animate objects than for the other object classes. In contrast, 10-year-old (age-matched) TD children performed similarly for all object classes, whereas 8-year-old (language-matched) TD children performed better on trials with solid objects than on trials with spatial configuration categories. Interestingly, receptive vocabulary had an impact on performance when children with DLD were matched with a same-age group.

Concerning the impact of within-category comparison, children with DLD needed more opportunities to compare the stimuli to correctly generalize the novel words for spatial configuration categories than for the other object classes and for nonsolid substances than for solid objects. This result is important given that spatial categories are defined by relations and nonsolid categories are not based on shape. Children with DLD also needed more exemplars than age-matched children to extend words of nonsolid substances and spatial configuration categories. In a similar way, 8-year-old (language-matched) TD children required fewer exemplars for solid objects and more for spatial relation categories. In contrast, 10-year-old (age-matched) TD children relied on the same number of exemplars for all the object classes.

Regarding response choices, children with DLD, as well as 8-year-old (language-matched) TD children, selected distractors based on shape more than distractors based on color for nonsolid substances and spatial configuration categories. In contrast, 10-year-old (age-matched) TD children selected distractors based on shape more than distractors based on color for spatial configuration categories only.

Discussion

The overarching aim of this study was to evaluate the ability of children with DLD to extend nouns referring to diverse object classes. In addition, we explored the impact of lexicon size on new word extension and examined whether this process could be enhanced when children were given the opportunity to perform within-category comparisons. Finally, we analyzed the patterns of response biases when the participants failed to choose the correct object to extend novel words. The comparison between the conditions allowed us to better understand which object properties were used by our three groups when extending different kinds of nouns and to understand toward which properties children with DLD might be biased across lexical conditions.

Higher-order generalization in children with DLD

Our results suggest that generalization abilities in children with DLD varied among different object classes. School-aged children with DLD performed similarly to TD children matched on age for solid and animate objects but performed worse than their same-age peers for nonsolid substances, functional role categories, and spatial configuration categories. Their same-age TD peers performed similarly and above chance level for all object classes. Ten-year-old TD children are able to focus on specific properties according to the object presented and are able to learn a property that is relevant to category membership with unfamiliar stimuli, as for spatial configuration categories.

Our results show for the first time that 10-year-old children with DLD can perform similarly to same-age peers and that they have developed a shape bias. Previously, Collisson et al. (2015) showed that 4-year-old preschool children with DLD were not able to rely on the shape bias. These children also demonstrated weaknesses in detecting visual regularities, suggesting that children with DLD were not able to fully exploit visual information characterizing objects in their environment to support object word learning. Collisson et al. argued that successful emergence of the shape bias depends on the interplay of linguistic and visual information and that both sources of information could be compromised in children with DLD. Studies that revealed difficulty in word extension in children with DLD involved preschool children (Gray, 1998; Schwartz et al., 1987). Our current results completed the picture; with age and experience, children with DLD could develop a shape bias, but this shape bias is developed later than in TD children. Linguistic and nonlinguistic limitations in children with DLD could be a hindrance but not an obstacle; for concrete and frequent material, school-aged children with DLD reached the same performance levels as their peers. Because solid objects are the most frequent in young children's daily life (Samuelson et al., 2008), children with DLD develop a shape bias, albeit some years later than their TD peers. Kan and Windsor (2010) also showed that the difference in word learning between children with DLD and their peers was greater in preschool-aged children than in school-aged children. These authors suggested that less well-developed cognitive skills, such as attention, in young children with DLD (Kapa, Plante, & Doubleday, 2017; Montgomery, 2008; Vissers, Koolen, Hermans, Scheper, & Knoors, 2015) could impair their word learning abilities, whereas age-related factors, such as language and school experience, could affect the performance of school-aged children. This may also be the case in our study; our school-aged participants with DLD may have compensated for their difficulty with age, experience, and the maturation of their cognitive skills. However, our study also showed that children with DLD performed worse than their age-matched TD peers for nonsolid substances and relational nouns (i.e., functional role and spatial configuration categories). Children with DLD may have difficulty when they need to attend to properties other than shape. Interestingly, for nonsolid substances and spatial relation categories, children with DLD performed at chance level. This may be explained by the fact that children with DLD require more time and experience with a specific object class to develop the appropriate attentional bias needed to extend it; school-aged children with DLD might not have enough experience with nonsolid substances and relational nouns to develop attentional biases for these object classes, especially given that these biases appear later and are less robust than the shape bias in TD children (Samuelson et al., 2008).

In sum, children with DLD can extend novel nouns when the relevant property to category membership is a salient feature such as shape. However, they face difficulty when the property to be used involves relational information or texture.

Impact of size of vocabulary on word extension

By definition, children with DLD have language impairment. As previously mentioned, their vocabulary is characterized by limited breadth and depth (McGregor et al., 2013). Comparing word extension in children with DLD with typical children matched on vocabulary size is one way in which to understand the contribution of vocabulary on word extension, in other words, the contribution of a linguistic component on a generalization task. Based on a previous meta-analysis (Kan & Windsor, 2010), word learning was expected to be similar in children with DLD to children matched on lexical abilities. Results from the word extension task in younger TD children matched on a vocabulary measure showed that these 8-year-old children have good capacities for extending nouns of different kinds; they performed above chance level for every object class except for spatial configuration categories. This may be because for spatial configuration categories children need to learn a property relevant for categorization that is arbitrary. It might also be stressed that the instruction format referred to the stimuli as an object, whereas the relevant aspect was a nonsalient spatial relation between two parts. We speculated that this unusual lexicalization situation might have triggered different learning processes. Children with DLD were at chance level. The instructions might have pushed them toward shape rather than the relevant relation (see below).

As predicted, the performance of children with DLD was similar to that of their TD peers matched on vocabulary. Vocabulary and labeling experience have indeed been found to be related to word extension ability (Smith et al., 2002; Thom & Sandhofer, 2009). Moreover, we found that receptive vocabulary influenced performance in the noun extension task for children with DLD and TD children matched on age. Therefore, our study seems to confirm the relationship between word extension ability and vocabulary knowledge or labeling experience. Nevertheless, performance of children with DLD varied more as a function of object category compared with their TD language-matched peers. Moreover, children with DLD performed at chance level for nonsolid substances, which was not the case for TD children matched on vocabulary. It seems that the generalization of substance names could discriminate between children with DLD and TD children of similar lexical abilities. This may be explained by the fact that textures are properties that are less salient than shape (Samuelson & Horst, 2007; Samuelson et al., 2008). Because children with DLD are impaired when detecting regularities in the visual domain (Collisson et al., 2015), texture could be a property especially difficult to identify as appropriate to generalization. Substance names also seem to be less frequent than solid object names, which are predominant in young children's daily life (Samuelson et al., 2008), and less frequent than relational categories, which are as frequent as object categories in adult discourse (Gentner, 2005). Because labeling experience is crucial to word extension (Thom & Sandhofer, 2009), limited experience with substance names could make the extension of such categories challenging, especially for children with DLD.

The benefit of within-category comparison

Children rely on the comparison of within-category exemplars to extend new words. Comparison can be used to identify concrete features, such as shape and texture (Augier & Thibaut, 2013; Smith et al., 2002), but it is especially useful for abstract words that rely on a conceptual or relational categorization criterion (Christie & Gentner, 2010; Gentner et al., 2011). In contrast, DLD has been related to difficulty in using comparisons (Leroy et al., 2012, 2014), whereas to our knowledge no studies have directly investigated the impact of comparison on novel word extension in children with DLD.

Regarding children with DLD, our results show that they relied on comparisons in that they needed more exemplars to extend spatial configuration categories and nonsolid substances than TD children matched on age. Therefore, comparison is beneficial for children with DLD, similarly as for TD children matched on vocabulary, even if some studies have shown difficulties in using comparison and structural alignment in DLD (Leroy et al., 2012, 2014). These findings are consistent with the study of Aguilar, Plante, and Sandoval (2018), which examined the role of object variability (one or three distinct exemplars) for new word learning in a between-group design comparing two groups of 5-year-old children with DLD. These authors found that children with DLD had better retention performance in a word extension task of solid objects when they had been presented with three distinct exemplars rather than one exemplar. The comparison of within-category exemplars seems to be beneficial for children with DLD when extending new words, for solid object names in preschool-aged children (Aguilar et al., 2018), and for spatial configuration categories and substance names in school-aged children. Comparisons may be useful to these children for compensating for their difficulty with higher-order generalization. However, because school-aged children with DLD have developed a shape bias, they do not require comparison to extend solid object names.

The benefit of the comparison observed in children with DLD seems to work in the exact same way as in TD children. TD children matched on age did not require comparison to extend novel words, suggesting that they have developed attentional biases that allow them to extend novel words following a single learning exemplar. In contrast, language-matched TD children used the comparison like children with DLD. These language-matched TD children needed fewer exemplars for solid objects and more for spatial configuration categories compared with the other object classes. This could mean that the shape bias is fully developed in these younger children, whereas they still rely on comparison when they need to learn the relevant property to category membership for nouns other than object names, as for spatial configuration categories.

The impact of shape on generalization

The analysis of incorrect responses has generated a better understanding of the strategies used by children with DLD. These children produced more incorrect responses than TD children matched on age for nonsolid substances, functional role categories, and spatial configuration categories when one, two, or three learning exemplars were provided. Interestingly, children with DLD selected the distractor based on shape to a larger extent for nonsolid substances and spatial configuration categories. This focus on shape suggests a less flexible use of dimensions other than shape when they are conceptually relevant for generalization. This is consistent with other studies showing that children with DLD were more dependent on perceptual features than their age-matched peers and that they required the support of perceptual features to identify relational similarities in linguistic or nonlinguistic reasoning tasks (Leroy et al., 2012, 2014). The current study suggests that children with DLD are biased toward shape even when shape is not relevant, which prevents them from extending nouns for which texture or a relational property needs to be used. Several interpretations of this bias may be distinguished.

First, children with DLD may overgeneralize the shape bias. These children indeed have difficulty in detecting regularities in the visual domain and in identifying contingencies between object properties and categories (Collisson et al., 2015). Therefore, it is likely that once they identify shape as a relevant property to extend novel words, they use it indistinguishably for diverse object classes. Moreover, children with DLD are impaired when they need to identify relational similarities (Leroy et al., 2012, 2014); they may have difficulty in identifying a novel relational criterion to extend spatial configuration categories and rely on shape, which is easily detectable.

Second, children with DLD may have more difficulty in inhibiting perceptual information such as shape. Inhibition has been related to the ability to move beyond perceptual matches in new word extension tasks. Snape and Krott (2018) found a positive relationship between the ability to extend new words on a conceptual feature rather than perceptual feature and inhibition as measured by a classical inhibition task in preschool-aged TD children. This relation was regardless of age and general cognitive maturation. Nevertheless, DLD has been linked to an executive function deficit, especially for inhibition (Cuperus, Vugs, Scheper, & Hendriks, 2014; Im-Bolter, Johnson, & Pascual-Leone, 2006). Therefore, it is possible that poor inhibition abilities lead to an overwhelming focus on salient perceptual features, such as shape, and prevent children with DLD from using texture or relational features to generalize novel nouns referring to nonsolid substances or spatial relations. Future studies will be needed to further investigate this hypothesis by evaluating inhibition in children with DLD and in TD children during word extension tasks.

Third, no differences appeared between children with DLD and TD children matched on vocabulary given that these TD children also selected the distractor based on shape more than the distractor based on color for nonsolid substances and spatial configuration categories. Therefore, this overwhelming bias toward shape may be related to lexical abilities. Word extension has already been linked to vocabulary and labeling experience (Smith et al., 2002; Thom & Sandhofer, 2009). In this study also, we saw that word extension ability was similar between children with DLD and TD children when vocabulary was controlled, whereas vocabulary affected word extension ability when children with DLD and TD children were matched on age. Therefore, it is possible that children with DLD and their language-matched peers have had more experience with solid object names, which drives them to focus on shape preferentially. It is also likely that the impact of vocabulary differs according to children's age; it may be significant for younger children, but it may diminish with language experience and the development of attentional biases such as the shape bias for solid object names.

Another possibility would be that nonsolid objects (or some of them) were not perfectly identified as nonsolid but rather were identified as stimuli with a shape. Indeed, from a methodological point of view, it is virtually impossible to remove all the shape cues from visual stimuli. However, both TD groups chose texture matches beyond chance, which was not the case for children with DLD. This strongly suggests that despite some potential heterogeneity between stimuli in terms of shape affordance, TD children went for the texture choice in this condition, which also did not differ significantly from the animate condition (for example), whereas children with DLD chose the relevant dimension in the nonsolid dimension significantly less than in the animate condition. Taken together, these results suggest that nonsolid objects were uniformly perceived as solid objects and remained special for children with DLD.

Implications

Our results provide new evidence about lexical deficits in children with DLD. There is indeed considerable debate regarding lexical capacities in these children; some authors consider these abilities unimpaired (Ullman & Pierpont, 2005), whereas others identify weaknesses in lexical learning and semantic representation (Kan & Windsor, 2010; McGregor et al., 2013). Our data suggest that a crucial step of word learning, namely word extension, is impaired in DLD. It is likely that children with DLD have difficulty in detecting regularities between language (i.e., object names) and the visual domain (i.e., object categories), which may explain the fact that the shape bias is still not observed in preschool children with DLD (Collisson et al., 2015; Kucker et al., 2019). Our results suggest that once this principle is established, children with DLD use it more rigidly for most noun categories. Moreover, word extension ability in children with DLD bears some resemblance to that in their language-matched peers. This has already been shown for word learning (Kan & Windsor, 2010). This also reinforces the relationship observed between vocabulary and word extension ability in TD children (Smith et al., 2002; Thom & Sandhofer, 2009). Our results are also compatible with a theoretical framework on DLD of a domain-general implicit learning deficit. Finally, this study also raises insights into how the procedure used to evaluate the lexicon in children with DLD can affect their performance. First, assessing word learning, word knowledge, or word extension triggers diverse competencies and will lead to different results (Collisson et al., 2015; Kan & Windsor, 2010; McGregor et al., 2013). Second, the object categories used will also affect the evaluation; using solid object names only, especially if children are school-aged, may lead to an inaccurate picture of their lexical capacities. In this case, it is possible that no deficit will be visible, whereas difficulties would emerge if relational nouns or nonsolid objects had been tested. Our study suggests that word extension tasks on an abstract lexicon such as nonsolid or relational categories were discriminant between school-age children with DLD and those without DLD. Additional studies are needed to investigate the usefulness of these tasks for clinical assessment purposes.

Limitations

This study has some limitations that need to be addressed. First, the sample was relatively small, and a larger number of participants could have increased statistical power. Second, we chose to present two-dimensional objects and not real objects, and this could also have influenced the results, mainly for nonsolid substances. Some authors indeed found that this variable had an impact on the shape bias in preschool-aged TD children; shape was used more often with two-dimensional inanimate objects than with three-dimensional inanimate objects in a word extension task (Davidson, Rainey, Vanegas, & Hilvert, 2018). Moreover, three-dimensional objects were used in previous studies of word extension using substance names (Soja et al., 1991), whereas we used two-dimensional objects, which could have affected our results. Additional information that we should have thoroughly collected is an estimation of children's vocabulary. We found that vocabulary was related to noun extension, but our vocabulary measures did not allow us to evaluate the lexicon size for different object classes. It is indeed possible that the ability to extend names for nonsolid substances would be related to the number of nonsolid substances that children can name. This is consistent with the study of Thom and Sandhofer (2009), who found that the number of color names that children learned was related to their ability to extend novel color names. However, to our knowledge there is no standardized measure of vocabulary allowing for this kind of evaluation. Finally, word extension ability may have been related to inhibition. As has already been discussed, inhibition has been linked to word extension for nouns whose category membership relies on conceptual features (Snape & Krott, 2018). Because children with DLD usually have poor inhibition capacities (Im-Bolter et al., 2006), this would have been an interesting hypothesis to investigate.

Conclusions

This study aimed at evaluating word extension in school-aged children with DLD, using various object classes. Our objective was to examine children's ability to identify regularities between object properties and category organization and so to select the relevant feature to category membership according to the object presented. Results revealed that children with DLD were impaired compared with TD children matched by age when extending nonsolid substances, functional role, and spatial configuration categories, whereas their performance approached the performance of TD children matched on language. Comparisons were beneficial for children with DLD, especially for spatial configuration categories. However, these children were highly influenced by shape even if it was not a relevant property to category membership. Ten-year-old TD children (matched on age) were successful in extending words for all the object classes presented. Eight-year-old TD children (matched on language) also had good capacities except for spatial configuration categories, for which a categorization criterion needed to be learned. In this case, these children relied on the comparison of within-category exemplars to extend new words. Our study presents new evidence about noun extension in children with DLD and in TD children. To our knowledge, this is the first study that compares word extension ability for five different kinds of entity names in TD children and in children with language disorders. Our work contributes some interesting data about word extension in children with DLD, especially regarding the benefit of comparison and the impact of salient features such as shape. Moreover, our findings reinforce the idea that children are able to learn regularities between object properties and category organization and so to focus on diverse features according to the object presented when extending new nouns. Finally, this study confirms the beneficial role of comparison in new word extension.

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Appendix

Nonwords used in the experimental task

/bate/	/bɔʃe/	/bɔdɑ~/	/buni/	/buse/	/ʃave/
/kɔʀi/	/kudɑ~/	/deto/	/dysi/	/dyfɑ~/	/dyzɔ~/
/fasi/	/falɑ~/	/fave/	/line/	/lito/	/malɔ~/
/mapi/	/mise/	/padi/	/patɑ~/	/sɛto/	/sudi/
/suvɛ/	/tavɑ~/	/tysɔ~/	/vido/	/viʒe/	/vilɛ/

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