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A comparison of learning and retention of a syntactic construction between Cantonese-speaking children with and without DLD in a priming task

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ABSTRACT

Procedural circuit Deficit Hypothesis (PDH) of Developmental Language Disorder (DLD) predicts problems with learning and retention of grammar. Twenty 7- to 9-year-old Cantonese-speaking children with DLD and their typically developing (TD) age peers participated in a syntactic priming task that was given in two sessions one week apart. Production of Indirect Object Relative Clause (IORC) was tested using a probe test before and after the priming task, and one week later. The study involved two cycles of learning and retention, and two levels of prior knowledge. Bayesian linear mixed effects modelling was used for data analysis. Children with DLD learned, and possibly retained, IORC less well than TD children after age, working memory and general grammatical knowledge were controlled for. No interaction effects were significant, meaning that cycle and prior knowledge affected both groups similarly in learning and retention. Results were discussed in relation to PDH and the Complementary Learning Systems Theory.

1. Introduction

Developmental language disorder (DLD) is a language learning disability that persists over time (see Bishop et al., 2016 for a recent review). Given a rate of growth that does not exceed but only parallels that of their age peers, primary school-age children with DLD remain behind in their language ability despite improvement in absolute terms with age and intervention (Norbury et al., 2017). Regarding the learning of specific language targets, children with DLD need more trials to reach the same level of performance as their age peers (e.g., Wada et al., 2020). There can be at least two reasons for children with DLD's slower learning rate. They do not learn the language target well when given input, and/or they do not retain much of what they have learned when input is withdrawn. Therefore, with subsequent input, they have less to build on, resulting in less learning. Current evidence from word learning studies suggests that children with DLD's problem was more in learning than retention (Bishop & Hsu, 2015; Gordon et al., 2021; McGregor et al., 2013; McGregor et al., 2017). It is however unclear whether the same findings can be observed in children with DLD when they learn a syntactic construction, especially when it has been argued that word learning and grammar learning involve different memory systems (Ullman, 2004). In this study, we compared the learning and retention of the Indirect Object Relative Clause (IORC) in two groups of Cantonese-speaking children, one with and the other without DLD, with training provided in two sessions one week apart using a syntactic priming task.

1.1. Cantonese-speaking children with DLD and relative clause

Like their English-speaking counterparts, Cantonese-speaking preschool children with DLD also have difficulties with function words, including modal auxiliaries (Leonard et al., 2007) and aspect markers (e.g., Fletcher et al., 2005). These function words are semantically or pragmatically motivated, and their absence is not considered a violation of the grammar of the language. With regard to syntax, preschool children with DLD have difficulties with passive construction (Leonard et al., 2006), who-object question (Wong et al., 2004) and serial verb constructions (Wong et al., 2021). Emerging evidence on school-age children with DLD suggested problems with complex sentences (To

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et al., 2010).

Specifically, relative clauses have recently found to be vulnerable in Cantonese-speaking school-aged children with DLD. Six- to 9-year-old children with DLD scored significantly lower than their age-matched typically developing peers in offline comprehension (Lai et al., 2023) and sentence repetition (Lai et al., under revisions, this issue) tasks, adding new empirical evidence to the Chinese and cross-linguistic literature that reported difficulties with relative clauses in children with DLD. Specifically, Lai et al. (under revisions, this issue) included the indirect object relative clause (IORC), the target syntactic construction in the current study (see Example 1 below for an illustration), and documented that children with DLD found it more challenging to produce IORC than their TD peers. IORC overlaps structurally with the frequently occurring prepositional dative main clause, and the competing interpretations could lead to potential pronoun resolution issues that pose challenges in the processing of IORC (see Lai et al., under revisions, this issue, for details). IORC was among the most challenging relative clause types for children with and without DLD to repeat (Lai et al., under revisions, this issue). Only 9.6 % of 6-year-old children were able to produce an IORC correctly in an elicited task (T'sou et al., 2009).

1.2. Syntactic priming and learning and retention across time

A syntactic priming task was used in this study because it shared several common features with grammar intervention (Leonard, 2011). While grammatical intervention can be explicit, implicit learning is typical in younger children (Ebbels, 2014). In both priming and intervention tasks, children are expected to implicitly learn to interpret and use the grammatical target without feedback and being explicitly told what the target is. Other common features include the provision of multiple exemplars of the grammatical target that is presented frequently within a short time frame in unambiguous and meaningful contexts; the goal of changing the child's linguistic behaviour by changing the child's degree of knowledge of the mapping between the grammatical target and its meaning; and the grammatical target is not well known by the child.

Syntactic priming is "the unconscious repetition of grammatical constructions across utterances (and speakers)" (Messenger, 2022, p, 2). When someone has experienced a construction in a previous utterance, s/he is more likely to produce, or expect to hear, the same construction (Leonard, 2011). Studies involving typically developing children reported three key findings. First, syntactic priming is implicit learning. Evidence came from Kumarage et al.'s (2022) longitudinal study on a group of 106 children who completed a priming task involving the English active and passive alternating constructions every six months from 36 months of age. The children showed an early emergence of the abstract priming effect and a later emergence of the lexical boost effect which increased over time. The lexical boost effect is observed when the priming effect is larger in items where the prime and the target pair share the same main verb. The abstract priming effect is observed when priming effect is present without lexical overlap. The syntactic priming documented in the study is more consistent with an implicit learning account of language acquisition (Chang et al., 2006).

Second, cumulative effects of multiple primes can last for at least a week (e.g., Savage et al., 2006; Vasilyeva et al., 2006). In Branigan and Messenger's (2016) study, 3- to 4-year-old children were given the same priming task twice, once in each session, 1 week apart. The children's production after each active and passive prime in the session was scored. They produced more passives after passive primes but not active primes, and they used more passives in the subsequent learning phase in Session 2 than in the initial learning phase in Session 1. The priming effect, however, was consistent across the two phases. These results suggested that the repeated use of the same priming task did not make it more or less effective for learning, and that learning from the priming task was cumulative and retained, leading to increased use of the passives in the subsequent priming task.

Third, effects of a prime are not transient. Messenger (2021) examined 3- to 4-year-old children's production of passives using the same priming task with the same alternating active and passive primes as used in Branigan and Messenger (2016). Unlike Branigan and Messenger (2016), this study involved just one session, but children's production was measured in two phases: the priming phase and the post-exposure test phase that did not include exposure to the prime constructions. There were three key findings. Children in both the immediate and delayed testing conditions produced more passives than those in the baseline condition who had no exposure to either the active or passive primes in the priming phase. The same pattern of findings was observed in the test phase. Children in the delayed condition completed a 2- to 3-minute word repetition task before the test phase. Children who produced more passives in the priming phase were more likely to produce passives in the test phase. These findings suggested that learning from the priming task persisted beyond an immediate prime trial, and that increase in the knowledge of the target passive construction that was primed was not transient. While children's use of passives in the priming phase is an indication of learning, their use in the test phase can be considered evidence of knowledge retention that is supported by memory consolidation.

Retention is observed when there is offline improvement or maintenance of the gains that result from training. Retention depends on consolidation, which is a memory process by which a relatively fragile knowledge representation of the learning item is retained in long term memory after the end of training and becomes more stable (Robertson et al., 2004). Individual differences in retention are related to age and working memory (Fenn & Hambrick, 2012). To our knowledge, there have been no studies that examined learning in the priming phase and retention in the test phase in the same session as in Messenger (2021) and involved two or more rounds of the same priming task over a number of sessions as in Branigan and Messenger (2016) and Kumarage et al. (2022). Such a study is particularly relevant for children with DLD as it will shed light on their process of learning in therapeutic intervention when there is interleaved exposure to and repeated testing of the language target across time.

1.3. Learning and retention in individuals with DLD

Four studies examined language learning and/or retention beyond one training session in individuals with DLD using various tasks. Three of these studies were on word learning. In McGregor et al. (2017), young adults with DLD recalled and recognized the new words less well than their typical age peers immediately after training. The performance gap between the two groups, however, remained the same in the word recall task one week later with no additional training provided. Another piece of evidence suggesting problems more with learning than retention came from Bishop and Hsu (2015). In their study, children with DLD, their age matched peers and younger children matched on receptive grammar participated in a word learning and a meaningless auditory-visual paired associate learning task. The three groups of children received four training sessions and a post-test session on the two tasks. The DLD group performed worse than the age matched group in the word learning task, which was evident early from the second of the three blocks in the first training session, suggesting learning problems. The DLD group, however, did not show a different learning rate across the four training sessions when compared with the other two groups, suggesting comparable performance in retention.

The third study was similar to the current study in that learning was examined over multiple training sessions, and retention was also measured between training sessions. In Gordon et al. (2021), preschool children with DLD and their typical developing age peers participated in training on names of nine unusual objects in six consecutive days. Each training session began with one block of testing, followed by three blocks of training and ended with another two blocks of testing. The training task was similar to the test tasks except that the children were repeatedly asked to say the words modelled for them and received feedback on their responses only during training. Results from three measures were of particular interest. First, the probability of producing the words was measured at the end of each training day as an index of the children's ability to encode the words during training. Results were in favour of the typical group, and most interestingly, the probability of producing the words increased to the same degree per training day across the groups. In other words, children in the DLD group had problems with learning and yet they showed a steady rate of learning just like their age peers. Second, changes in the probability of producing the words at the end of one training session and at the beginning of the subsequent training session were examined as an index of retention during training. Results did not favour either group, suggesting that children in the DLD group were comparable with their same age peer group on retention. Third, the probability of producing the words at the end of the last training day and the one-month delay were measured as an index of post-training knowledge retention. Results indicated that the probability decreased in a similar degree in both groups of children, suggesting comparable ability to retain knowledge of the words without further training and incidental additional exposure in their everyday environment.

One priming study on children with DLD involved repeated exposure of a syntactic construction and multiple testing points over time. It reported results for comparable performance in retention in children with DLD as well. A group of Italian-speaking children with DLD and their age matched peers participated in Bettelli et al. (2023). All 42 children in the DLD group participated in a once-a-week program that trained them on the third-person object clitic pronouns (3DO clitic) using a story-based priming task for four weeks. Twenty-three children with typical development were also in the training group (TDT), and the other 29 typically developing children in the alternative group (TDA) did not receive training but participated in a book reading activity for the same amount of time. Children received an evaluation of their 3DO clitic at three time points: pre-training (pre-evaluation), one week (post evaluation) and 3.5 month (late evaluation) after training. As expected, the DLD group produced fewer number of the 3DO clitic than both the TDT and TDA groups at pre-evaluation. An important finding is that in both post and late evaluations, the DLD group did not use the 3DO as well as the TDT group, but they used it at a comparable level as the TDA group. The fact that the DLD group caught up to the TDA group suggested retention of knowledge from the prime task training. Further evidence of the DLD group's retention comes from the fact that the same level of performance was maintained at post and late evaluation much in the same way as the TDT group. Given no report on the children's use of the 3DO during the prime training task as is typical in priming studies, no conclusion, however, could be drawn on children with DLD's initial learning of grammar relative to the TDT group.

Learning and retention in individuals with DLD have also been examined using non-language tasks, but the results were mixed. In Earle and Ullman (2021), adults with and without DLD completed two tasks, a recognition memory task and a serial reaction time task, twice with a 12-hour overnight period in between. The former was used as a measure of declarative memory and the latter of procedural memory. Performance in the first round was interpreted as learning and in the second round as retention. Different results were reported for the two tasks. In the recognition memory task, the DLD group learned as well as the typical group. Unlike the typical group, the DLD group only maintained their gains with no further improvement in performance, suggesting reduced retention. This pattern of results was the reverse of those reported in McGregor et al. (2013), McGregor et al. (2017) and Gordon et al. (2021) study of word learning, a task that has been argued to involve declarative memory as well. In the serial reaction time task, the DLD group did not do as well as the typical group in learning, as predicted given their reported problems with learning that involves procedural memory. Both groups, however, did better in the first round than the second round, with no group by round interaction, suggesting comparable retention in the two groups.

Findings from Earle and Ullman (2021) were not replicated in an earlier study with children with DLD using a similar serial reaction time task (Desmottes et al., 2017). Children's performance was examined during the task, 24 h and one week after the task. The DLD group performed as well as the typical age-peer group during the task suggesting comparable learning. The DLD group did not do as well as the typical group 24 h and one week later, suggesting poorer retention.

1.4. Memory in learning and retention

There are two types of human memory: declarative or explicit and non-declarative implicit (Squire & Zola, 1996), which are associated with different brain structures (Squire & Knowlton, 1994; Ullman et al., 2020). Language learning recruits both declarative and non-declarative, also known as procedural memory. Ullman (2004) argued, however, that the two memory systems are responsible for different aspects of language: learning the meaning of words involves primarily declarative memory, while learning grammar involves primarily procedural memory.

McClelland et al. (1995) proposed a different view. According to the Complementary Learning Systems Theory, learning is also a process that requires two separate but complementary memory systems that are located in different parts of the brain. The two systems, however, contribute jointly to language learning, without specialization into either word or grammar learning. The system located in hippocampus supports rapid learning of words and grammar in sentences, leading to the formation of representations that are often imprecise, unstable and context bound. The system located in the neocortex supports gradual acquisition of structured and abstract word and grammatical knowledge. Each of the systems cannot be sufficient on its own. The hippocampal system has limited capacity and can only support initial learning and storage of item-specific information. The neocortical system aggregates information from repeated exposure to individual words and sentences in the environment. Learning supported by the neocortical system is therefore slow, but structured and abstract knowledge thus acquired can be generalized to other contexts.

The Complementary Learning Systems Theory also postulates that the two systems interact. During offline periods while asleep or within the short wake time window after learning, or during ongoing new exposure to the words or sentences heard previously, the representation in the hippocampus is re-activated and linked back to the neocortex. Repeated reactivation of the initial representation will lead to abstraction and strengthening of the representation involving a memory process generally known as consolidation (Lewis & Durrant, 2011). Consolidation is supported in the neocortical memory system and through interactions of the two systems via replay of memory traces from the hippocampal to the neocortical system and through interleaved learning across sessions. Consolidation will lead to long term retention of the representation.

1.5. Effects of prior knowledge on learning and retention

How well one is to learn is based on what one already knows. In a seminal study on the effects of prior knowledge on learning and retention of new information, Anderson (1981) first taught a group of adult participants some information about four groups of five individuals. The participants were given different amounts of prior knowledge on each group of individuals from no mention, to names only, description in a sentence and elaboration in a paragraph. Then the participants were asked to learn about the one or two locations of the individuals in each of the groups, and the locations were not related to the prior knowledge on the individuals. After the location learning phase, the participants were tested on how well they recognized the name-location combinations. The participants clearly did the worst in the no-mention condition as the participants had to learn both the names and the locations of the individuals. Most interestingly, the participants did better in the description and elaboration conditions than the name-only condition, suggesting the effects of prior knowledge on learning. A recent study by Stärk et al. (2022) on typically developing children also reported that prior knowledge of distributional properties in their input language supported their learning of bi-syllabic words that are based on frequently occurring syllable transitions in the target language in an experimental task. To our knowledge, no studies have examined the effect of prior knowledge of the target on grammar learning and retention in children with and without DLD.

1.6. This study

This study used a syntactic priming task to compare the learning and retention of IORC in Cantonese-speaking children with DLD and their age peers over time, where the task was given in two sessions on two different days one week apart. Table 1 below illustrates the design of the study. The children's production of IORC was measured during the priming task (i.e., P1 and P2), and using a custom-designed probe test before (T1, T3) and after (T2 and T4) the task. In the third session, one week after the last priming session, children received the probe test (T5) again without a subsequent priming task. P1 and P2 were measures of learning, with T1 and T3 taken as measures of prior knowledge before entering a priming task; and T3 and T5 were measures of retention, with T2 and T4 taken as measures of prior knowledge. In this design, behavioural changes on the production of IORC were measured in two cycles of learning and retention, where the two cycles represented two distinct conditions. In Cycle 2, the children had more time (one more week) for memory consolidation of the knowledge learned and retained than in Cycle 1. The Cycle 1 therefore refers to initial learning or retention, and Cycle 2 refers to subsequent learning or retention. Table 1 illustrates the tests and training schedules.

The study aimed to examine if there was any strong evidence for a group difference (DLD vs TD) in learning and/or retention of the syntactic construction IORC, and if prior knowledge and cycle had similar effects across groups. A significant effect of group was predicted. The DLD group would do worse than the TD group on learning and retention. Given their memory deficits, children with DLD would have difficulties in identifying and encoding the form-meaning mapping realized in the exemplars of the construction, and in consolidating and maintaining the memory trace of the initial representation over time.

Strong evidence for a significant effect of prior knowledge on learning was expected on the basis that the stronger the learner's existing knowledge of the target construction, the easier it might be to identify the commonalities between exemplars of the target construction encountered during the priming session in the learning phase and its existing representation, leading to a more complete and more integrated representation. A significant effect of prior knowledge on retention was expected on the basis that the stronger the existing knowledge of the target construction, the easier it might be for the learner to retain the (new) linguistic knowledge in response to time lapse after priming, as the new exemplars of the target construction were more tightly integrated into a stronger representation, and/or the integration may further promote abstraction of the target construction for generalization. In addition, since the focus of this study was to compare children with DLD and their typically developing children's learning and retention of a syntactic construction, the presence or absence of an interaction between group and prior knowledge was examined. This allowed us to explore, given the same increase in prior knowledge, whether the degree of facilitation in learning and retention would be different or similar across the two groups, when cycle was considered, and other covariates were being controlled for. This interaction has not been examined in previous studies.

Strong evidence for a significant effect of cycle was expected. When more time is given to consolidate the knowledge just learnt (and being given more exposure of the target exemplars too), there is a general facilitation effect in children's learning and retention, regardless of their clinical status. That is, children were expected to perform better in Cycle 2 than Cycle 1 in general for both the TD and DLD groups. In addition, the presence or absence of an interaction between group and cycle was examined. This allowed us to explore, given the additional time and exposure, whether the degree of facilitation in learning and retention would be different or similar across the two groups when prior knowledge was considered, and other covariates were being controlled for. This interaction has not been examined in previous studies.

2. Method

2.1. Participants

Forty 7- to 9- year-old children with a diagnosis of language disorder were recruited from university teaching clinics and the second author's personal contact. DLD status was confirmed for 20 children using the Hong Kong Cantonese Oral Language and Assessment Scale (HKCOLAS; T'sou et al., 2006). They all scored below the evidence-based cut-off for language disorder provided in the test manual, demonstrated normal hearing in a screening, did not attend a special school and presented no parental or teacher concerns in intellectual development, and no report of biomedical conditions including autism spectrum disorder. All

Table 1
Tests and training schedules.

<--------Cycle 1 (***initial*** learning and retention)------------→

<--------Cycle 2 (***subsequent*** learning and retention) ---------→

Session 1	Session 2 (one week later)	Session 3 (one week later)
Probe test T1 (measure for prior knowledge before the ***first*** priming session)	Probe test T3 (outcome measure for ***initial*** retention, for analyses of 'retention") (also taken as measure for prior knowledge before ***subsequent*** priming, in a separate statistical model, for analyses of "learning")	Probe test T5 (outcome measure for ***subsequent*** retention)
Priming P1 (outcome measure for ***initial*** learning)	Priming P2 (outcome measure for ***subsequent*** learning)	
Probe test T2 (measure of prior knowledge before assessing ***initial*** retention one week later)	Probe test T4 (measure of prior knowledge before assessing ***subsequent*** retention one week later)	

parents reported that Cantonese was the primary language at home, and that language disorder had negative impact on their child's life. In sum, they met the criteria of significance, persistence and functional impact as discussed in Bishop et al. (2017). Of note is that none of the 20 children was able to produce the target structure on the one IORC test item in an elicited production task in the expressive grammar subtest in the HKCOLAS, indicating that these children did not show competence with IORC, the target syntactic construction to be learned in the priming task, at the outset of this study.

Thirty-five 7- to 9-year-old children without an earlier diagnosis of language disorder were recruited from primary schools and personal contact. Thirty of these children were confirmed to show typical language development for this study as they all scored above the evidence-based cut-off for language disorder in HKCOLAS, had no history of speech language therapy support and parental or teacher concern of intellectual development, and demonstrated normal hearing in a screening. All parents reported that Cantonese was the primary language at home. Five typically developing (TD) children were excluded as they scored correct on the IORC item in the HKCOLAS expressive grammar subtest. The other five children were not invited to receive training because there was not a sex-and-age matched child in the DLD group for them.

The final sample consisted of 40 participants, including 20 children in the DLD group and 20 children in the TD group. There were 14 males and six females in each group. All children were seen individually in their schools, or in the teaching clinics for this study. Socio-economic backgrounds of the children's family were not collected from the brief case history form. The project was approved by the Human Ethics Committee at the University of Hong Kong.

2.2. Procedures

As part of the initial assessment, all participants also completed a working memory task. As presented in Table 1, all children received two priming sessions of IORC during which their production was recorded. They were tested on their use of IORC via a custom-designed probe test in five occasions: before and after each administration of priming task and 1 week later after last priming session. The paragraphs below begin with a description of the working memory task, the probe test and the priming task, and end with a description of the structure of IORC in Cantonese and their scoring.

2.2.1. The working memory task and its administration

A Cantonese version (Wong et al., 2017) of the Competing Language Processing Task (CLPT; Gaulin & Campbell, 1994) was administered to measure the child's' verbal working memory. In the CLPT, the child was asked to judge the truth value of a set of simple spoken sentences by giving a 'yes' or a 'no' response. After each set of sentences, the child was required to verbally recall the last word of each sentence in any order. The number of sentences in each set ranged from two to six. As a measure of working memory, the CLPT required the child hold the last word of the set of sentences in memory at the same time as they processed the meaning of each sentence. The number of words the child recalled and the percentage accuracy in answering the questions were recorded.

2.2.2. The probe test and its administration

There are 16 items in the probe test used to examine children's knowledge of IORC. Each test picture contained an animal (Animal A) giving an item to another animal (Animal B) in the set who has a smiley face. Another three animals in the picture looked exactly the same as animal B, except that they did not have a smiley face. Please refer to supplemental materials for the picture illustrating the example of a test item. In the picture for each of the 16 test items, there was an animal holding an object and showing the same 'giving action.' The animals and objects used in the 16 pictures included: cat, turtle, rabbit, dog, bear, monkey, pig, elephant, mouse, cow, candy, cup, ball, book, flower. The child was asked to name all the animal and object names before the first administration of the probe test, to confirm that s/he was familiar with the name of the animals and objects. The probing question, 'Who is smiling?' was provided for all test item, and s/he was expected to answer the question with IORC.

2.2.3. The structural priming task and its administration

A structural priming task following the dialogic comprehension-to-production paradigm as described in Garraffa et al. (2015) and Garraffa et al. (2018) was used. In this paradigm, prime cards and target cards were presented alternatively, with filler cards interspersed between them to make the whole set of cards look unrelated, hence reducing the probability of perseverated responses. Both the experimenter and the child were given a unique set of 44 cards with the pictures facing down. There were five types of cards: 12 IORC filler cards, 12 ANP filler cards, 16 IORC prime cards, 16 noun phrase with attributive adjective (ANP) prime cards, and 32 IORC target cards. As illustrated in the examples below, ANPs are noun phrases with one or more attributive adjectives. ANP was chosen as the other prime for two reasons. First, ANP and IORC are structurally similar in that their modifiers are linked to the following head noun either with the use of the particle *ge3* or a combination of the demonstrative *go2* and a classifier. Second, IORC and ANP serve the same pragmatic function as noun modifiers. Last but not least, the simpler and earlier acquired ANP should be familiar to all children.

The set of cards used by the experimenter included two types of prime cards (16 each) and two types of filler cards (six each) which were pre-arranged in a specific order with one filler card inserted after one or two prime cards. The set of cards used by the child included 32 IORC target cards and two types of filler cards (six each). The cards were ordered in the same way as the experimenter's set except that the prime cards were replaced with the IORC target cards. Basically, the child's IORC target cards followed either a IORC prime card or a ANP prime card from the examiner. The ANP prime cards were included to examine how they might affect the structure of the child's description of the IORC target cards that followed, which could be described using the ANP or IORC. Effects of the two prime types, which differ in syntactic complexity, on the production of IORC in the two groups of children will be examined in a separate study. In this study, we only focused on the analysis of the effect of the IORC prime on the learning and retention of the IORC as the target construction.

Whenever filler cards appeared, the same card (e.g., IORC filler) appeared at the same time in both the examiner's set and the child's set. Note that the pictures illustrated in the experimenter's IORC prime card and the child's subsequent IORC target card were different, while those illustrated in their IORC filler cards were the same. The nouns included in the IORC produced with the prime cards were common objects for school-aged children such as shoes, sofa, jacket, hamburger, and stone, and the adjectives included in the ANP to be produced in the presence of the ANP prime cards were also developmentally appropriate as they were selected from the corpus 'A Comparative Study of Modern Chinese and Cantonese in the Development of Teaching Resources' (Dang et al., 2014). Please refer to supplemental materials for the figures illustrating the examples of the prime cards.

Fig. 1 illustrates in detail the administration of the priming task. In the first turn (1), the experimenter flipped over the top card, which was a IORC prime card, and described the picture with a corresponding IORC. In (2), the child was asked to describe the picture on his/her top card, the first target IORC card, after he/she flipped it over. In (3), the experimenter turned over the next card, which was an ANP prime card, and described the picture with a noun phrase. In (4), the child flipped his/her next card and described the second target picture illustrating the

IORC target. In (5), the experimenter turned the next card, which was a IORC filler card, and described the picture with an IORC. In (6), the child turned his/her next card, the IORC filler card that showed the same picture as the IORC filler card the experimenter just presented. The child described the picture. Finally, in (7), both the experimenter and the child said ‘Snap’ (zuk1 “捉” means catch) as the two cards matched. The first person to say ‘Snap’ kept the two matched cards. In (8), the entire routine repeated itself. The experimenter flipped over the top card and continued the task repeating steps (1) to (7). The task was finished when all the cards were used, and whoever collected the most cards at the end won the game. To summarize, the child was expected to provide a IORC response after a IORC prime in (2) and after an ANP prime in (4). In (6), the child was expected to give the same IROC as given by the experimenter after the IORC filler card.

Before the actual priming task, the child was given a trial round with a set of eight cards arranged in the same fashion as described earlier. In the trial round, the experimenter provided two exemplars of IORC, one after a IORC prime card and one after a IORC filler card. In the actual priming task, the experimenter provided 16 exemplars of IORC following a IORC prime card and six after a IORC filler card. Altogether in each of the two sessions, the experimenter provided 24 exemplars of IORC to the trial.

2.2.4. *Grammatical structure of the IORC and the ANP*

As illustrated in (1) below, IORC in Cantonese includes a prepositional dative that involves the transfer of an object from one individual to another. Several verbs can be used in prepositional datives (Tang, 1998), but in the context of the priming task and the probe used in the study, the same verb *sung3* (送 “give as a gift”) was used. The head noun being modified in the IORC is the indirect object of the clause.

(Example 1)

龜	送	花	俾	佢	嘅	豬
gwai1	sung3	fa1	bei2	keoi5	ge3	zyu1
turtle	give (as a gift)	flower	PREP	3SG	PRT	pig

‘The pig that the turtle gave (as a gift) a flower to.’

As illustrated in (2) to (5) below, two sets of markers are used to link the head noun and the relative clause or the adjective in Cantonese. While most of the time the two markers are interchangeable (Yip & Matthews, 2017), relative clauses with the linking particle *ge3* (Type A) are frequently used in formal registers while relative clauses with the demonstrative *go2* and a classifier (Type B) are commonly heard in colloquial registers. Both Type A and Type B relative clauses are commonly used by primary school children, and they were used in the same number with the IORC prime cards.

(Example 2) Type A. RC with the particle *ge3* linking the head noun and the clause.

‘媽媽	送	嘅	花’
ma4ma1	*sung3*	*ge3*	*fa1*
mother	give (as a gift)	PRT	flower

‘The flower that mammy give.’

(Example 3) Type B. RC with the demonstrative *go2* and a classifier linking the head noun and the clause.

‘媽媽	送	嗰	朵	花’
ma4ma1	*sung3*	*go2*	*do2*	*fa1*
mother	give (as a gift)	that	CL	flower

‘The flower that mammy give

(Example 4) Type A. ANP with the particle *ge3* linking the head noun and the adjective.

‘污糟邋遢	嘅	皮鞋’
wu1zou1laat6taat3	*ge3*	*pei4haai4*
Dirty	PRT	shoes

‘This is a pair of dirty shoes.’

(Example 5) Type B. ANP with the demonstrative *go2* and a classifier linking the head noun and the adjective.

‘污糟邋遢	嗰	對	皮鞋’
Wu1zou1laat6taat3	*go2*	*deoi3*	*pei4haai4*
Dirty	PRT	CL	shoes

‘This is a pair of dirty shoes.’

2.2.5. *Scoring of the IORC*

The probe test was recorded using an audio-recording application and the child’s response to each of the 16 items was transcribed orthographically for scoring and reliability check. The priming task was also recorded, and the child’s production for each of his 32 IORC target cards was transcribed orthographically for scoring and reliability check. A response was scored correct if it contained a complete IORC structure with an appropriate head noun and name for the object. A IORC given with either one of the relative clause markers, was accepted as correct, and received one point. There was a total of 16 points for the probe test and 32 for the prime task. A response was scored correct if it contained a

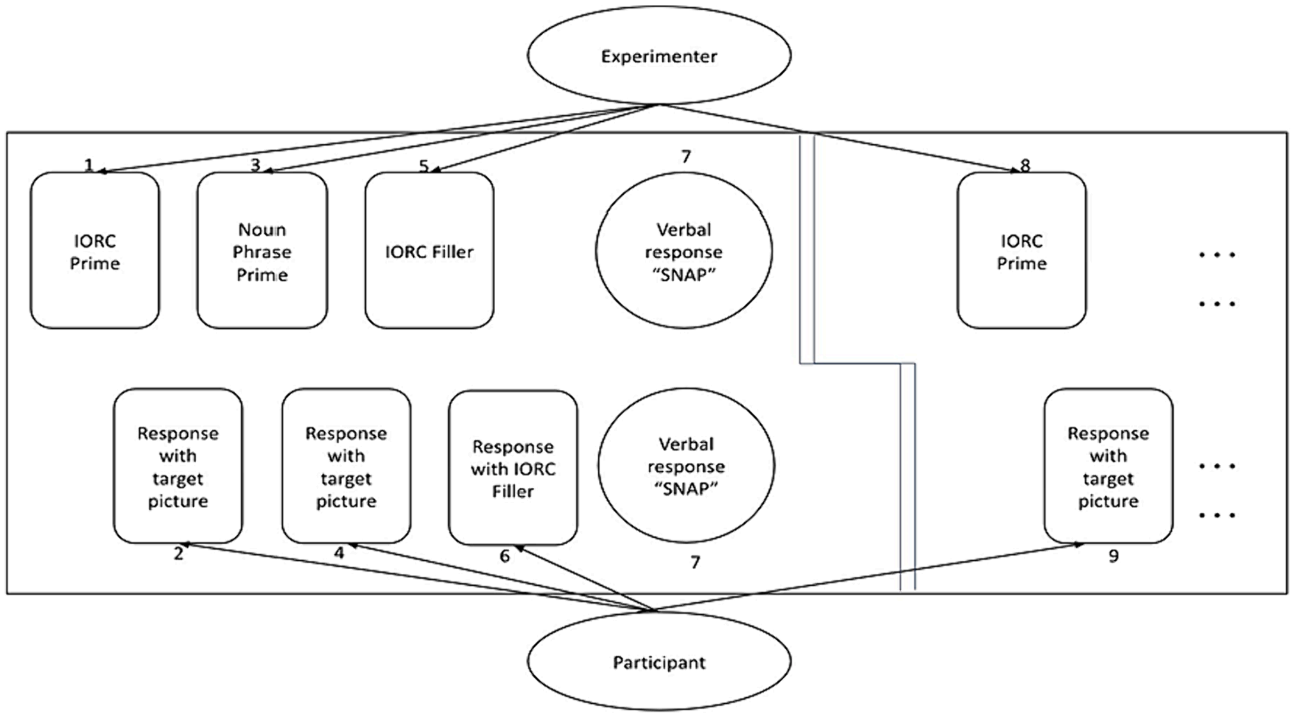

Fig. 1. Illustration of the structural priming task.

complete [IORC + relative marker + head noun] form, where the relative marker can be a classifier, or the particle *ge3*, or a hybrid form of [*ge3* + demonstrative *go2* + classifier]. The IORC would be in the form of [Agent (Subject) + Verb + Theme (Direct Object) + Prepositional Dative Marker *bei2* + Recipient (Indirect Object)], where the Recipient (Indirect Object) is a resumptive pronoun *keoi5,* coindexed with the head noun.

2.3. Statistical analysis

To examine the evidence for effects of group, prior knowledge, and cycle on the learning and retention of IORC and their interactions, Bayesian linear mixed effects modelling was used. The procedure in Kruschke (2021) was adopted in the analysis and reporting of results. The package brms was used (Bürkner, 2017) in R version 4.2.2. (R Core Team, 2018). Four chains, four cores, and 10,000 iterations, 2,000 of which were warm-ups, were used based on the recommendation by Vasishth et al. (2018). The dependent variable was binary measuring the accuracy of response (1 = correct or 0 = incorrect). All continuous predictor variables were standardized before the models were run (mean = 0, SD = 1). Group (DLD and TD) and cycle (1 and 2) were deviation coded (−1 and 1). The following analysis pipeline was used similarly to address questions on learning and retention.

Fixed effects included group (DLD and TD), cycle (1 and 2), prior knowledge, age, grammatical knowledge, and working memory capacity in the analysis on learning and on retention in two models. Note the grammatical knowledge was the children's raw scores in the Cantonese Grammar subtest in the HKCOLAS we used to ascertain their language status. In the model to examine learning, Cycle 1 was initial learning and Cycle 2 was subsequent learning. Prior knowledge referred to the children's scores in the probe task in Cycle 1 (T1) and in Cycle 2 (T3). The children's response in Cycle 1 was P1 and in Cycle 2 was P2. In the model to examine retention, Cycle 1 was initial retention and Cycle 2 was subsequent retention. Prior knowledge referred to the children's scores in the probe task in Cycle 1 (T2) and in Cycle 2 (T4). The children's response in Cycle 1 was T3 and in Cycle 2 was T5. The group × cycle interaction, and group × prior knowledge interaction were included in both models. For the random effects structure, we included items and participants as random intercepts. Group and cycle were used as by-item random slopes and cycle was used as a by-participant random slope. Correlation parameters for the random effects were not included to avoid any convergence problems. The following is the structure of the full models. The specified random effects structure considers the fact that the same item was repeated across the cycles and groups and the same participant is involved in both cycles.

Response ~ Group*(Cycle + Prior knowledge) + Age + Grammatical knowledge + Working memory capacity + (1 + Group + Cycle || Item) + (1 + Cycle || Participant)

Since the response variable was binary (0 or 1), the Bernoulli family with link function logit was adopted, and weakly informative priors were used. The advantage of using weakly informative priors over default priors is that they produce stable inferences (Nicenboim et al., 2020). Moreover, the use of flat priors is not recommended in logistic regression because they tend to place most of the probability on either end (See McElreath, 2020). The following priors in brms were used.

prior = c (set_prior ("normal (0,1)", class = "b"),
set_prior ("normal (0,10)", class = "Intercept"),
set_prior ("normal (0,10)", class = "sd"))

Table 2
Scores from the probe test for the groups of children.

	Group	T1	T2	T3	T4	T5
N	DLD	20	20	20	20	20
	TD	20	20	20	20	20
Mean	DLD	0.00	0.750	0.850	2.25	2.35
	TD	0.00	4.70	3.90	11.8	8.30
Median	DLD	0.00	3.35	3.57	4.79	5.15
	TD	0.00	6.15	6.94	6.25	7.42
Range	DLD	0–0	0–15	0–16	0–16	0–16
	TD	0–0	0–16	0–16	0–16	0–16

Table 3
Scores from the priming task for the two groups of children.

	Group	P1	P2
N	DLD	20	20
	TD	20	20
Mean	DLD	1.35 (SD = 2.32)	5.20 (SD = 7.98)
	TD	13.7 (SD = 11.8)	23.6 (SD = 10.7)
Median	DLD	2.32	7.98
	TD	11.8	10.7
Range	DLD	0–8	0–32
	TD	0–31	0–32

To do model diagnostics, the Potential Scale Reduction Factors value (PSRF, also called Rhat in brms) was used. Rhat values should be close to 1 when the model converged. We also did a visual inspection of the chains and consulted the effective sample sizes (ESS). Posterior predictive (PP) checks were used to see if the data fitted the model properly or not (see Schad et al., 2021 for more on these diagnostics).

3. Results

Tables 2 and 3 below summarize scores from the probe test and from the priming task for the two groups of children. Recall that the maximum score for the probe test was 16. Children in both groups improved from T1 to T5 but the TD group performed better than the DLD group in all test points. The same group difference across the two sessions was observed in the priming task with a maximum score of 32. Note that for both the probe test and the priming task, there were children who scored zero on IORC when their production was measured. In the next two sessions, the groups' learning, and retention were reported separately.

3.1. The learning of IORC

The results revealed strong evidence for the main effects of group, cycle and prior knowledge. Children in the TD group learned more IORC than those in the DLD group. Children demonstrated more learning of IORC in subsequent than in initial learning. Children with more prior knowledge learned more IORC than those with less prior knowledge. There was no evidence for any of the interactions. Specifically, there was no evidence that the effect of prior knowledge was different between the two groups, and that the effect of cycle was different between the two groups.

The results of the learning analysis are presented in Table 4. Model diagnostics does not reveal any discrepancies. PSRF (also Rhat) and ESSs look normal (Table 4). The observed data and simulated data do not show any systematic deviation from each other. Please refer to supplemental materials for the figures illustrating the posterior of variables in the model and the observed and simulated data.

Table 4
Bayesian results for the learning data.

Predictors	Estimate	95 % CI	Rhat	Bulk ESS	Tail ESS
Intercept	−2.19	−3.60, −0.86	1	4988	9611
Group	1.62	0.34, 2.86	1	7980	13,338
Cycle	1.28	0.63, 1.94	1	7569	13,543
Prior Knowledge	1.43	0.40, 2.56	1	15,939	20,836
Age	0.45	−0.61, 1.54	1	8805	14,216
Grammatical Knowledge	0.56	−0.68, 1.83	1	10,426	16,729
WM	0.52	−0.65, 1.71	1	8598	14,962
Group * Cycle	0.07	−0.57, 0.69	1	7972	12,601
Group * Prior Knowledge	−0.42	−1.55, 0.62	1	14,812	19,746
Random effects					
Item (Intercept)	1.17	0.85, 1.60	1	9000	16,285
Group	0.36	0.05, 0.67	1	6958	7061
Cycle	0.21	0.01, 0.48	1	8018	10,625
Participant (Intercept)	3.61	2.57, 5.07	1	7836	14,264
Cycle	1.58	1.10, 2.25	1	10,349	17,163

3.2. The retention of IORC

The results showed only strong evidence for the effect of prior knowledge. Children with more prior knowledge retained more than those with less prior knowledge. There was weak evidence suggesting that TD children possibly retained more IORC than children with DLD and that children retained more IORC in the subsequent retention than the initial retention phases. However, since their posterior distribution includes 0, this evidence should be treated with caution. There was no evidence for the interaction effects. Specifically, there was no strong evidence that the effect of prior knowledge was different between the two groups of children, and that the effect of cycle was different between the two groups of children. There was no evidence observed for the effects of the other variables in the model (See Table 5 for the full model). Model diagnostics does not show any deviations (See Table 5). Please refer to supplemental materials for the figures illustrating the posterior of variables in the model and the observed and simulated data.

4. Discussion

Children with DLD did learn IORC from the priming task but learned less well than their peers with typical development, after age, working memory and general grammatical knowledge were controlled for. There were no interactions between group and cycle, or group and prior knowledge. In other words, children in both groups learned IORC better in subsequent learning when being given an equal amount of additional time to consolidate the knowledge just learnt and being given an equal amount of additional exposure to exemplars of the target construction in cycle two, and with more prior knowledge. Different results were observed on the retention of IORC. Weak evidence indicated that children with DLD retained IORC less well than children with typical development, suggesting that children with DLD might also have problems with retention. Moderate evidence was also observed showing that children retained more IORC in subsequent than initial retention, suggesting that retention might improve when given additional time and additional exposure in cycle two. Strong evidence indicated that children with more prior knowledge retained more IORC than those with

Table 5
Bayesian results for the retention data.

Predictors	Estimate	95 % CI	Rhat	Bulk ESS	Tail ESS
Intercept	−8.25	−13.28, −4.74	1	7812	10,548
Group	0.53	−1.14, 2.23	1	22,502	23,629
Cycle	0.99	−0.46, 2.45	1	19,067	20,422
Prior Knowledge	3.02	1.24, 4.68	1	13,988	17,385
Age	0.77	−0.88, 2.37	1	16,214	20,904
Grammatical Knowledge	0.03	−1.67, 1.77	1	21,400	23,429
WM	0.52	−1.17, 2.17	1	21,321	22,511
Group * Cycle	0.07	−1.34, 1.54	1	18,911	20,964
Group * Prior Knowledge	0.58	−1.02, 2.24	1	22,106	21,689
Random effects					
Item (Intercept)	0.86	0.08, 1.84	1	5689	5881
Group	0.47	0.02, 1.22	1	10,327	12,702
Cycle	0.66	0.04, 1.57	1	6471	9388
Participant (Intercept)	7.84	4.10, 13.90	1	6566	11,131
Cycle	3.80	2.00, 6.81	1	9388	12,544

less knowledge. None of the interaction effects with group were significant, suggesting that the degree of facilitation of additional time and exposure, as well as prior knowledge, in learning/retention was not different across the two groups of children, when age, working memory and general grammatical knowledge were controlled for.

4.1. Effects of prior knowledge and cycle on grammar learning and retention

In this study, children's productions of IORC were measured in two cycles of learning and retention (See Table 1) over a duration of 3 weeks with consideration of the effect of prior knowledge. The probe tests at T2 and T4 were included as measures of prior knowledge, with the former to be considered before assessing *initial* retention at T3 and the latter before assessing *subsequent* retention at T5, one week later. Prior knowledge supported both learning and retention of IORC in the priming task for both children with and without DLD, with more prior knowledge leading to more learning and more retention subsequently during the three weeks of the study. Results from this study extended the findings of Anderson (1981) and Stärk et al. (2022) on adults and children with typical development to children with DLD. As in Anderson's study, prior knowledge referred to knowledge that was learned from exposure during the experimental task. When differences in their general knowledge of grammar were controlled for, the main effects of prior knowledge registered in learning and retention suggest that the knowledge gained from the priming task was not transient for children with DLD, in much the same way as for their TD age peers, and that it was in long term memory to support subsequent learning and retention.

One may argue that the children might already have some representation of the IORC despite zero scores in the probe test at T1. The argument came from the fact that some TD children were able to be primed in P1 that was immediately administered after T1, as indicated by a median score of 11.8 out of 32 (range: 0–31). It certainly is plausible that some TD children might already have some level of representation of the IORC before T1, as only one item in the expressive grammar subtest of the HKCOLAS was used to ascertain children's absence of knowledge of IORC. The other reason for success in the learning of IORC in some TD children in P1 was that the demands for the priming task was much lower than those for the probe test. In the priming task, they only had to focus on the internal structure of the construction, but not its pragmatic use for disambiguation of multiple referents as required in the probe test. The probe test, however, gives a more reliable estimate of the children's level of knowledge of IORC required for successful communication.

Both children with DLD and children with typical development learned a new syntactic construction better, and retained more of what was learned when given more exposure and more time for memory consolidation. Findings on the effects of prior knowledge and cycle provided strong evidence to support the common intervention practice of supporting children with DLD's language learning and retention over time. Typically, speech-language pathologists provide repeated multiple exposure of exemplars of the target construction in meaningful contexts across therapy sessions. From these exemplars, children identify and encode the form-meaning mapping of the construction into a representation that is initially less abstract. This developing construction then shapes subsequent learning and retention in the presence of more different exemplars in the language input, making the representation more abstract and stronger. Eventually, children's representation of the syntactic construction becomes abstract and adult like, allowing them to use it productively to generate sentences for use in different communication contexts.

4.2. Learning and retention in children with DLD

The fact that children in both the TD and the DLD groups used more IORC in the second than the first session provided strong evidence of learning from the priming task, suggesting that there were long-term changes in the representation of the language target (Kaschak et al., 2011). Children with DLD, however, demonstrated less learning of IORC than the TD children. This finding was consistent with priming studies reported earlier on Italian speaking children with DLD's problems in learning relative clauses as well (Garraffa et al., 2015; Garraffa et al. 2018). Procedural memory is involved in implicit learning (see Krishnan et al, 2016 for a review), and evidence from this priming study of IORC suggests that Cantonese-speaking children with DLD also have procedural memory problems.

Further research with Cantonese-speaking children on other grammatical constructions is needed to test the Procedural circuit Deficit Hypothesis of DLD as discussed in Ullman et al. (2020), which argues that children with DLD have problems with the aspects of grammar that rely on procedural memory which cannot be compensated for by declarative memory (Ullman et al., 2020), but they do not have problems with aspects of grammar that "likely depend importantly on declarative memory in typically developing individuals" (p. 404) as well as word learning. Evidence from this study suggested that children with DLD possibly have poorer retention of syntactic constructions they are learning when compared to the TD children. Research is therefore needed to further examine retention to reconcile findings in Earle & Ullman (2021), where adults with DLD showed poorer learning but comparable retention in the serial reaction time task, a measure of procedural memory.

The Complementary Learning Systems Theory, which does not make a distinction between the memory systems responsible for the learning of words and grammar, provided an alternative explanation to the findings in this study. Principles of this theory have been applied to studies on the learning and retention of words (Davis & Gaskell, 2009) and grammatical morphemes (Mirković et al., 2019). The theory rests on the premise that the hippocampal and the neocortical memory systems do not function in isolation but interact. Initial learning leads to an initial representation of the language target in the hippocampus, while retention requires reactivation of the initial knowledge in the hippocampus, and the linkage of this representation to the neocortex. This theory could therefore predict difficulties in both learning and retention of grammar in children with DLD, a plausibility that needs to be confirmed in future research.

This study contributed to the emerging body of research that examined language learning and retention in children with DLD. It did not, however, provide evidence that would support either the Procedural circuit Deficit Hypothesis or the Complementary Learning Systems Theory account of DLD. Future studies can compare the learning and retention of words and grammatical constructions in the same group of children with DLD and their TD age peers.

4.3. Limitations and directions for future research

Like the learning of words (Gordon et al., 2022), the learning of syntactic constructions can involve two stages: rapid online learning from the initial experience, and then slower offline consolidation of the initial representation in memory for it to be retained. If the representation of the syntactic construction is adequately consolidated, it can be successfully retrieved when given subsequent exposure in the next learning opportunity, during which it is refined with new information and further strengthened. Through the processes of learning, memory consolidation, retrieval and subsequent learning, children build a robust and increasingly abstract representation of the syntactic construction that was once new to them for productive and meaningful use. These processes, however, are interconnected and problems in one can have knock-on effects on others. While grammar intervention typically focuses on the facilitation of learning, results from this study suggest that there might be a need to support children with DLD's retention through memory consolidation. Research has shown that the use of retrieval-based practice facilitates the learning and retention of new words

(Leonard & Deevy, 2020). In studies of retrieval-based practice, children are asked to retrieve the new words during the learning process. When retrieval is effortful, and the spacing of the retrieval is narrow, retention of the new words is enhanced. Future studies can examine whether the adoption of retrieval-based practice may also enhance learning and retention of grammatical constructions in children with DLD.

Before the priming task, it was confirmed that all children scored zero in the probe test before the first priming task, showing no evidence that IORC was within their expressive repertoire at the study outset. While general grammatical knowledge was also controlled in the analysis, children in the two groups might still have different levels of prior knowledge of other types of related constructions. This knowledge could have supported or interfered with their learning and retention of the target construction IORC. In future studies, children's knowledge of related constructions should also be assessed.

The priming task used in this study involved the same verb of transfer in all prime and target items. This study, therefore, only examined the very early phase of learning of IORC that was likely verb specific. In future studies, it will be interesting to use different verbs in the priming task and the probe test to examine if the same pattern of results on learning and retention for children with DLD still hold when they develop a more verb-general representation of the syntactic construction.

In this study, learning and retention were examined only in two cycles, where learning via the priming task was measured twice one week apart, and retention was also measured two times one week apart. In future studies, it will be informative to examine more cycles and more distal measures of retention (longer than one week) to see how children with DLD compared to their typically developing age peers. It is expected that there will be stronger effects of group (clinical status) on learning and more reliable group effects on retention.

With consideration of the effects of prior knowledge, children with DLD showed poorer learning of a syntactic construction and possible problems with retention. Results different from the ones reported here could have emerged if prior knowledge were not included in the analyses as in Gordon et al. (2021) word learning study. In this case, the probe tests T2 and T3 could be taken as short-term and long-term retention of learning of the priming task P1, and T4 and T5 could be taken as short-term and long-term retention of learning in P2. A review of the descriptive statistics in Table 3 suggested that the DLD group demonstrated poor learning in P1 and P2 but stable retention of IORC from T2 to T3 and from T4 to 5 over one week (See Table 2). These results would be consistent with those reported in Gordon et al. (2021) word learning study, if confirmed in statistical analyses that compared the DLD and the TD groups. Future studies should consider incorporating short-term retention of learning immediately after the priming task in the research design.

Results from the statistical analysis revealed high variability in the participant factor, suggesting heterogeneity in the children's performance. Individual variability is a fact in language learning and development (Kidd & Donnelly, 2020), and disorder (Lancaster & Camarata, 2019). There was a low variability in the item factor. The item factor in the analysis for the learning of IORC involved the priming task that consisted of 32 items. The item factor in the analysis for the retention of IORC involved the probe test that consisted of 16 items. Low variability was more obvious in the probe test given its smaller number of items. In addition, the items were not randomized in either the priming task or the probe test. Randomization of the items, particularly of those in the probe test, would increase its variability.

4.4. Implications for clinical intervention

As Leonard (2011) argued, there are clear parallels between priming and grammar intervention. The fact that the children with DLD were able to learn and retain IORC from the priming task, albeit at a lower level as their age peers, and that their knowledge of IORC accumulated over time, suggest that priming can be further examined as an intervention procedure for grammar. A recent study (Wada et al., 2020) provided evidence that a combination of syntactic priming and focused recast did lead to the learning of relative clauses in school-aged children with DLD. Further research is needed to provide evidence on the efficacy of grammar intervention using a syntactic priming task.

CRediT authorship contribution statement

Anita M.-Y. Wong: Writing – original draft, Supervision, Methodology, Conceptualization. **Cecilia W.-S. Au:** Writing – review & editing, Project administration, Investigation, Data curation, Conceptualization. **Angel Chan:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Mohammad Momenian:** Writing – review & editing, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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