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Using gestures to help children with developmental language disorder in word learning

1. INTRODUCTION

Developmental language disorder (DLD) refers to a linguistic developmental pathology in which children present slow development of spoken language in the absence of neurological, emotional, sensory or cognitive impairments (Bishop, 2017; Leonard, 2014; Schwartz, 2017). Children affected by such a disorder (hereafter referred to as children with DLD) present varied profiles of language deficits (Schwartz, 2017) that can affect both expressive and receptive language development, as well as each language component (phonological, lexical, morphosyntactic or pragmatic). More specifically, problems with vocabulary development occur in many, although by no means all, children with DLD (Nash & Donaldson, 2005). A large body of evidence supports the view that vocabulary deficits in children with DLD are likely to be attributable to word learning difficulties that make their acquisition of new lexical items slower and/or less extensive in comparison to age-matched children (Kan & Windsor, 2010). A growing body of research suggests that this poor word learning by children with DLD is related to difficulty creating and storing phonological and semantic representations of new words and establishing a strong link between those representations (Alt & Plante, 2006; Gathercole et al., 1997; Gray, 2005; McGregor et al., 2002; Storkel, 2001). Specific

pathways for treatment are therefore needed in order to help children with DLD in learning new words. Among the various types of intervention targeting word learning, gesture-support speech is used in some special education classrooms for children with DLD: teachers, speech and language therapists and other caregivers offer a whole series of visual aids, including gestures, to children along with oral language in an everyday context. We nevertheless must support theoretically why a gesture can help someone to recover a piece of information by providing an additional cue. In addition, empirical evidence for the contribution of gestures to helping children when learning words, either in typical development or DLD, is required. Better understanding of the underlying processes in children could lead to more targeted and, therefore, more effective interventions.

1.1. The scaffolding effect of gestures on word learning from a theoretical point of view

Dual coding theory (Paivio, 2010) supports the idea that gestures can play an important role in scaffolding word learning: information processing in both the visual-manual and auditory-oral channels would create a stronger connection in memory (Capone & McGregor, 2005). Someone using the auditory and visual modalities together when learning words will create two paths to the concept in memory. Gestures will then support the link formed between the phonological form of the word and its referent (semantic representation). As a result, the information will be better retained compared to pure verbal encoding (Allen, 1995; de Nooijer et al., 2014; Macedonia & von Kriegstein, 2012; Tellier, 2008). Such a beneficial effect of input from more than one

modality on word learning is called the "multimodality effect"(Paivio, 2010). Similarly, Macedonia (2003; cites in Macedonia & von Kriegstein, 2012) proposed the connectivity model of semantic processing to account for the high memorability of novel words learned with gestures. According to this model, a complex code involving sensory and motor information is deeper and so improves retrievability. Along the same lines, the levels of processing model (Craik & Lockhart, 1972) established a positive relationship between greater effort or more elaborate processing and better comprehension and recall. Deeper levels of analysis produce more elaborate, longer lasting, and stronger memory traces than shallow levels of analysis. Finally, because the lexical learning deficits of many of children with DLD are associated with deficient short-term memory functioning (Majerus et al., 2006; Montgomery, 2003), using multimodality could be useful in order to reduce the burden on verbal short-term memory during encoding and retrieval. Using gestures could then minimize the memory deficit often reported in children with DLD and help them to retrieve words easily.

1.2. Empirical evidence of the effectiveness of the use of gestures for children with typical development (TD) and children with DLD

First, for children with TD, the use of multiple channels (e.g., speech and gesture) appears to facilitate their language development, including word learning (Capone & McGregor, 2005; de Nooijer et al., 2014; Goodwyn et al., 2000; Marentette & Nicoladis, 2011) and aids second-language word acquisition (Tellier, 2008). For example, Goodwyn et al. (2000) instructed an experimental group of 32 parents of 11-month-old infants to

add iconic[1] gestures (of their own invention) and a control group of 32 parents to only label words in their interaction with their children. The target gestures included simple movements for five objects and three non-object concepts, although the eventual goal of the study was to get families in the experimental group to model many iconic gestures and to get families in the control group to label many words. Results showed that the children in the experimental group (iconic gestures) scored significantly higher than children in the control group did on receptive lexical measures at the ages of 19 and 24 months, and on expressive measures at the ages of 15 and 24 months. The authors concluded that iconic gestures support word learning better than verbal labelling.

In the same vein, McGregor et al. (2009) demonstrated the beneficial effect of iconic gestures on the understanding of the preposition "under" in 20- and 24-month-old infants. Forty children participated in one of three training conditions: the gesture group viewed an iconic gesture for *under* during training; those in the photo group viewed a photograph of objects in the under relationship and those in the control group did not receive any supplemental symbolic support. Only the gesture group demonstrated overall gains; their improvement from pretest to delayed post-test was significant. The authors proposed the following explanation for their results: gestured input likely reduced cognitive load, while emphasizing both the location and the movement relevant to the meaning of "under". In a study with 19 toddlers (mean age: 28 months), Capone

[1] Iconic gestures, also referred to as representational gestures, are manual or facial movements that represent the semantic content of the segments of speech that they accompany (Capone & McGregor, 2005). For example, opening and closing two fingers in the form of a "V" can represent a pair of scissors.

and McGregor (2005) compared 3 word-learning conditions: gestures cued attention to object shape in one experimental condition or to its function in the other, and no semantic cue was provided under the control condition. Six stimuli were used for each condition. Results showed that young children were better in word retrieval in both gesture conditions (shape gesture or function gesture) than in the no-gesture condition, but shape gesture was more effective than function gesture. The authors concluded that semantic representation of objects can be enriched by gestures. In So et al.'s experiment (2012), 4- to 5-year-old children (*n* = 38) watched 3 different videos, each consisting of a list of 5 words in 3 conditions (words accompanied by iconic gestures or by beat gestures[2] or without gesture), and were asked to recall the words without moving their hands. Children recalled more words when encoding them with iconic gestures than when encoding words alone or with beat gestures. These data therefore suggest that gesture that is not semantically meaningful does not enhance memory in comparison to iconic gesture.

In contrast, van Berkel-van Hoof et al. (2016) did not report any effect of gestures on word learning in 9- to 11-year-old children when teaching them new labels for new words/unfamiliar words. The materials consisted of 20 pictures of friendly looking aliens. Half of the words were presented with an iconic gesture and half without one. It was observed that children performed similarly in the gesture condition and no-gesture condition.

[2] Beat gesture is a non-meaningful gesture involving simple motoric movement produced along with the rhythm of the speech (e.g., hand with open palm flips outwards).

Some studies have also investigated the contribution of gesture type to word learning by comparing the contribution of iconic and arbitrary[3] gestures. For example, Marentette and Nicoladis (2011) exposed 86 two- to 5-year-old children to 20 objects (10 familiar and 10 novel), each of which was associated with an iconic or an arbitrary gesture. The child was introduced to each object, shown the gesture and received the label verbally ("Look at the ….; this is a…."). The results from a picture pointing task with 3 foils showed that children rapidly mapped both types of gestures as labels for objects. In addition, the performance for iconic gestures appeared to increase with age. Along the same lines, Luke and Ritterfeld (2014) reported an effect of arbitrary and iconic gestures in 3- to 5-year-old children (*n* = 20; mean age of 4;9 years) compared to a no gesture condition, suggesting that word learning can profit as much from arbitrary as from iconic gestures. In this study, children had to associated nine new phonological patterns (novel words equally divided among words having one, two, or three syllables, constructed following German phonotactic rules) with new concepts (cartoon characters). However, more recently, Vogt and Kauschke (2017) showed that children aged 4 benefited more successfully from observing iconic gestures for word learning than those in two control non-iconic conditions (attention-directing gesture[4] or arbitrary gesture). In their study, children were taught words that they did not know prior to training: six nouns (rare animal species) and six verbs (unusual movement types).

[3] Arbitrary gestures are manual movements having no relation between the form or embodiment of the gesture and the meaning of the verbalisation, for example, moving one's index finger up and down in front of one's head to represent a cup.

[4] In the control condition, stimuli were paired with an attention-directing gesture in the form of a raised forefinger in front of the upper body.

Overall, while not all authors agreed, most studies conducted with TD children showed a contribution of gestures to word learning compared to a condition without gestures. In addition, both iconic and arbitrary gestures appeared to be beneficial, although some studies noted a slight advantage of iconic gestures.

Second, for **children with DLD**, contradictory data were reported. Some studies showed that, as for children with TD, gestural cues had a positive influence on novel word acquisition. For example, Weismer and Hesketh (1993) observed in a receptive task that word–spatial concept pairings (for example, "under") that were taught with iconic gestural support were learned significantly better than using verbal input only. This benefit was found for 5- to 6-year-old preschool children both with DLD (*n* = 8) and with TD (*n* = 8). Luke and Ritterfeld (2014) investigated whether preschool children with DLD could benefit from gestures in learning words using fast and slow mapping; the slow mapping–fast mapping contrast was used because there is growing evidence that children often require considerable input and repetition to fully acquire a word (Deák, 2014). Participants were asked to learn nine novel words corresponding to nine new concepts (cartoon characters) presented in a game format. Twenty children with DLD (3;1 to 5;7 years old) were assigned to two matched experimental groups: with iconic gestures or with no gestures. While comparisons of the two groups revealed no difference after one session (fast mapping), the performance for word learning increased over the intervention sessions, the iconic gestures group outperforming the control group after the third intervention. It is worth noting that, contrary to the results

obtained by Weismer and Hesketh (1993), the groups did not differ at any time in their receptive learning outcomes: the only differences that were noticed were in expression. More recently, Vogt and Kauschke (2017) found that observing iconic co-speech gestures made word learning more efficient in age-matched (*n* = 20) or language-matched typically developing children (*n* = 20) and also in children with DLD (*n* = 20; age 4) than attention-directing or arbitrary gestures. The target items consisted of 12 German words (6 nouns and 6 verbs). Note, however, that while results revealed a numerical advantage for the iconic gestures, the difference between iconic and non-iconic gestures was not significant.

However, as with TD children, some studies have found no effect of gestures on word learning in children with DLD. Van Berkel-van Hoof et al. (2016), using a fast-mapping design similar to Luke et al. (2014; see above for a detailed description), reported that 9- to 11-year-old children with DLD performed similarly in the gesture and no-gesture conditions.

In summary, although the positive influence of gestures has been reported for TD children in most studies (Capone & McGregor, 2005; de Nooijer et al., 2014; Goodwyn et al., 2000; Marentette & Nicoladis, 2011; Tellier, 2008), results suggest that the effect of multimodal input may be more complex than has been assumed so far, especially with regard to non-typical populations. Indeed, only a few studies have focused on multimodal learning in children with DLD. Moreover, those few studies obtained mixed and inconclusive results (Luke & Ritterfeld, 2014; van Berkel-van Hoof et al., 2016; Vogt & Kauschke, 2017; Weismer & Hesketh, 1993). Many differences between the studies

could explain these conflicting data. First, children's age was quite variable, from 2 to 11 years old. Second, the criterion for diagnosis of DLD was quite different from one study to another, with participants presenting various profiles of severity of oral language impairment. Third, some studies compared the performance of children with DLD to that of a typically developing control group, while others did not. Fourth, in some studies, each participant was assigned to one condition (with gestures or without gestures) while, in others, children learned half of the words with a gesture and half without one; this latter method is more reliable. Finally, various materials and learning paradigms were used to train children. In some studies, children already knew target words, while in other studies children were taught new words for new objects; target words were illustrated by pictures in some cases and not in others; slow or fast mapping was used, and so on. Tasks assessing the effect of the gestures were also different (expression or comprehension), as well as the learning tasks. It therefore seems difficult to compare these studies and their results. Based on this literature review, further research in this field is definitely needed to understand in what condition gestures are likely to scaffold lexical development in children with DLD.

1.3. Research goals

This study aimed to examine the impact of iconic and arbitrary gestures on word learning for children with DLD who still showed word learning difficulties. In order to determine whether the results could be related to differences in language level, two control groups were set up: a group of children matched on chronological age (AC group)

and a group of children matched on receptive language level (LC group). More specifically, this study addressed three questions:

(1) Will children with TD and children with DLD benefit from gesture in comparison to a control condition (no gesture) in retrieving newly learned phonological patterns during word learning (fast mapping task)? Our hypothesis here, based on the multimodality effect (Paivio, 2010), was that supporting novel phonological labels with gestures would lead to better learning in children with DLD and TD because input using more than one modality enhances word learning by reducing the load on phonological short-term memory.

(2) Will children with DLD and children with TD benefit more from iconic than from arbitrary gestural cues (in the same task of word learning)? Our second hypothesis, supported by the levels of processing model (Craik & Lockhart, 1972) was that the use of iconic gestures would be more beneficial than the use of arbitrary gestures, because iconic gestures are closely related to meaning and would therefore produce stronger traces than arbitrary gestures, thereby reinforcing the connection between phonological and semantic representations.

(3) Will children with DLD and children with TD perform differently in word learning suggesting a variable benefit of gestures? Due to the persistent difficulties in word learning experienced by children with DLD, it could be expected that they would be particularly helped by the presence of gestures, especially the iconic ones.

In this experiment, children were taught new phonological labels for familiar concepts under three conditions: with the help of iconic gestures, with arbitrary gestures and

without gestures. While in most previous studies, children knew neither the phonological pattern nor semantic referent prior to training, we decided to investigate word learning in a context similar to that of learning a new language, as Tellier (2008) did, in order to determine if gestures help children to encode and retrieve new phonological patterns (pseudword) linked to well-known common concepts. This type of design would allow us to focus on a sub-part of the word-learning process.

2. METHOD

Participants

Thirty French-speaking children, divided into 3 subgroups, were recruited from primary schools to participate in the present study. None of the children was diagnosed with a sensory, cognitive, motor, or emotional disorder. No bilingual children were included and none of them had any experience of sign language or benefiting from treatment-involved gestures. For the purpose of the present research, all children were tested with the Coloured Progressive Matrices (Raven et al., 1998) in order to assess non-verbal intelligence quotient (IQ). All children fell within the normal range (performance superior to 10^{th} percentile) on this non-verbal IQ task. The French version of the Peabody Picture Vocabulary Test–PPVT (Dunn & Theriault-Whalen, 1993) was also administered to evaluate receptive vocabulary level in order to match children. AC and LC children fell within the normal range (> 25^{th} percentile) on this picture-pointing task (Dunn, 1993). Written informed parental consent was obtained for all children and each child participated voluntarily in the study. Procedures were approved by the Research Ethics Boards of the Psychological Institute (approval Projet2015-22).

Three subgroups of children participated (see Table 1):

Children with DLD (DLD group)

10 children (8 boys and 2 girls) with DLD were recruited from three special schools for children with language impairment; they had a mean age of 8 years (*M* = 8;3, *SD* = 12.3 months, range = 6;5–10;1). All the children were previously diagnosed by a multidisciplinary team as having severe and persistent developmental language disorder and all of them were enrolled in speech and language treatment.

Age-matched children (AC group)

The AC group consisted of 10 children (3 boys and 7 girls) matched to the children with DLD for chronological age. They ranged between 6;2 and 9;9 years old (*M* = 8.2, *SD* = 13.1 months); $t(18) = 0.25$, $p = .80$. According to their teacher's report and the background information supplied by the parents, they had no history of speech, language or hearing problems, and no special needs.

Language-matched children (LC group)

Ten typically developing children (5 boys and 5 girls) served as language-matched control children (LC). They had a mean age of 6 years (*M* = 6;2, *SD* = 10.4 months, range = 5;4–8;1). In order to select the group of children matched on receptive vocabulary with our DLD group, we tested a larger group of 26 normally developing children with the PPVT (Dunn et al., 1993), picking those children who fell within the target range. The results obtained on the PPVT were used to select the language-matched control group children; $t(18) = 0.34$, $p = .74$.

INSERT TABLE 1

Material

Fifteen novel words (non-words) were constructed following French phonotactic rules. Because research on children with DLD has shown that they have more difficulties repeating words as the number of syllables increases (Parigger & Rispens, 2010), 2-syllable words were constructed, with a consonant-vowel-consonant-vowel (CVCV) structure. We did not want to make the task too easy by using monosyllabic words or too difficult by using longer words. As children with DLD have more precise representations of initial phonemes than final phonemes (Alt & Suddart, 2012), position-specific biphone frequency (New et al., 2001) was also controlled for. Moreover, we ensured that these non-words were not phonologically close to each other or to real words.

Each novel word was associated with a familiar concept (a noun). To be sure that the concepts were well known to the participants, all selected words were concepts considered to be acquired before 3 years old (Chalard et al., 2003).

Each novel word–familiar concept pair was randomly assigned to one of the three conditions: iconic gestures, arbitrary gestures or no gestures (five per condition). Moreover, the five concepts in each condition corresponded to the same five semantic categories. Table 2 presents all the 15 items constructed as well as their linguistic properties.

INSERT TABLE 2

For the two conditions using manual movements, all gestures were produced in the head and chest area. Each gesture consisted of a sequence of two repeated movements that could be easily imitated. Iconic gestures give semantic or functional information about a concept. For example, the gesture associated with the novel word /beRO/ that designates “rabbit” consisted of miming rabbit ears with two hands on the head. In contrast, arbitrary gestures show no relation between the form or embodiment of the gesture and the meaning of the verbalization. For example, the gesture for “pen” consisted of making two circles with the index finger in front of the nose. In a pilot study, gestures were tested for their iconicity by presenting them to seven French-speaking adults who were unaware of the purpose of the study. Iconic gestures were selected when all the adults were able to recognize the concept associated with the gesture without giving them any cue. By contrast, arbitrary gestures were chosen when no adult recognized the concept even when a semantic cue was given. Figure 1 gives some examples of the gestures used.

INSERT FIGURE 1

Procedure

The participants attended four 30-minute sessions. The first session involved the administration of the screening tests (PPVT and Coloured Progressive Matrices) in order to compose our groups, while the following three sessions were devoted to the experimental tasks. All children participated in each experimental condition: (1) iconic gestures, (2) arbitrary gestures and (3) no gestures. The order of encountering the experimental conditions was counterbalanced across participants. The three conditions

were identical with regard to procedures, task and frequency of naming the novel words. Children participated in the experiment individually in a quiet room at school.

In each experimental session, the child had to learn five novel words (non-words), which were introduced as words used by Martians. Each word was associated with a familiar concept. Each experimental session (one session for each condition) consisted first of a training phase (of about 20 minutes) followed by an interference task (of about 5 minutes) and ending with the test phase (of about 5 minutes). In order to limit interference between sessions, a minimum interval of 2 days occurred between each session.

(1) Training phase

In order to stimulate participants, the training task was presented as a game. Children were instructed that they were going to learn some "funny-sounding" words. A board game was created to give some visual motivation. They were told about the game as follows: "*A little Martian has arrived on Earth but he speaks another language. The Martian needs your help to find his flying saucer. To understand what he is saying, you have to learn his language. Each time you learn a word, you will move the little Martian on the board.".*

In each condition, novel words were presented many times in two semi-standardized tasks, which were introduced as games. In the **first game (the discovery game)**, the experimenter named the novel word twice ("*the Martian calls a hat /tuna/, a hat is a /tuna/ for the Martian").* After that, the child had to produce the novel word: the first

time after being prompted with the first syllable and the second time without any prompt. The experimenter then gave the child feedback and said the correct novel word again. The five novel words were presented in this way, with a reminder of the word just learned being given before each new word was introduced. In the **second game (the reminder game)**, all associations (concept–novel word) were reviewed using rapid recall. First, the experimenter gave a novel word and the child had to recall the associated concept. Next, the experimenter pronounced a French word and the child had to recall the novel word linked to it. In each case (correct response, incorrect response or no response), the experimenter gave feedback by recalling the novel word and the associated concept. In this first phase, the concept–novel word pairs were heard six times (four times in the discovery game and twice in the reminder game) and the child repeated each novel word orally four times (twice during the discovery game and twice during the reminder game). In the iconic gestures condition and the arbitrary gestures condition, the procedure was the same, but a gesture was added to the novel word. The gestured input was given at the same time as the word to be learned. The children were not asked to imitate any of the gestures in any of the conditions[5]. Figure 2 illustrates the underlying mechanisms of the training task. In daily life, when a child learns a new word, he or she has to associate a phonological representation with a semantic representation. In this experiment, we tested if the use of gesture helps children to link a phonological form (the novel word to learn, e.g., /ZynE/) and a pre-existing semantic representation (a familiar concept, e.g., scissors).

[5] None of the participants spontaneously imitated the gestures during the tasks.

INSERT FIGURE 2

(2) Interference task

As an interference task, participants and the experimenter played the published game "Dobble" (*Amsodéé Edition*) for about five minutes. The aim of this game is to identify a common picture on two different cards as quickly as possible.

(3) Testing phase

During the testing phase, the experimenter explained that the Martian was coming to check whether the child had learned the words properly. The child had to recall the novel word associated with each concept: *"Could you remind me what the Martian calls scissors?"*. In case of an incorrect or no answer, the gesture or the first syllable was given as a prompt. If the child still failed, a word recognition task was administered. In this task, the child was asked to select the correct novel word from a choice of three: the correct answer, a phonological distractor and an interference distractor (one of the novel words associated with another concept). Four points were awarded for mentioning the target word directly, three points for recalling the novel word after being prompted by the gesture (in gestures conditions), two points for recalling the novel word after being prompted with the first syllable and only one point if the child identified the target word only in the recognition task. The maximum score per condition was thus 20 points.

Analyses

The analyses were performed using the statistical software SPSS 19. We first checked each variable (PPVT score, non-verbal IQ and word learning score) in our experimental model for normal distribution and homogeneity of variance (Levene's test). These conditions being met, a repeated-measures ANOVA was conducted on the word recall scores, in which the learning condition was the within-subjects variable (iconic gestures, arbitrary gestures and no gestures) and the group (AC, LC and DLD) was the between factor.

3. RESULTS

The mean performance and standard deviation per group and condition are displayed in Table 3. As illustrated in Figure 3, DLD and LC children performed more or less identically, while AC children showed higher performance.

INSERT FIGURE 3

INSERT TABLE 3

More specifically, the data first showed a **group effect:** $F(2,27) = 4.326$, $p = .023$, $\eta^2 = 0.243$. The Tukey test for post-hoc comparisons revealed that the AC group showed a significantly higher performance in word learning than the DLD group ($p = .039$) and the LC group ($p = .048$). In contrast, no significant difference was identified between the DLD and LC groups ($p = .99$).

Second, the results revealed a **significant condition effect:** $F(2, 27) = 3.43$, $p = .040$, $\eta^2 = 0.113$. Performance was better for the two conditions using gestures in comparison to the control condition (no gesture). Because our hypothesis is that gestures play a role in

retrieving phonological patterns during learning words, we used a unilateral test. A Bonferroni correction for post-hoc comparisons revealed a significant difference between the iconic gestures and no gestures conditions (p = .041) and between the arbitrary gestures and no gestures conditions (p = .009), but no significant difference between iconic and arbitrary gestures (p = .87).

Note that the data showed **no interaction effect between group and condition:** $F(2,27) = .204$, p = .935, η^2 = .015. Gesture type influenced word learning performance in the same way for our three groups.

We also calculated the mean percentage of each type of answer in the testing phase for each group of children, depending on condition. As a reminder, in the testing phase, the children had three possibilities for answering: directly (free recall), by being prompted (gestural or phonological prompt) or as a choice among three words (recognition). Because the data lacked normal distributions and homogeneity of variance, non-parametric tests were used. When we treated performance separately depending on the type of answer (free recall, with prompting or recognition), there was no significant effect of condition. As far as group effects, the data showed no significant difference between the LC and DLD groups for free recall (U = 37.5, p = .33), prompting (U = 36.5, p = .294) or recognition (U = 48, p = .878). In contrast, the data showed a significant difference between the AC and DLD groups for free recall (U = 21, p = .027) and for prompting (U = 22.5, p = .035); the difference for recognition was not significant (U = 49.5, p = .969). The same significant differences were observed between the LC and AC groups for free recall (U = 17.5 p = .013) and prompting (U = 15.5, p = .007) but not for

recognition (U = 48.5, p = .908). As illustrated in figure 4, the AC group mainly used free recall, while the DLD and LC groups needed a prompt in order to recall a novel word, regardless of condition.

INSERT FIGURE 4

4. DISCUSSION AND CONCLUSION

4.1. The scaffolding effect of gestures on word learning

First of all, on the basis of these data, it appears that word learning continues to be a challenging area for children with DLD in comparison to age-matched children (Alt & Plante, 2006; Gray, 2003, 2004, 2005; Kan & Windsor, 2010), even if they only have to learn a new phonological form. Nevertheless, children with DLD showed performances similar to those of younger children at the same lexical receptive level. Second, our results showed that gestures had a beneficial effect on word learning for both children with DLD and TD children. More specifically, LC children and children with DLD performed similarly in word learning taking the form of retrieving a new phonological pattern for already known words, while the AC group showed better performance, but every group showed higher scores for both gesture conditions in comparison to the control condition without gestures. However, none condition (iconic, arbitrary or no gesture) did not seem to facilitate free recall and/or prompted recall separately. Globally, in terms of groups, children in the AC group were mainly able to answer using free recall, while DLD and LC children needed a prompt to recall novel words.

Memorization seemed to be more effective for AC children. Note that our design enables us to identify some tendencies, but it would need to be adjusted to really determinate the role of response modality. We would have to assess each participant in separate response modality: one with only free recall, another with only recall with a prompt and a last one for recognition (see section on limits).

These data confirm previous studies with TD children showing improved performance when more paths are created through multimodal input when learning new words (Capone & McGregor, 2005; Goodwyn et al., 2000; Luke & Ritterfeld, 2014; So et al., 2012) or learning a second language (Macedonia & von Kriegstein, 2012; Tellier, 2008). These results also underline the scaffolding effect of gestures reported for some preschool children with DLD (Luke & Ritterfeld, 2014; Weismer & Hesketh, 1993). Because gestures give visual/gestural cues when learning words, the information is retained better by TD children and children with DLD, supporting the multimodality effect as predicted by dual coding theory (Paivio, 2010).

In contrast, this study did not replicate the findings reported by van Berkel-van Hoof and al. (2016), namely, that children with DLD and TD do not benefit from augmentative gestures for word learning. The difference between that previous research and the present study may lie in the age of the children tested: 8 years old in our study, but 9 to 11 years old in van Berkel-van Hoof et al. (2016). The beneficial effect of gestures may no longer be apparent at this older age, as suggested by McGregor and colleagues (2009), because these older children would have already developed compensatory strategies. At 9 or 10 years old, children have perhaps already created specific ways of learning words and do not need gestures anymore to acquire words. Another difference

is that in this present study, we focused on learning new object labels for familiar objects (e.g., Macedonia et al., 2011; Tellier, 2008), so that participants only had to remember a novel word for an existing concept. By contrast, in van Berkel-van Hoof's study (2016), the participants had to learn both a new phonological pattern and a new concept. A last difference between the present study and van Berkel-van Hoof's research is that our participants with DLD seemed to present more severe and more persistent lexical deficits, and therefore probably had more opportunities to benefit from gestures.

4.2. Influence of the nature of the gesture on lexical learning

While our main expectation was that iconic gestures would better aid children in learning new words than arbitrary gestures, we observed no difference between the two gesture types in their impact on novel word learning in DLD, AC and LC children. In agreement with the findings of Luke and Ritterfeld (2014), TD children showed similar performance with iconic or arbitrary gestures. Thus, both types of gestures reinforce the connexion between phonological and semantic representation and are easier to retrieve, as supported by the levels of processing model (Craik & Lockhart, 1972). Both types of gestures seem to have a compensatory effect with TD children and children with DLD. The data did not confirm previous research conducted on young TD children that found significantly better memory performance for iconic gestures than for meaningless gestures (Feyereisen, 2006; Macedonia et al., 2011; Marentette & Nicoladis, 2011; So et al., 2012; Vogt & Kauschke, 2017) as well as in second-language learning (Kelly et al., 2009).

The fact that iconic and arbitrary gestures affected word learning in the same way in our three groups suggests that gesture may only play a role as an additional form of information. Adding gesture may increase the child's attention to novel word and improve the ability to retain the word for later retrieval. Note that, in the present study, participants have to learn phoneme chains associated with already known concepts. This may explain why the semantic properties of the gestures seemed to matter less.

4.3. Limitations

Some limitations of this study need to be mentioned. First, it must be considered as exploratory research. The small number of items per condition and small sample size limited the statistical power.

Second, we did not objectively measure phonological short-term memory skills, although children with TD are known to have stronger short-term memory skills than children with DLD (Gray et al., 2019). Differences in word learning could therefore be related to the phonological short-term memory component. Indeed, given the brief number of exposures and interference task prior to response, there is likely to be a memory component in addition to word learning. It would then be necessary, in future studies, to take phonological short-term memory skills into account in order to check their potential impact in word learning when gestures are provided.

Third, it is sometimes suggested that children show higher rates of learning when they perform the gestures themselves (Engelkamp & Cohen, 1991), rather than merely observing another person gesturing and hearing the words (Allen, 1995; Cohen & Otterbein, 1992; Saltz and Donnenwerthnolan, 1981 cited in Macedonia & von

Kriegstein, 2012; Tellier, 2008). Indeed, some authors have suggested that gesture and language form one integrated communication system (Mc Neill, 1992; Wray et al., 2016). Some studies lead to assume that physical enactment creates a motor trace in the memory representation of the verbal item (see Macedonia & von Kriegstein, 2012, for a review of the possible mechanisms underlying the effects of gestures on verbal memory). In the present study, children were not encouraged to enact the gestures. Future research is therefore needed in order to tackle questions with regard to the possible added value of using the motor modality during word learning. Is retrieval better if participants (TD or DLD) have to imitate gestures?

Fourth, it is well known that the amount of exposure to words plays a role: children with DLD need more exposures than TD children. In the present study, only fast mapping was tested.

Last, combining free recall, prompted recall and recognition measure to derive a single unit of retrieval accuracy is challenging; these various measures focus on different types and aspects of word learning. It would be necessary to assess each participant in separate response modality: one with only free recall, another with only recall with a prompt and a last one for recognition.

4.4. Future directions

In addition to the various avenues suggested by the above-mentioned limitations, several future directions could be investigated. First, children's age and the severity of their language impairment could influence the results. A controlled study of children of

different ages could be conducted in order to check if the effect of scaffolding gestures disappears with time, suggesting that this type of support does not help after a certain point. Controlling the level of language impairment could also help for understanding whether a specific level of language skills is required to benefit from gesture input.

In order to prove that gesture is a real support in word learning and to identify the role of any symbolic support in general, we could test the beneficial effects of using photographs, pictograms or drawings, by comparing the learning of children who received gesture support to children who received photograph/drawings/pictogram supports or no extra symbolic support.

Future research could also attempt to replicate the beneficial effect of both types of gestures by assessing and controlling for the gestures' degree of iconicity. Macedonia and von Kriegstein (2012) showed that material paired with actions during learning leaves a motor trace independently of the kind of gestures used. Moreover, it could be relevant to pretest our novel words and our gestures on a larger group of normally developing children in order to check if any of them are easier to remember. This would reduce any effect of condition linked with our materials.

Furthermore, the type of words the children learn may influence the gesture effect. De Nooijer et al. (2014) studied the effect of augmentative gestures on verb learning by children with DLD. In their study, gestures only aided word learning for locomotion verbs, but not for verbs for object manipulation or abstract verbs. The benefit of augmentative gesture should thus be investigated for different types of words (nouns, verbs, etc.).

Last, when assessment occurs may play a role in memorization. Because learning is a long-term process, it would be relevant to check any variations in maintenance of gains over the long term, and not assess memorization only right after the training (fast versus slow mapping).

4.4. Clinical implications

These findings have relevant implications for practice, specifically for speech and language therapists, as well as teachers who work with DLD or TD children. Based on these data, we would recommend the use of gesture for word learning or other memorization tasks, particularly in children with language development barriers (DLD) up to the age of about 8. Using visual aids such as gestures could also help TD children in learning spoken words.

4.5. Conclusion

While this study indicates a scaffolding effect of both types of gestures for children with DLD and TD children in comparison to a control condition without gestures, the effectiveness of the use of gestures in speech therapy or language training in primary school and preschool needs to be further assessed, as well as the respective role of iconic and arbitrary gestures in learning new words.

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Table 1.

Sex, Chronological Age, Raw Score on PPVT-R and Nonverbal Intelligence Score for the Three Groups of Participants

Measure	AC	LC	DLD
Sex			
Female/Male	7/3	5/5	2/8
Chronological age (months)			
M	98.0	74.0	99.4
SD	13.16	10.40	12.30
Min–max	74–117	64–97	77–121
Raw scores on PPVT-R			
M	96.9	73.0	70.8
SD	17.09	13.67	15.01
Min–max	74–117	54–100	55–93
Raw scores on nonverbal intelligence test			
M	28.5	21.6	26.7
SD	4.70	5.08	3.40
Min–max	20–35	14–31	22–32

Note. AC = age-matched children; LC = language-matched children; DLD = children with developmental language disorder; Min = minimum; Max = maximum; PPVT-R = Peabody Picture Vocabulary Test-Revised (the French version was used in this study; Dunn & Theriault-Whelan, 1993). Nonverbal intelligence was measured with the Coloured Progressive Matrices (Raven et al., 1998).

Table 2.

Items Used in the Experiment and Their Linguistic Properties

Condition	Familiar concept	Semantic category of the concept	Novel word (in SAMPA)	Biphone frequency
Iconic gestures	Moto (motorbike)	Means of transport	/dite/	2016
	Lapin (rabbit)	Animal	/beRO/	292
	Couteau (knife)	Kitchen	/fOza~/	350
	Lunettes (glaces)	Clothes	/se~Ri/	660
	Ciseaux (scissors)	School	/ZynE/	421

Arbitrary gestures	Camion (trucks)	Means of transport	/puti/	337
	Cheval (horse)	Animal	/kytO/	286
	Poubelle (bin)	Kitchen	/laze/	788
	Chaussures (shoes)	Clothes	/naso~/	396
	Crayon (pen)	School	/fima~/	2024
No gestures	Vélo (bicycle)	Means of transport	/kORo~/	2028
	Souris (mouse)	Animal	/ma~de/	398
	Bouteille (bottle)	Kitchen	/vEZi/	356
	Chapeau (hat)	Clothes	/tuna/	293
	Ballon (ball)	School	/seta~/	749

Note. SAMPA = Speech Assessment Methods Phonetic Alphabet.

Table 3.

Mean Scores and Standard Deviation for Each Group in Each Experimental Condition

		AC	LC	DLD
Iconic gestures	*M*	13.3	10.7	11.4
	SD	3.4	3.65	3.17
Arbitrary gestures	*M*	13.8	11.2	10.8
	SD	3.91	2.44	3.45
No gestures	*M*	11.8	9.8	9.2
	SD	2.97	2.09	2.30

Note. AC = age-matched children; LC = language-matched children; DLD = children with developmental language disorder.

Figure 1. Illustration of the Different Types of Gestures

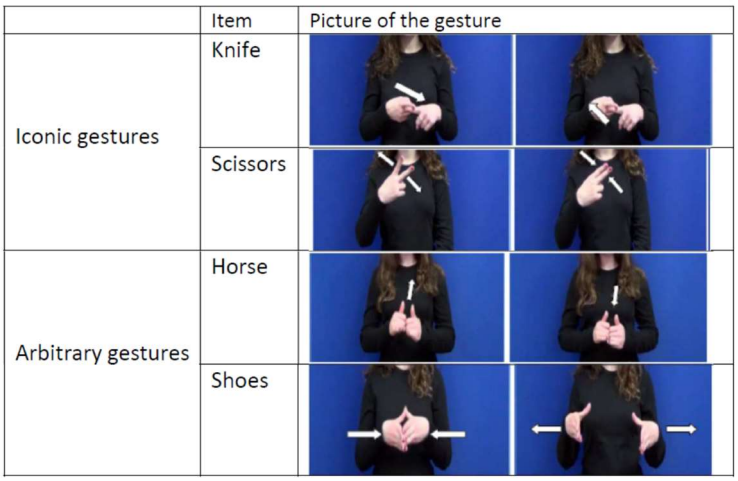


Figure 2. Illustration of the Underlying Mechanisms in the Word-Learning Process and in This Experiment

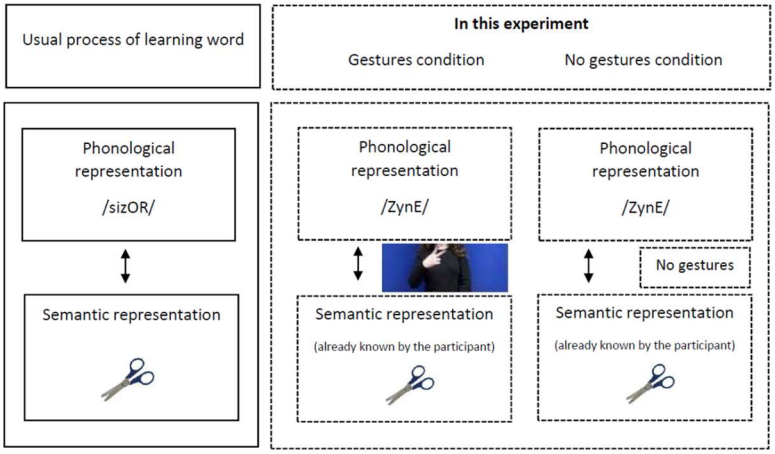
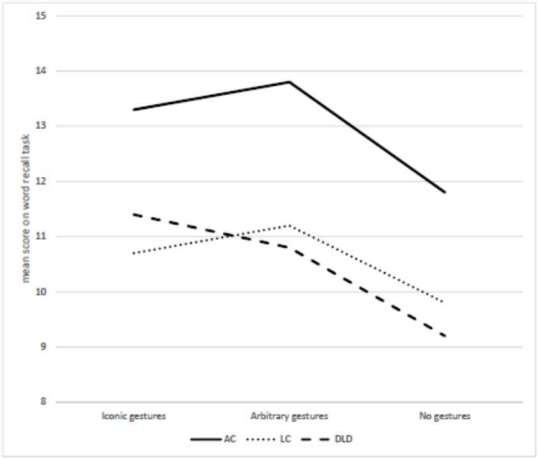
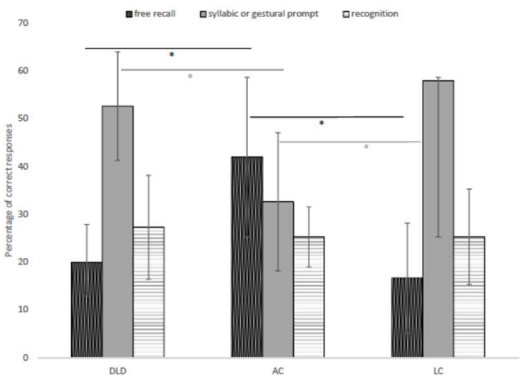


Figure 3. Children's Performance Per Group and Condition (Mean Score)



Note.AC = age-matched children; LC = language-matched children; DLD = children with developmental language disorder

Figure 4. Mean Percentage of Responses Across Groups Depending on Type of Answer



Note.Error bars display 95% confidence interval. AC = age-matched children; LC = language-matched children; DLD = children with developmental language disorder.
* $p < .05$