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Karadöller, D.Z.; Sümer, B.; Özyürek, A.

DOI
10.1080/15475441.2020.1823846

Publication date
2021

Document Version
Final published version

Published in
Language Learning and Development

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LANGUAGE LEARNING AND DEVELOPMENT
2021, VOL. 17, NO. 1, 1–25
https://doi.org/10.1080/15475441.2020.1823846

Effects and Non-Effects of Late Language Exposure on Spatial Language Development: Evidence from Deaf Adults and Children

Dilay Z. Karadöller [a,b], Beyza Sümer [a,b,c], and Aslı Özyürek [a,b,d]

[a]Centre for Language Studies, Radboud University, Nijmegen, Netherlands; [b]Max Planck Institute for Psycholinguistics, Nijmegen, Netherlands; [c]Department of Linguistics, University of Amsterdam, Amsterdam, Netherlands; [d]Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen, Netherlands

ABSTRACT

Late exposure to the first language, as in the case of deaf children with hearing parents, hinders the production of linguistic expressions, even in adulthood. Less is known about the development of language soon after language exposure and if late exposure hinders all domains of language in children and adults. We compared late signing adults and children (MAge = 8;5) 2 years after exposure to sign language, to their age-matched native signing peers in expressions of two types of locative relations that are acquired in certain cognitive-developmental order: view-independent (IN-ON-UNDER) and view-dependent (LEFT-RIGHT). Late signing children and adults differed from native signers in their use of linguistic devices for view-dependent relations but not for view-independent relations. These effects were also modulated by the morphological complexity. Hindering effects of late language exposure on the development of language in children and adults are not absolute but are modulated by cognitive and linguistic complexity.

Majority of studies aiming to understand linguistic and cognitive factors giving rise to language development uses data from typically developing children who are exposed to a language early on from their caregivers. Unfortunately, this is not the case for many deaf children. Most deaf children (90%) are born to hearing parents (Mitchell & Karchmer, 2004) and thus they lack immediate access to a conventional language input – even with hearing aids which may not provide enough access to the surrounding spoken language. For these children, the first exposure to a conventional language can be in the form of sign language after entering a school for the deaf at around 6 years of age or even later. As a result of such a delayed exposure to language, these children (i.e., late signers) learn sign language quite late compared to deaf children with deaf parents (i.e., native signers) who are exposed to sign language from birth. The current study investigates such atypical cases of language acquisition which can shed light and give unique insights into the complex interplay between cognitive and linguistic development in ways that may not be possible by studying typically developing children.

Here, we investigate the effects of late sign language exposure on expressions of space and specifically locative spatial relations. We focus our investigation on the effects of late sign language exposure on the acquisition of two categorically distinct spatial relations that are acquired in a certain order due to cognitive development: a) spatial expressions that are not dependent on the viewpoint of the viewer (e.g., view-independent as in IN, ON, and UNDER) and b) expressions that are dependent on the viewpoint of the viewer (e.g., view-dependent as in LEFT and RIGHT; see Martin & Sera, 2006 for discussion). We ask whether late language exposure hinders development and final attainment for all aspects of language or is modulated by the cognitive and linguistic complexity.

CONTACT Dilay Z. Karadöller dilay.karadoller@mpi.nl Max Planck Institute for Psycholinguistics, Nijmegen 6525 XD, Netherlands

All of the late signers in our study, both children and adults, have been exposed to Turkish Sign Language (Türk İşaret Dili [TİD]) only when they started going to a deaf school at around 6 years of age. Additionally, at the time of testing signing children had 2 years of exposure to sign language. Before this time, they had no access to a conventional language in the form of sign or speech but only used gestural communication at home with their hearing non-signing parents (i.e., so-called homesign situations; Goldin-Meadow, 2005; see also Gentner et al., 2013 for the Turkish context). In order to see whether and how such deaf children and adults' acquisition of two types of locative expressions are influenced by late language exposure, we compare their expressions to age-matched native signers who have been exposed to sign language from birth onwards by their caregivers. This comparison relies on the data we analyzed in our previous work on the development of spatial language patterns by native signing children and adults using TİD (see Sümer, 2015; Sümer & Özyürek, 2020). This comparsion helps us see which aspects of language can be easily learned or not in late exposure – when the cognitive developmental stage is the same across native and late signers.

Linguistic development of locative relations in spoken and sign languages

The order of learning different types of locative expressions in spoken language acquisition has been argued to be in line with the nonverbal conceptual development about space. We know from previous research that there are some regularities across many spoken languages for children in learning to express spatial relations. Specifically, children first show an understanding of view-independent spatial concepts, such as containment (i.e., IN), support/contact (i.e., ON), and occlusion (i.e., UNDER; see Casasola, 2008; Casasola et al., 2003; Clark, 1973; Johnston & Slobin, 1979) and learn to map spatial words to these concepts at around age 2. View-dependent spatial relations such as LEFT and RIGHT, however, appear latest and are found to be delayed for hearing children even until 9 years of age (Benton, 1959; Harris, 1972; Piaget, 1928/1972; Sümer, 2015; see also Corballis & Beale, 1976). Delays in the acquisition of view-dependent relations, as opposed to view-independent relations, are usually attributed to the requirement of development of an understanding of children's own LEFT-RIGHT (Howard & Templeton, 1966) and then mapping these spatial concepts on other people or items (Howard & Templeton, 1966; Piaget, 1928/1972). Thus, specifically using these terms to refer to the spatial relation between objects appears late (Benton, 1959; Harris, 1972; Piaget, 1928/1972; see also Sümer, 2015 for Turkish).

For sign languages, acquisition of spatial expressions by native signers is found to be delayed in general due to the morphological complexity of such expressions (i.e., due to so-called *classifier predicates*) and especially for motion event descriptions (e.g., Kantor, 1980; Newport & Meier, 1985; Schick, 1990; Supalla, 1982; Slobin et al., 2003 for American Sign Language (ASL); Engberg-Pedersen, 2003 for Danish Sign Language; Tang et al., 2007 for Hong Kong Sign Language). However, a recent study investigating the acquisition of different types of locative relations by native signing compared to hearing children did not find delayed acquisition patterns for view-dependent relations compared to view-independent ones for native signing children. It was found that native signing deaf children acquiring TİD encode view-independent relations (e.g., IN, ON, and UNDER), as well as the view-dependent relations (e.g., LEFT and RIGHT) in adult-like ways already at 5 years of age (Sümer, 2015; Sümer & Özyürek, 2020; Sümer et al., 2014). These results are rather surprising because hearing children learning Turkish, who were tested in the same study with the same materials, were found to describe view-dependent relations in adult-like ways later (at around age 8–9 years) than view-independent relations, which is similar to what has been found for other spoken languages.

A possible explanation for the earlier acquisition of view-dependent relations by native signing deaf children learning TİD compared to hearing children learning Turkish could be due to the iconic and body-anchored linguistic forms that are used to encode such descriptions in sign languages. Unlike speech, sign language descriptions of space, despite their morphological complexity, incorporate a high similarity between the shape and position of the signers' hands and what they refer to in the real space. In addition to the iconic and body-anchored linguistics forms used in sign language expressions of space, one-to-one mapping between the exact spatial relation and sign language expression of space might have eased the production of view-dependent forms for native signing children (see Martin & Sera, 2006; Morgan et al., 2008). Furthermore, semantic simplicity of locative relations compared to motion events might also account for their early acquisition (see Talmy, 1985, 2003).

Sign languages in general and TİD specifically have two main ways to encode locative relations. The most frequent way for describing locative relations (Perniss et al., 2015) is through the use of morphologically complex classifier predicates (CL), as shown in the 3rd still of the example below (1a). In these predicates, the location of the hands encodes the location of the referents, while the handshape encodes referent type by classifying it in terms of certain semantic features such as size and shape (Emmorey, 2002; Perniss et al., 2015; Supalla, 1982; Zwitserlood, 2012). These forms incorporate the use of iconic mappings of referent features to handshapes and space-to-space mappings between the real space to signing space (Perniss, 2007). To illustrate, in order to describe a picture of "a pen is to the left of the paper", signers first introduce the lexical signs for the pen and the paper and later they choose classifier handshapes to indicate the size and shape of these two items. Specifically, they choose a flat handshape (i.e., flat hand) to represent the flat nature of the paper and an elongated handshape (i.e., index finger) to represent the elongated shape of the pen. Later, they position their hands in the signing space in a way analogs to the real space. As depicted in the example below (1a), signers position the two handshapes in the signing space placing "the pen" to the left of "the paper" from their own viewpoint. This is typical as TİD signers, like signers of many other sign languages, use their own viewpoint in signing left-right spatial relations (Sümer et al., 2016).

(1a)

LH: -------- PEN CL(long)$_{loc}$

RH: PAPER CL(flat)$_{loc}$ -------- HOLD --------

"There is a paper. There is a pen. The pen is to the left of the paper."

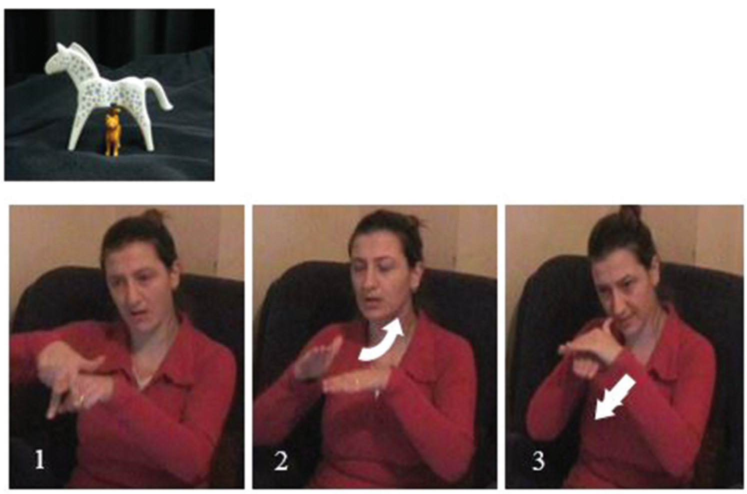
In addition to classifier predicates, signers can also choose, even though less frequently, so-called "relational lexemes" (RL), to express spatial relations (Arık, 2013; Perniss, Zwitserlood et al., 2015; Sümer, 2015; Sümer et al., 2014). These forms encode spatial relationship between entities but not the information about the shape of the specific entities themselves. Thus, RL are semantically less specific and iconic to the size and shape of referents than CL are since they only exhibit the relationship between any two objects regardless of objects' size and shape. Therefore, as RL do not require classifier handshapes and locations in space they are considered to be morphologically simpler. Although RL for some spatial relations, such as IN, ON, and UNDER are signed in the signing space rather than on the body, RL for LEFT and RIGHT are found to be body anchored in TİD (see Sümer, 2015; Sümer et al., 2014). The third still of the below example (1b) shows a relational lexeme for RIGHT in TİD to describe a spatial relation between the box and the cake. The third still of the example (1c) shows a relational lexeme for UNDER in TİD to describe a spatial relation between a cat and a horse.

(1b)

LH:	RECTANGULAR	------- HOLD -------	RIGHT
RH:	RECTANGULAR	CAKE	RIGHT

"There is a rectangular-shaped object. There is a cake. The cake is located to the right of the rectangular-shaped object."

(1c)



LH:	HORSE	CAT	UNDER
RH:	HORSE	CAT	UNDER

"There is a horse. There is a cat. The cat is under the horse."

As depicted in above examples, producing locative spatial relations in sign languages always uses the following word order conventions when CL are produced: Ground item, Figure item and CL to indicate the location of the Figure item for both view-dependent and view-independent relations (see

Sümer (2015) for TİD and see also Perniss (2007) for German Sign Language and Manhardt et al. (2020) for Sign Language of the Netherlands). In TİD, production of RL also follows the same word order conventions for both view-dependent (1b) and view-independent relations (1c; Sümer, 2015). However, for RL the word order is more variable in different sign languages.

Sümer (2015) found that native signing children use both of these forms (i.e., CL and RL) that allow for iconic and body-anchored mappings to describe view-dependent and view-independent relations in adult-like ways around 5 years of age. Here we ask whether late signing children would also benefit from iconicity of these locative expressions and learn view-dependent relations as early as view-independent ones 2 years after exposure or whether late exposure affects view-dependent relations more than view-independent ones as the former is known to be acquired later by hearing children possibly driven by their conceptual complexity. We also ask whether mastery of these two types of locative relations is differentially influenced by late exposure in adulthood.

Before we move onto the present study, we will review previous studies investigating the effects of late sign language exposure on linguistic abilities in general and the production of spatial language more specifically.

Effects of late exposure on sign language development

Studies on effects of late sign language exposure on the general linguistic abilities (see Mayberry & Kluender, 2018 for a review) have investigated the influence of both the age of exposure as well as years of exposure on patterns of sign language acquisition focusing mostly on adolescent and adult late signers. Longitudinal studies investigating the developmental trajectories of sign language acquisition of deaf adolescent late signers compared to younger native signing children (groups matched in terms of the years of exposure to language) found similar acquisition patterns in the development of mean length of utterance and sentence complexity (see Ramirez et al., 2013). Additionally, a study by Cheng and Mayberry (2019) investigating the developmental trajectories of 3 deaf adolescent late signers (data collected longitudinally from 12 months to 6 years of ASL exposure) show that deaf adolescent signers go through stages similar to the literature reported for native signing deaf children in the development of canonical word order. Similarly, late signing children who are exposed to sign language around age 6 showed comparable performance in all of the language measures (e.g., Mean Length of Utterance) to native signing deaf children who have equal years of exposure to sign language (Berk & Lillo-Martin, 2012). Even though these studies show similar patterns of development after late exposure, studies conducted with adult signers show that late exposure has enduring effects in adulthood in which late signing adults have lower accuracy in the grammatical judgment of ASL sentences (Boudreault & Mayberry, 2006) and decrease in recall performance of complex ASL sentences (Mayberry, 1993) as a function of age of exposure to language. It should be noted that in above studies developmental patterns in late signing children have not been compared directly to age-matched native signing children but to those with equal years of language exposure.

To our knowledge, even a smaller number of studies have been conducted on the effect of delayed exposure on the production of spatial language. These few studies have focused mostly on the domain of motion event descriptions that are semantically and morphologically more complex than locative spatial relations (Talmy, 1985, 2003). These studies have investigated the acquisition of motion event expressions either by late signing adults (Newport, 1988, 1990; Schick, 1990) and adolescents who have been exposed to sign language first time (Morford, 2003) or homesigning children around 5 years of age without any exposure to sign language (Gentner et al., 2013).

In a series of studies with late signing adults, Newport (1988, 1990) found that early exposure to sign language is crucial especially for mastering morphologically complex verbs of motion and that delayed input has long-lasting effects for their mastery even in adulthood. She studied production patterns of late signing adults who were exposed to sign language at ages between 4–6 as well as after age 12 at school from their deaf peers by comparing them to native signing adults in descriptions of motion events. Results show a linear decline in their mastery as a function of age of acquisition to language. This study, however, was restricted only to late signing adults and information about late signing children after they have been exposed to sign language is missing.

Morford (2003) investigated the language acquisition patterns of 2 adolescent late signers who are exposed to ASL after age 12;1 and 13;7. These children are tested after 2, 8, 14, 20, 31 months of exposure to ASL on describing motion events in the frog story that are typically expressed by morphologically complex verbs of motion. She found different patterns of acquisition between the two signers in using these forms. One of her participants started using monomorphemic signs (e.g., to encode the frog climbing out of the jar, she used the sign OUT) in the first session and gradually replaced monomorphemic signs with verbs of motion with classifier predicates in the subsequent sessions. However, the other participant showed the acquisition trajectory resembling first language acquisition patterns of native signers. He first expressed verbs of motion at the second testing session although with errors (i.e., handshape is correct but the location is wrong) and gradually improved his use of these forms and never used monomorphemic signs in any of the testing sessions. Results of this study show that although these participants showed variability in acquiring verbs of motion to describe motion events, both of them increased the frequency and accuracy of their use of these forms by 31 months of exposure to ASL. Thus, linguistic structures to encode space requires some time for late signing adolescents to acquire.

Finally, there is also research about communicative strategies used by deaf children (ages 5–6) before they had any exposure to conventional sign language input (i.e., homesigners; Gentner et al., 2013). In this study, deaf children were shown video clips that are likely to elicit spatial relations between Figure and Ground items (e.g., a box moves on top of a school bus). Results showed that homesigning children studied in Turkey showed no evidence for language-like expressions in their gestures to convey spatial relations (i.e., to indicate the position of the Figure in relation to the Ground) while describing motion event video clips. Therefore, language input seems to be crucial for children to express spatial relations in language like ways and cannot evolve through gestural interactions with caregivers without any conventional sign language input and in spite of the iconic features of these expressions.

To sum up, late input seems to hinder the acquisition of linguistic patterns in adults as well as in adolescents for motion event expressions. However, several issues regarding the role of delayed language input on the language development of space remain to be asked with regard to production studies conducted with late signers. First of all, they do not give a comprehensive picture as to how late signing children develop linguistic strategies for communicating about space after being exposed to sign language. Morford (2003) conducted her research on 2 adolescent late signers that showed different profiles for the development of spatial language and Newport (1988, 1990) conducted her studies with late signing adults only. Moreover, Gentner et al. (2013) looked at deaf children before they were exposed to sign language but did not follow up on their development after starting school.

Without focusing on late signing children shortly after exposure to sign language and comparing them to their native signing peers and late signing adults, we cannot fully comprehend the role of cognition and development in delayed sign language acquisition of spatial expressions. This information is crucial to see as to *what extent the spatial language development is shaped* by early versus late input. Furthermore, most research has been in the domain of motion events that have complex morphological structures and semantics (Talmy, 1985, 2003) and not much is known on the development of simple locative relations.

Hence, in the present study, we investigate the developmental patterns of locative relations in late signing children after 2 years of exposure compared to age-matched native signing children as well as late signing adults compared to their native signing peers in the final attainment. It is possible that locative relations are more resilient to late input for adults and/or children due to their semantic simplicity unlike shown for motion event expressions. More specifically, we are interested in whether view-dependent and view-independent relations are equally sensitive to late language input in children and adults, due to their iconic affordances as found in Sümer (2015) for native signing children or whether view-dependent relations are harder to learn in delayed input situations as they are learned at later stages of cognitive development. Lastly, we investigate if morphological complexity of the linguistic forms (e.g., CL vs RL) to encode locative spatial relations are differentially affected by late sign language exposure.

The present study

Our overall aim in this study is to get an understanding of the effect of delayed language input on the development of spatial language by children and adults in the domain of locative spatial relations. In order to accomplish this, we focused on descriptions of locative relations of two types: view-dependent and view-independent relations. We collected data from late signing adults and from late signing children at around age 8 that is after 2 years of sign language exposure, with the same materials that we had collected data from the native signing children and adults in a previous study for a comparison (see Sümer, 2015).

The rationale for choosing 2 years of exposure to sign language by late signing children is twofold: First, we wanted to allow late signing children to get enough exposure to observe a developmental pattern. Also, we wanted to make sure that children are cognitively mature enough to learn to express view-dependent relations as they are known to be learned late by hearing children (Benton, 1959; Harris, 1972; Piaget, 1928/1972; Sümer, 2015; see also Corballis & Beale, 1970; Hermer-Vazquez et al., 2001).

Here, we investigate first whether late signing children and adults lag behind their native signing peers in expressing locative relations in general as found for motion event expressions (see Morford, 2003; Newport, 1988, 1990) or whether such forms are more resilient to the delayed input.

Secondly, we are interested in whether late sign language acquisition impacts view-dependent and view-independent relations differently either in the early stages of language development as well as in the final attainment. It is possible that even after only 2 years of exposure, late signing children *do* acquire descriptions of both forms of locative spatial relations in adult-like ways as found for native signing children by Sümer (2015) due to their iconic properties. However, it is also possible that view-dependent relations might be delayed compared to view-independent relations as they are learned later by hearing children and thus effects of delayed language input might be more salient for view-dependent relations than view-independent relations. This would indicate the order of conceptual development of space playing a role in spatial language development also in late language exposure (Benton, 1959; Bowerman, 1996; Clark, 1973; Corballis & Beale, 1976; Harris, 1972; Johnston & Slobin, 1979; Piaget, 1928/1972; Sümer, 2015; Sümer et al., 2014). If the early effects carry on to the final attainment of language development, we could also see different patterns for view-dependent and view-independent relations in descriptions of late signing adults, the former being more susceptible to late input than the latter.

Finally, we are interested in whether the morphological complexity of the linguistic forms to encode locative spatial relations would be differentially affected by the late sign language exposure. It is possible that morphologically complex forms such as CL might be more susceptible to the effect of late language exposure compared to simpler forms such as RL either in the early stages of language development or in the final attainment. If morphological complexity is sensitive to delayed input (see Newport, 1988, 1990), we might expect CL to be more delayed by late signing children and adults compared to morphologically simpler forms (e.g., RL) and perhaps morphological complexity of the forms might even interact with the type of locative relation expressed.

Methods

Participants

Forty-four deaf signers of TİD residing in Istanbul, Turkey were recruited for this study. Participants reported in this study consisted of four groups: 12 late signing deaf adults (Mean Age = 38;2; Age Range = 28;8–49), 9 late signing deaf children (Mean Age = 8;5; Age Range = 7;9–9;9, additional 2 children were excluded from the analyses after the coding due to failing to follow the instructions), 10 native signing deaf adults (Mean Age = 31;4; Age Range = 18;5–45;10), and 11 native signing deaf children (Mean Age = 8;5; Age Range = 7;2–9;11). All data from native deaf signers, except one child, was collected by the second author as part of a bigger project conducted between 2010 and 2015 and reported in Sümer (2015). All native signers have had exposure to sign language from birth on. All late signing adults and children started to learn TİD at primary school for the deaf (Age Range = 6–7). At the time of data collection, late signing children had around 2 years of sign language exposure in their school environment. Adult participants reported in this study have reported themselves to be profoundly deaf and unable to understand spoken Turkish. For child participants, this information was obtained from their parents and/or teachers.

Unlike in the countries with general newborn hearing screening and robust early intervention, deaf children in Turkey typically get exposed to sign language when they start deaf school around 6–7 years of age (İlkbaşaran, 2015). In deaf schools in Turkey, deaf children do not learn sign language as a part of their curriculum as all of these schools employ oral education. These children receive all of their sign language input by interacting with their late or native signing peers.

Stimuli

Stimuli consisted of 36 displays with a set of 4 pictures. These displays have been adapted by Sümer (2015) from pictures originally developed by Dr. Jennie Pyers. Each picture showed Figure (small item; e.g., pen) and Ground (large item; e.g., paper) items placed in various spatial configurations (e.g., "Pen is to the left of the paper", "Apple is to the right of the box", "Ball is in the bowl", "Toothbrush is on the cup", "Cup is under the table", "Cake is in front of the box", "Cup is behind the box"). Each display had one target picture, which was marked with a red outer frame, to be described to a confederate addressee sitting across the table. The remaining pictures in each display either contained three other pictures with the same Figure and Ground items in different spatial configurations or two other pictures with the same Figure and Ground items in different spatial configurations and an additional picture with different Figure and Ground items. Some of the items (e.g., ladybug, pig, motorcycle, giraffe) used in the dataset were not familiar to participants and thus participants failed to identify and name them. Thus, first, we took them out of further analyses. Later, we created and analyzed a remaining subset of 15 displays that contained view-independent relations for containment (IN), support/contact (ON) and occlusion (UNDER), as well as displays in which the target picture required signers to take a viewpoint such as LEFT, RIGHT. These included quasi-randomly selected 3 displays per spatial relation type for which participants were able to name all of the objects in target pictures. While selecting the final displays to be analyzed, we also ensure to reflect the general qualities of the overall dataset mentioned above. Half of the displays included four pictures in the one display with the same Figure and Ground items (n = 8) and a half included three pictures with the same Figure and Ground items and a remaining picture with different Figure and Ground items (n = 7). See Figure 1 for example, displays and Appendix for the all displays.

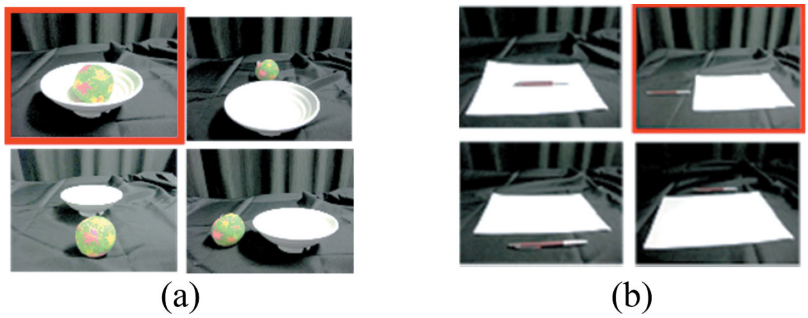


Figure 1. Example of displays with target picture with (a) view-independent spatial relation (i.e., IN) and (b) view-dependent spatial relation (i.e., LEFT).

Procedure

Participants were seated across a confederate addressee who was a deaf native TİD signing adult. Due to the small size of the deaf community in Istanbul, addressee was familiar to some of the participants in a few cases. Stimuli were presented through a 15-inch MacBook Pro computer. The computer screen was only visible to the participants. All instructions were given in TİD by the addressee herself. Participants were asked to describe the target pictures to the addressee in a fixed order. In order not to prime participants in certain linguistic strategies, no examples from TİD was given to the participants. In order to create a communicative nature for the task, the addressee was given a booklet containing the same displays without a red frame and was asked to find and point at the picture that the participant described on the booklet. Addressee did not give any feedback on whether the descriptions were correct or not. In cases where the participants did not express the spatial relations, addressee only asked for the location of the Figure item using the lexical sign of WHERE in TİD and the lexical sign of the Figure item in the target picture. Thus, addressee feedback did not provide any linguistic strategies to locate the Figure item in relation to the Ground item. At the end of the study, adult participants received a small monetary compensation and child participants received a gender-neutral color pencil kit. Figure 2 illustrates the experimental setup.

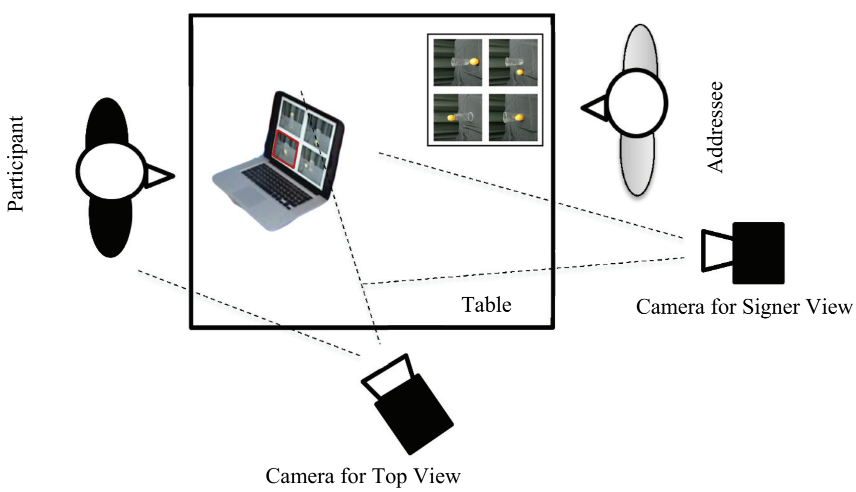


Figure 2. Illustration of the experimental set up.

Coding

All TİD descriptions were annotated sign by sign and coded using ELAN (Version 4.2 for Native Signers and Version 4.9.3 for Late Signers), a free annotation tool (http://tla.mpi.nl/tools/tla-tools/elan/) for multimedia resources developed by the Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands (Wittenburg et al., 2006). Data was annotated by a hearing research assistant with advanced knowledge and fluency in TİD and annotations were checked by a trained deaf native signer of TİD.

Later, data were coded in two steps. First of all, we coded for the presence of Figure item, Ground item and the presence of the correct spatial encoding to localize the Figure item in relation to the Ground item per description. Secondly, we coded the linguistic strategies used in encoding the location of the Figure item in relation to the Ground item for each description. There were some descriptions with incorrect spatial relation between the Figure and Ground items (e.g., describing that the pen is to the front of the paper, although the target picture showing that the pen is to the left of the paper). Moreover, we also encountered descriptions with missing spatial relation (i.e., descriptions containing only labeling of the presence of Figure and Ground items but not the spatial relation of the Figure item in relation to the Ground item). We did not further code for the linguistic strategy used in these descriptions. The data from the native signers were coded by the second author and coding was checked by a trained deaf native signer of TİD. The data from the late signers were coded by the first author and the coding was checked by a trained deaf native signer of TİD.

Linguistic strategies

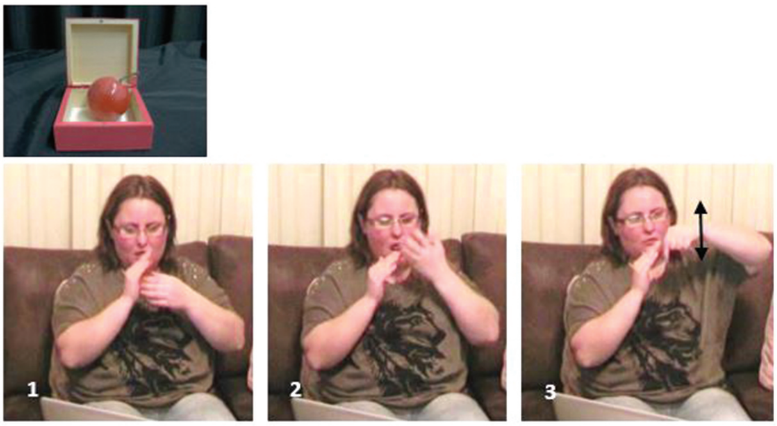
Coding of the linguistic strategies used to localize the Figure item in relation to the Ground item showed that our participants used five strategies that we grouped into three categories: a) classifier predicates (CL), b) relational lexemes (RL), and c) Other forms (pointing, tracing of the object shapes in the signing space and lexical verb placements).

Use of CL (see 3rd still of the example 1a above) is one of the most common linguistic strategy to localize Figure item in relation to the Ground item in general for sign languages (e.g., Emmorey, 2002) and also for TİD (see Arık, 2013; Sümer, 2015; Sümer et al., 2014). The use of CL is semantically the most specific way of encoding a relationship between two entities since they allow for encoding the information about the entities through the handshape classifications of the objects (see Manhardt et al., 2020; Perniss, et al., 2015). Within our data, we encountered two types of CL (i.e., Entity and Handling; Zwitserlood, 2012). For the analyses, we collapsed these two types into one group. Moreover, within all three linguistic categories (CL, RL and Other forms), CL are the most common strategy to differ in terms of handshape choices and are morphologically the most complex. In order to ensure that late and native signers are comparable in their CL use, we checked all the CL handshapes used by late signers to see if native signers also used the same handshapes as CL for the same item. As a result, none of the handshapes produced by late signers was found to be idiosyncratic and all were present in the handshape repertoire of the native signers for the exact same item. We checked this at the item level.

The second common strategy we looked at was using RL. This is a strategy used in TİD as an alternative to or in combination with CL as described above and is morphologically simpler than CL (Arık, 2013; Sümer, 2015; Sümer et al., 2014; see 3rd stills of the examples 1b and 1c above).

Finally, we grouped a few other types of strategies into a third category. These included a) pointing to the location of the Figure item in the signing space (Example 2a below), b) tracing the shape of the Figure item in the signing space (Example 2b below) and c) placing a lexical verb (see Newport, 1988 for the discussion of single-morpheme signs) in sign space to represent the Figure item in the signing space (Example 2c below). We labeled them as "Other forms". We grouped them together because none of them was frequent enough to make a unified single category.

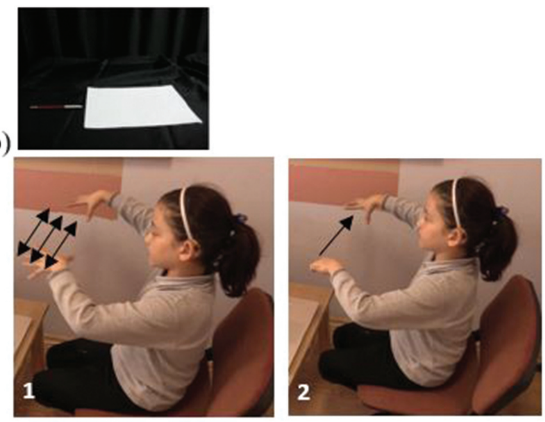
(2a)



LH:	BOX	APPLE	Point(apple)locL
RH:	BOX	CL(box)locR	----HOLD----

"There is a box. There is an apple. Apple is here."

(2b)



LH:	Tracing (Paper)	Tracing (Pen)
RH:	Tracing (Paper)	----HOLD----

"There is a paper. Pen is located left to the paper."

(2c)

LH:	GIRL	BATH	Tracing (Bath)	LV (to sit)
RH:	------------------	BATH	Tracing (Bath)	----HOLD----

"There is a girl. There is a bath. The girl is located to the left of the bath."

Note that Other forms, like RL, are morphologically less complex than CL as these forms do not incorporate the size and shape information of the entities in describing spatial relations.

Results

Data presented in this section were analyzed using generalized binomial linear-mixed effects modeling (*glmer*) with random intercepts for Subjects and Items. All models were fit with the lme4 package (version 1.1.17; Bates et al., 2014) in R (R Core Team, 2018) with the optimizer *bobyqa* (Powell, 2009). This mixed effects approach allowed us to take into account the random variability due to having different participants and different items. For completeness, we chose the most inclusive model over the most parsimonious model and did not remove the non-significant effects for the models presented in this section.

Encoding of correct spatial relations

First, we investigated the frequency of encoding the correct spatial relation of the Figure item in relation to the Ground item by Language Status and Age Group for all descriptions produced by participants. Table 1 presents the proportion of encoding the correct spatial relation of the Figure item in relation to the Ground item across different age groups and language statuses. We used *glmer* model to test the fixed effects of Language Status (Late, Native) and Age Group (Children, Adults) on binary values for presence of the correct spatial relation in descriptions (0 = No for missing or incorrect spatial relation, 1 = Yes) at the item level. Subject and Item was entered as random intercepts. Fixed effects (i.e., Language Status, Age Group) were analyzed with centered contrasts (−0.5, 0.5).

Table 2 presents fixed estimates from *glmer* model for encoding the correct spatial relation. The model revealed a main effect of Age Group. Adults generated more spatial encodings compared to children regardless of the language status. No other effects or interactions were significant, indicating that both native and late signers generated equal amounts of correct relational encodings.

Table 1. Mean proportions (SD) of encoding a correct spatial relation of the Figure item in relation to the Ground item out of all descriptions.

	Native	Late
Adults	0.98 (0.14)	0.98 (0.15)
Children	0.94 (0.24)	0.85 (0.36)

Table 2. Fixed effect estimates from the glmer model for encoding the spatial relation between Figure item in relation to the Ground item.

Fixed Effect	β	SE	z	p value
(Intercept)	3.559	0.404	8.817	.000***
$\text{Language}_{\text{Native vs Late}}$	0.587	0.568	1.033	.302
$\text{Age}_{\text{Adults vs Children}}$	1.735	0.577	3.004	.003**
$\text{Language}_{\text{Native vs Late}}$:$\text{Age}_{\text{Adults vs Children}}$	−1.124	1.145	−0.981	.327

Significance codes: *** 0.001, ** 0.01, * 0.05
Formula in *R*: Spatial_Encoding ~ Language * Age + (1|Subject) + (1|Item)

All subsequent analyses were conducted on descriptions where correct spatial relation encoding was present. As a next step, we analyzed for factors (i.e., Language Status, Age Group, Viewpoint) that contribute to the choice of the linguistic strategies (i.e., CL, RL, and Other forms) used to encode the location of the Figure item in relation to the Ground item. In the sections below, models for CL, RL and Other forms are discussed.

In some of the descriptions, participants used more than one linguistic strategy to describe the spatial relation in the target picture. For example, one description could include both CL and RL. These cases were counted for the presence of CL category as well as for the RL category. Consequently, the results presented in this part include all of the strategies for a single description and thus allow us to investigate each linguistic strategy with separate models.

Classifier predicates

First, we investigated the frequency of CL used for the Figure item by each Language Status, Age Group and Viewpoint. Table 3 and Figure 3 show the proportion of CL use across Language Status, Age Group and Viewpoint. We used *glmer* model to test the fixed effects of Language Status (Late, Native), Age Group (Children, Adults) and Viewpoint (view-independent, view-dependent) on binary values for the presence of spatial description by CL (0 = No, 1 = Yes) at the item level. All fixed effects (i.e., Language Status, Age Group and Viewpoint) were analyzed with centered contrasts (−0.5, 0.5). Subject and Item were entered as random intercepts.

Table 4 presents the fixed effect estimates from *glmer* on descriptions with CL. Model revealed an interaction between Language Status and Viewpoint. When describing view-dependent relations late signers produced less CL (0.60) compared to native signers (0.87). However, late (0.73) and native (0.62) signers produced CL equally frequently when describing view-independent relations (see Figure 3). No other effects and interactions were significant indicating that choice of CL as a linguistic strategy to describe spatial relations between items did not vary across Age Groups.

Table 3. Mean proportions (SD) of types of linguistic forms across age group, language status and viewpoint.

	Viewpoint Independent		Viewpoint Dependent	
	Late	Native	Late	Native
Classifier Constructions				
Children	0.70 (0.46)	0.53 (0.50)	0.54 (0.50)	0.86 (0.36)
Adults	0.74 (0.44)	0.71 (0.46)	0.65 (0.50)	0.88 (0.33)
Relational Lexemes				
Children	0.14 (0.35)	0.33 (0.47)	0.06 (0.23)	0.18 (0.39)
Adults	0.29 (0.45)	0.21 (0.41)	0.28 (0.45)	0.28 (0.45)
Other forms				
Children	0.19 (0.39)	0.12 (0.33)	0.52 (0.50)	0.06 (0.23)
Adults	0.05 (0.21)	0.10 (0.30)	0.27 (0.45)	0.04 (0.19)

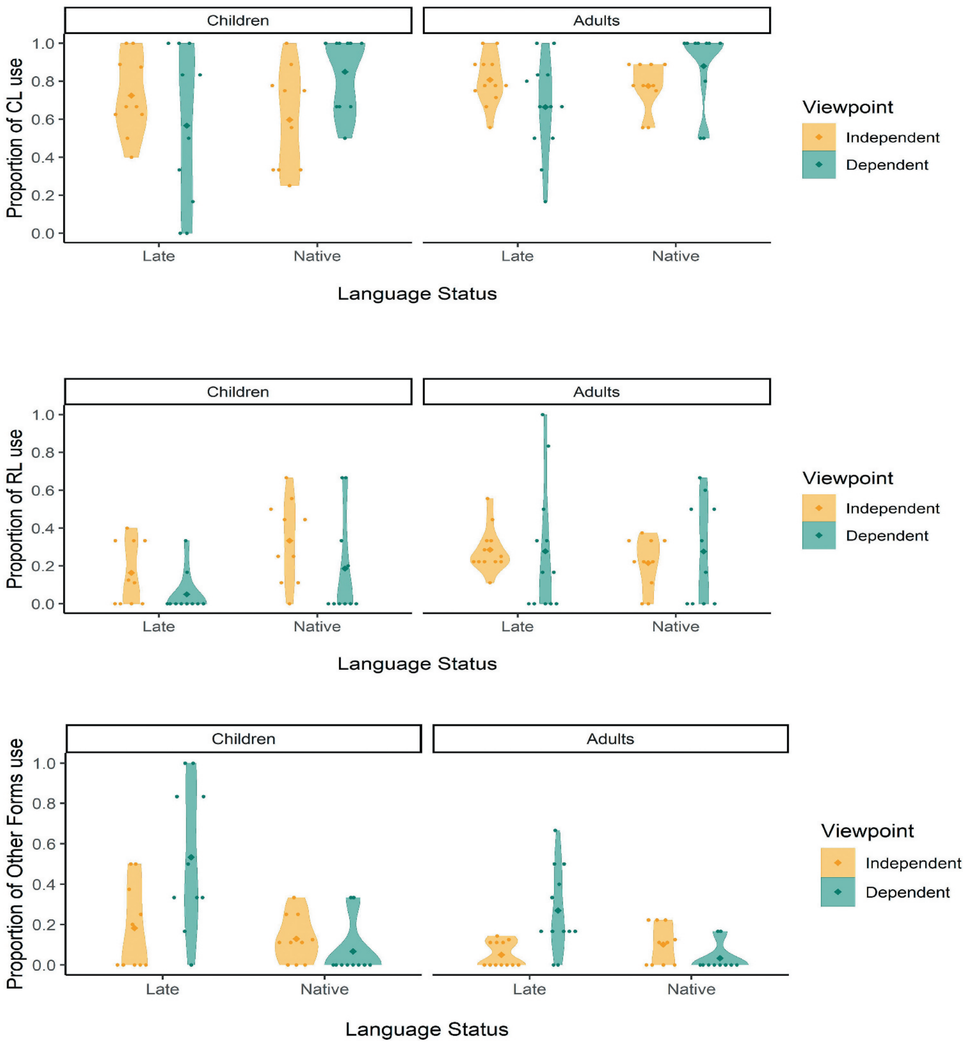


Figure 3. Proportion of types of linguistic forms as a function of age group, language status and viewpoint. Dots represent the average data for each participant. Rectangle represents the mean. The width of the violins represents the density of the data distribution. Length of the violins depict the range of the data points.

Table 4. Fixed effect estimates from the *glmer* model for frequency of CL use.

Fixed Effect	β	SE	z	p value
(Intercept)	1.556	0.393	3.960	.000***
$\text{Age}_{\text{Adults vs Children}}$	0.628	0.443	1.416	.157
$\text{Language}_{\text{Native vs Late}}$	0.636	0.443	1.434	.152
$\text{Viewpoint}_{\text{Dependent vs Independent}}$	−0.139	0.682	−0.204	.839
$\text{Age}_{\text{Adults vs Children}}$:$\text{Language}_{\text{Native vs Late}}$	−0.070	0.885	−0.079	.937
$\text{Age}_{\text{Adults vs Children}}$:$\text{Viewpoint}_{\text{Dependent vs Independent}}$	−0.494	0.483	−1.022	.307
$\text{Language}_{\text{Native vs Late}}$:$\text{Viewpoint}_{\text{Dependent vs Independent}}$	2.393	0.490	4.885	.000***
$\text{Age}_{\text{Adults vs Children}}$:$\text{Language}_{\text{Native vs Late}}$:$\text{Viewpoint}_{\text{Dependent vs Independent}}$	−0.802	0.961	−0.834	.404

Significance codes: *** 0.001, ** 0.01, * 0.05
Formula in *R*: CL ~ Age * Language * Viewpoint + (1|Subject) + (1|Item)

Relational lexemes

Next, we investigated the frequency of RL use by each Language Status, Age Group, and Viewpoint. Table 3 and Figure 3 present the proportion of RL used across each Language Status, Age Group and Viewpoint. We used *glmer* model to test the fixed effects of Language Status (Late, Native), Age Group (Children, Adults) and Viewpoint (view-independent, view-dependent) on binary values for the presence of spatial description by RL (0 = No, 1 = Yes) at the item level. All fixed effects (i.e., Language Status, Age Group and Viewpoint) were analyzed with centered contrasts (−0.5, 0.5). Subject and Item were entered as random intercepts.

Table 5 presents the fixed effect estimates from *glmer* on RL. Model revealed a main effect of Age Group. Adults (0.26) used more RL compared to children (0.19). Model also revealed an interaction between Age Group and Viewpoint. That is averaged across Language Status, while describing view-dependent relations, Adults (0.28) used more RL than children (0.12), whereas, while describing view-independent relations Adults (0.25) and Children (0.24) used RL equally frequently. Moreover, model also revealed a significant interaction between Age Group and Language Status. Averaged across Viewpoint, late signing children used RL less than all other groups. That is late signing children used RL (0.11) less than native signing children (0.27) and native signing adults use RL equally frequently (0.24) to late signing adults (0.28). No other effects and interactions were significant.

Other forms

Finally, we investigated the frequency of Other forms by each Language Status, Age Group and Viewpoint. Table 3 and Figure 3 presents the proportion of Other forms across each Language Status, Age Group and Viewpoint. See also Tables 7 and 8 for the distribution of types of Other forms for each Language Status, Age Group and Viewpoint. We used *glmer* model to test the fixed effects of Language Status (Late, Native), Age Group (Children, Adults) and Viewpoint (view-independent, view-dependent) on binary values for the presence of spatial description by Other forms (0 = No, 1 = Yes) at the item level. All fixed effects (i.e., Language Status, Age Group and Viewpoint) were analyzed with centered contrasts (−0.5, 0.5). Subject and Item was entered as random intercepts.

Table 6 presents the fixed effect estimates from *glmer* on descriptions with Other forms. Model revealed a main effect of Age Group. Children (0.21) use Other forms more than adults (0.11). Moreover, model also revealed a main effect of Language Status in which late signers (0.22) used Other forms more than native signers (0.09). Additionally, model reveled a significant interaction between Language Status and Viewpoint. That is averaged across age group, when describing view-dependent relations late signers (0.38) produced Other forms more than native signers (0.05), when describing view-independent relations, however, late (0.11) and native (0.11) signers used Other forms equally frequently.

Table 5. Fixed effect estimates from the glmer model for frequency of RL use.

Fixed Effect	β	SE	z	p value
(Intercept)	−1.765	0.366	−4.823	.000***
$\text{Age}_{\text{Adults vs Children}}$	0.785	0.372	2.111	.035*
$\text{Language}_{\text{Native vs Late}}$	0.536	0.371	1.444	.149
$\text{Viewpoint}_{\text{Dependent vs Independent}}$	−0.084	0.671	−0.125	.901
$\text{Age}_{\text{Adults vs Children}}$:$\text{Language}_{\text{Native vs Late}}$	−1.612	0.744	−2.167	.030*
$\text{Age}_{\text{Adults vs Children}}$:$\text{Viewpoint}_{\text{Dependent vs Independent}}$	1.136	0.514	2.212	.027*
$\text{Language}_{\text{Native vs Late}}$:$\text{Viewpoint}_{\text{Dependent vs Independent}}$	0.171	0.513	0.333	.739
$\text{Age}_{\text{Adults vs Children}}$:$\text{Language}_{\text{Native vs Late}}$:$\text{Viewpoint}_{\text{Dependent vs Independent}}$	0.618	1.030	0.600	.549

Significance codes: *** 0.001, ** 0.01, * 0.05
Formula in *R*: RL ~ Age * Language * Viewpoint + (1|Subject) + (1|Item)

Table 6. Fixed effect estimates from the glmer model for frequency of Other forms.

Fixed Effect	β	SE	z	p value
(Intercept)	−2.261	0.295	−7.661	.000***
$Age_{Adults\ vs\ Children}$	−0.913	0.405	−2.252	.024*
$Language_{Native\ vs\ Late}$	−1.389	0.408	−3.407	.000***
$Viewpoint_{Dependent\ vs\ Independent}$	0.606	0.509	1.191	.234
$Age_{Adults\ vs\ Children}$:$Language_{Native\ vs\ Late}$	1.229	0.812	1.513	.130
$Age_{Adults\ vs\ Children}$:$Viewpoint_{Dependent\ vs\ Independent}$	0.142	0.651	0.218	.828
$Language_{Native\ vs\ Late}$:$Viewpoint_{Dependent\ vs\ Independent}$	−2.983	0.655	−4.555	.000***
$Age_{Adults\ vs\ Children}$:$Language_{Native\ vs\ Late}$:$Viewpoint_{Dependent\ vs\ Independent}$	−0.747	1.300	−0.575	.566

Significance codes: *** 0.001, ** 0.01, * 0.05
Formula in *R*: Other forms ~ Age * Language * Viewpoint + (1|Subject) + (1|Item)

Table 7. Mean proportions of different strategies out of all Other forms used in the descriptions of view-independent relations.

	Pointing	Tracing	Lexical Verb Placement
Native Signers			
Adults	1.00	-	-
Children	0.83	-	0.17
Late Signers			
Adults	0.80	0.20	-
Children	0.69	0.31	-

Table 8. Mean proportions of different strategies out of all Other forms used in the descriptions of view-dependent relations.

	Pointing	Tracing	Lexical Verb Placement
Native Signers			
Adults	0.50	-	0.50
Children	0.20	0.60	0.20
Late Signers			
Adults	0.78	-	0.22
Children	0.79	0.07	0.14

Summary of results

In summary, late sign language acquisition did not affect the amount of correct spatial encoding. Both native and late signers generated equal amounts of correct spatial encodings. Thus, late signing children after 2 years of exposure to sign language seem to be able to express spatial relations as frequently as their native signing peers. However, factors such as Language Status, Viewpoint and Age Group differentially affect the choice of linguistic strategies used to describe spatial relations between two items.

Frequency of CL and Other forms are modulated by the interaction between delayed sign language acquisition and the viewpoint of the items to be described. Results showed that both child and adult late signers produced CL less frequently in describing view-dependent spatial relations compared to native signers. This pattern, however, is opposite for Other forms, in which, when describing view-dependent relations both child and adult late signers use them more than native signers. When describing view-independent relations, these effects are not present for using either CL use or Other forms. Both child and adult late signers produce CL and Other forms as frequently as their native signing peers do in describing view-independent relations. Moreover, children use Other forms more than adults and late signers use Other forms more than native signers as found in main effects regardless of the viewpoint.

RL use is also influenced in general by Age Group where adults use more RL compared to children. The frequency of RL use is further modulated by separate interactions between Age Group and

Viewpoint on the one hand and Age Group and Language on the other. These interactions indicate first of all that for view-dependent relations, children use RL less frequently than adults while for view-independent relations children and adults use RL equally frequently. Secondly, averaged across viewpoint of the items, late signing children use RL less frequently compared to their native signing peers. Late signing adults, however, become native-like in the frequency of RL use. Thus, for late signers, unlike what was found for the frequency of CL and Other forms use, late exposure to sign language does not affect the frequency of RL use in the final attainment but only in childhood. Consequently, late signing adults can use RL like native signing adults in their final attainment regardless of the type of spatial relation.

Discussion

In this study, we investigated the effects of late sign language acquisition on expressions of spatial language by deaf adults and children acquiring TİD. We took a comprehensive approach and studied age-matched native and late signing adults and children in the same study with the aim of understanding the effect of input characteristics (i.e., late input) on the development of spatial language use. Extending the knowledge in the literature, first, we investigated the impact of late exposure on descriptions of locative spatial relations to see whether the effects found for motion event descriptions in previous research extend to simpler forms of spatial language. Second, we base our investigation on two different types of spatial relations, namely view-dependent, and view-independent relations in order to capture the possible effect of cognitive development in learning to express spatial relations interacting with late language exposure. Moreover, we investigated whether the morphological complexity of the linguistic strategies to encode locative spatial relations differentially affected by late exposure to sign language and whether this is modulated by the type of spatial relation to be described.

First of all, our study showed that late sign language acquisition does not affect the number of correct spatial encodings of locative relations by late signers compared to native signers. This is a rather novel finding, as we know from previous research on Turkish deaf home signing children that their gestural descriptions do not convey spatial relations prior to sign language exposure (Gentner et al., 2013). Thus, within 2 years of exposure to sign language late signing children can already express equal amounts of spatial encodings compared to their native signing peers in describing locative relations.

Secondly, we found that late sign language acquisition has a differential impact on different types of locative relations: View-dependent relations are more prone to the effects of delayed sign language acquisition compared to the view-independent relations both for late signing children and late signing adults. Delayed sign language acquisition therefore hinders the acquisition of descriptions of view-dependent relations as it does for motion events (Newport, 1988, 1990) but not for view-independent ones.

Moreover, we found that especially for the descriptions of view-dependent relations, frequency of linguistic devices (CL, RL, Other forms) that signers use was differentially affected by late exposure. It seems that due to the morphological complexity of CL, late signing children and adults use them less frequently compared to morphologically simpler forms even in adulthood, and choose simpler devices such as Other forms instead. It is also the case that while describing view-dependent relations, late signing adults become native-like in the use of simpler forms such as RL even though they are not picked up early on by late signing children.

Finally, we also found that regardless of the viewpoint of the descriptions and years of sign language exposure, children differed from adults in their choice of linguistic strategy use. Children overall used more Other forms. Moreover, children used less RL compared to adults. The lower frequency of RL use by children compared to adults interacts with the age of exposure to language and type of spatial relation to be described, separately.

Below we discussed the implications of these findings with regard to language development, late exposure, morphological complexity, and cognitive development. Additionally, we discussed the robustness of these findings concerning the individual differences in handedness and item type.

Late sign language exposure hinders the acquisition of expressions of view-dependent relations but not view-independent ones

Previous research shows that native signing but not hearing children are able to describe view-dependent locative spatial relations in adult-like ways around 5 years of age possibly due to the iconic affordances of the modality of the sign languages (Sümer, 2015; Sümer et al., 2014). Although both types of static spatial relations, (i.e., view-dependent and view-independent) are acquired early by native signing children (Sümer, 2015; Sümer et al., 2014), our findings suggest that this is not the case for late signing children. Despite the iconic and body-anchored representation of locative forms to express spatial relations in TİD, deaf children still need early exposure to be able to benefit from iconicity in these forms for acquiring descriptions of view-dependent relations. Thus, iconicity cannot be taken for granted (see Cartmill et al., 2017). Our findings show that late signers *do* need early sign language input to benefit from iconic forms.

Rather results show that late signing children parallel the trends in spoken language acquisition with an earlier acquisition for view-independent relations than view-dependent relations. Such an earlier acquisition is argued to be due to the mapping of linguistic forms on to the already existing prelinguistic conceptual categories of containment and support (E. Clark, 1973; Johnston & Slobin, 1979) in which children first show an understanding of these concepts prior to language (e.g., Casasola, 2008; Casasola et al., 2003) and at around two years, they use linguistic forms for containment and support (Bloom, 1973; Bowerman, 1996; Brown, 1973). Therefore, late signing children might already have an understanding of the view-independent relations before exposure to language and thus can easily map the linguistic forms to these concepts after two years of exposure to sign language. However, it is argued that for view-dependent relations, conceptual development takes more time (see Benton, 1959; Harris, 1972; Piaget, 1928/1972; Sümer, 2015). Therefore, in the case of late exposure to sign language the mapping of expressions for these concepts might also be delayed and this delay persists into adulthood. This finding points to a complex interplay between late language acquisition and the effects of conceptual development in the spatial domain (see Berk & Lillo-Martin, 2012; Boudreault & Mayberry, 2006). Moreover, our findings also parallel the argument on the importance of maturational constraints on the receptivity of spatial semantics by L2 learners of English in spoken language acquisition (Munnich & Landau, 2010).

The difference between view-independent versus view-dependent relations can also be explained by the informativeness of the strategies used in Other forms. The most frequent strategy, that is pointing, used in Other forms would be less informative in distinguishing between the exact spatial configuration between the Figure and Ground item for view-independent relations than they are for view-dependent relations. For instance, imagine describing “a pencil in a cup”. When signers locate the cup in the signing space and then point toward the cup to indicate the location of the pencil, it will not be clear whether the pencil is “in” the cup or “on” the cup or whether the signer is simply pointing towards the cup. This is not the case for view-dependent spatial relations, where pointing to an empty space next to where the Ground object is signed would be less ambiguous and indicate the location (e.g., right or left) of the Figure item in relation to the Ground item. Thus, an informativeness strategy might be guiding the acquisition of linguistic forms in late exposure (see Grigoroglou et al., in press for similar claims for the role of informativeness in the acquisition of spatial language in spoken language development).

Morphological complexity of the linguistic devices is differentially affected by late exposure

Our findings show that the morphological complexity of the forms also plays a role in sensitivity to late exposure and in ways interacting with the conceptual complexity of the relations described. CL which are morphologically the most complex forms compared to RL and Other forms and they are used less frequently by late signers compared to native signers for view-dependent relations but equally frequently when describing view-independent relations. These are in line with findings from previous research on CL being vulnerable to late input also for complex descriptions such as motion events (see Newport, 1988, 1990). The fact that we found hindering effects of late input for CL for conceptually complex relations (i.e., view-dependent relations) provides evidence for an interaction between late exposure, morphological and conceptual complexity. On the other hand, RL, which are morphologically simpler than CL, are used as frequently as native signers in adulthood even for view-dependent relations by late signing adults. It could be that, although less informative (i.e., in terms of size and shape of the objects) compared to CL, RL could be easier to learn and generalizable to other contexts and can be used in native-like frequencies by late adult signers –but not by late signing children with 2 years of sign language exposure yet. Given that, sign language populations are dominated by late signers, the existence of RL in sign languages as an additional strategy to CL could be due to the their ease of learnability and generalizability of the forms themselves by late signers compared to CL (see Gordon, 1990; Fulop & Chater, 2013 for a discussion on the ease of learnability).

Finally, our study is first to point out that signers choose also Other forms, that are morphologically simpler, instead of CL in sign language descriptions of locative spatial relations between two items. This finding is also modulated by the interaction between the late language acquisition and type of spatial relation to be described, in which late signers, both adults and children, choose these simple forms more for descriptions of view-dependent relations than native signers but not for descriptions of view-independent relations. Thus, despite the years of exposure to language, hindering effects of late exposure persist for language productions of some types of spatial relations.

Children differ from adults in the use of linguistic devices

Regardless of the late sign language exposure and years of exposure to sign language, children, in general, differed from adults in the frequency of types of linguistic devices they used. Children used Other forms more than adults, in general. Additionally, children also differ from adults in the frequency of RL in which children used less RL compared to adults. This effect also interacts with the type of spatial relation to be described and the age of exposure to language, separately.

First of all, we believe that high frequency of Other forms used by children compared to adults gives insights into the developmental trajectory of leaning to describe spatial relations between two entities. These forms, such as pointing, tracing, etc., can be considered as the "building blocks" of visual modality in learning to express spatial relations. We can generalize from this finding that children start with "simpler forms" in learning to encode locative spatial relations.

Nevertheless, when it comes to RL, although RL are also simpler than CL (Arık, 2013; Perniss, et al., 2015), children use them rarely compared to adults. This age effect also interacts with the type of spatial relation and age of exposure to language, separately. The first interaction indicates that both late and native signing children use RL less frequently than adults for view-dependent relations but equally frequently for view-independent relations. This is possibly due to the complex interplay between morphological complexity of the linguistic devices and conceptual complexity of the types of spatial relations to be described as discussed above. Secondly, the interaction between age group and age of exposure to language posits that averaged across the type of spatial relation, late signing children use RL less frequently than late signing adults, although native signing children were adult-like in terms of the frequency of RL use. A possible explanation for the lower frequency of RL use by late signing children can be due to the fact that RL are in general used less frequently to encode spatial relations by native signing adults (see Perniss, et al., 2015 for discussion; also see Arık, 2013; Emmorey, 2002; Johnston et al., 2007; Özyürek et al., 2010; Perniss, 2007) and children (Sümer, 2015; Sümer et al., 2012). The lower frequency of RL use by the native signers, in general, can possibly reduce the exposure of RL to late signing children who are exposed to the sign language from their native signing peers at school.

Effects of handedness and items

Finally, we would also like to discuss the robustness of these findings with regard to the interaction of possible factors such as individual differences in handedness and types of items we used displaying different types of relations. We checked whether handedness of participants (either left-handed or right-handed) could be the reason for the frequent use of Other forms by late signing children in describing view-dependent relations. It is possible that late signing children might have used Other forms in descriptions of view-dependent relations where the location of the Figure item had to be signed by the non-dominant hand compared to cases where it had to be signed by the dominant hand. To illustrate, in order to sign "Apple to the right of the box" on the signing space via CL, signers need to locate the classifier handshape for "apple" with their right hand that is on the right side of the signing space and in order to sign "Apple to the left of the box", signers need to locate the classifier handshape for "apple" with their left hand that is on the left side of the signing space. We checked if this general tendency could make it harder for late signing children especially when Figure item needed to be signed by the non-dominant hand. Thus, such an effect could have led to a higher frequency of using Other forms, instead of using CL, in describing view-dependent relations.

There were a total of 6 view-depended pictures to be described in the stimuli set per child. We found that left-handed late signing children (n = 3) preferred Other forms in 13 out of 18 descriptions. Similarly, right-handed late signing children (n = 4) used Other forms in 10 out of 24 descriptions. That is, left- or right-handed children did not differ in their use of Other forms. We did not have handedness information of the remaining two children. These results show that interaction between handedness and stimulus type did not systematically lead to a choice of Other forms by late signing children in describing view-dependent relations.

Secondly, we wanted to see if different linguistic strategies used in the descriptions of view-independent and view-dependent relations could be driven by certain Figure items used in the stimuli pictures. We compared descriptions of three Figure items (apple, pen, and cat) that are present in both view-independent and view-dependent relations. It turned out that late signing children were not affected by the possible intrinsic qualities of the Figure items in their choice of linguistic strategy. In pictures depicting view-independent relations, these three items in total were described more frequently with CL (73%) compared to Other forms (24%). However, when these items were in pictures depicting view-dependent relations, the frequency of linguistic strategies used was the opposite, and in line with the general patterns we observed: CL (38%) compared to Other forms (55%). Thus, we can rule out the possibility that the differences in linguistic strategies used in different types of locative relations are driven by item characteristics but driven by the spatial relation between the two items.

Conclusion

Overall, the present study demonstrates that late sign language input can influence the acquisition of simple locative relations for children and adults. However, this effect depends on the type of locative relation and the type of linguistic device used. While view-independent relations are quickly learned 2 years after the late exposure and in native-like ways by children and adults, acquisition of view-dependent relations takes more time. Late signing adults become native-like in expressing view-dependent relations in the use of morphologically simpler forms (e.g., RL vs CL). These findings shed some new light into the complex interplay between the differential impact of cognitive and linguistic factors in spatial language development and late language input. They show that linguistic expressions that appear later in cognitive development (i.e., view-dependent relations) might be more susceptible to the effects of delayed language input than the ones that appear cognitively earlier (i.e., view-independent relations; see Benton, 1959; Bowerman, 1996; Clark, 1973; Corballis & Beale, 1976; Harris, 1972; Johnston & Slobin, 1979; Piaget, 1928/1972). This suggests that cognitive factors might be modulating which types of linguistic expressions will be influenced by late exposure.

Moreover, these results are in line with the literature showing that the morphological complexity of the forms used in sign language descriptions of space plays a role in late exposure (Newport, 1988, 1990) – in our case comparison of morphologically complex CL to morphologically simpler RL and Other forms. Nevertheless, our study goes beyond this finding and shows that in addition to morphological complexity, factors outside of language such as type of spatial relation (i.e., view-dependent vs view-independent) also interact with late exposure to language.

Our study also uniquely displays these patterns for late signing *children* for the first time in the literature comparing them to their native signing peers as well as to late signing adults. The latter comparison also allowed us to see that late signing adults of TİD who have lengthier language experience compared to late signing children, who have only a 2-year of sign language exposure, still have less preference for CL and more preference of Other forms. This finding is also in line with other studies that underlie the significance of the age of acquisition, rather than the length of exposure, in both sign and spoken language development (see Mayberry, 2010). Our study goes beyond in showing that the hindering effect of late exposure to language is modulated by cognitive and linguistic complexity.

Nevertheless, our study has certain limitations. Further studies should investigate the possibility of handshape differences at the phonological level in CL used by late signing adults and children and compare them to their native signing counterparts.

Furthermore, in order to capture the developmental patterns of learning to express locative relations fully it would be informative to focus on word order conventions by late signing children and adults and compare them to what has been already found for the native signing adults and children (see Perniss, 2007 for German Sign Language; Sümer, 2015 for TİD). These will further enhance our understanding of the complex interplay between different aspects of linguistic mastery, conceptual complexity, age and length of language exposure in the future.

Acknowledgments

We thank our deaf assistants Sevinç Yücealtay Akın, Şule Kibar, Yusuf Ermez and hearing assistant Hükümran Sümer for their help in collecting, annotating, and coding data. The stimuli in the study were originally developed by Dr Jennie Pyers (Wellesley College, The USA), and we thank her for sharing these materials with us. Moreover, we are also very thankful to Dr Ercenur Ünal for her intellectual contribution for the various stages of this manuscript and Francie Manhardt for her contributions to the statistical analyses. The authors are very grateful to Nick Wood† and Jeroen Geerts for helping us with processing the video data.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research is supported by the NWO VICI Grant and European Research Council (ERC) Starting Grant awarded to the last author. Portions of this work were presented at several international conferences between 2010–2018.

ORCID

Dilay Z. Karadöller http://orcid.org/0000-0001-5160-7679
Beyza Sümer http://orcid.org/0000-0002-1605-4551

Aslı Özyürek http://orcid.org/0000-0002-0914-8381

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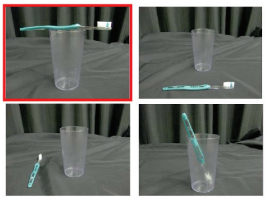
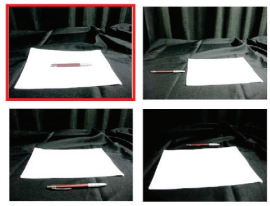
Appendix Target displays

Toothbrush on cup

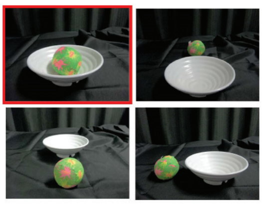


Pen on paper

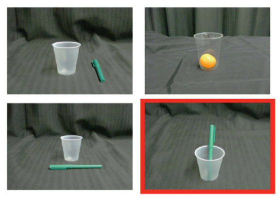


Cup on table

Ball in bowl

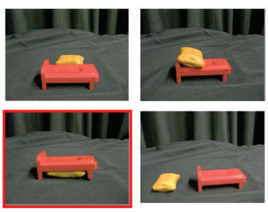


Pen in cup

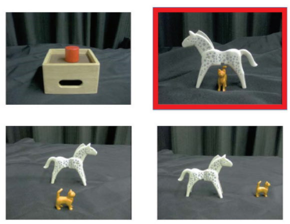


Apple in box

Pillow under bed

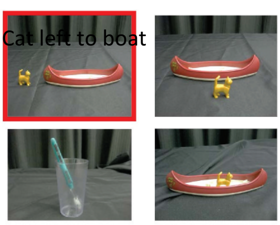


Cat under horse

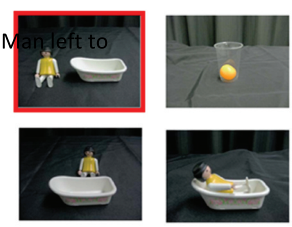


Cup under table

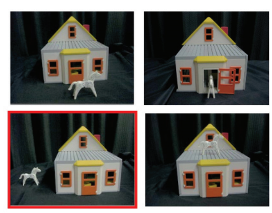
Cat left to boat



Man left to bathtub

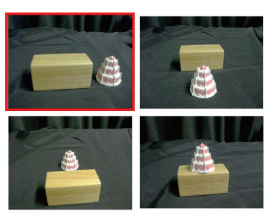


Horse left to house



Apple right to box

Cake right to block



Pen left to paper