**Gradual Route to Productivity: Evidence from Turkish Morphological
Causatives**

Ebru Ger¹, Guanghao You², Aylin C. Küntay³, Tilbe Göksun³, Sabine Stoll^{2,4}, and
Moritz M. Daum^{1,4,5}

¹Department of Psychology, University of Zurich, Switzerland

²Department of Comparative Language Science, University of Zurich, Switzerland

³Department of Psychology, Koç University, Turkey

⁴Center for the Interdisciplinary Study of Language Evolution (ISLE) Zurich, Switzerland

⁵Jacobs Center for Productive Youth Development, University of Zurich, Switzerland

**This version of the article has been accepted for publication at Cognitive Science after peer
review but is not the Version of Record and does not reflect post-acceptance
improvements. The
Version of Record is online at: <https://doi.org/10.1111/cogs.13210>**

Date: 22.02.2023

Author Note

Correspondence concerning this article should be addressed to Ebru Ger
<https://orcid.org/0000-0002-6140-1807>, University of Bern, Institute of Psychology,
Fabrikstrasse 8, 3012 Bern, Switzerland. E-mail: ebruger@gmail.com
Sabine Stoll and Moritz M. Daum share the senior authorship. Declarations of interest:
‘none’. During her PhD, Ebru Ger was a fellow of the “International Max-Planck Research
School on the Life Course” (IMPRS LIFE, <http://www.imprs-life.mpg.de>)

Abstract

Becoming productive with grammatical categories is a gradual process in children's language development. Here, we investigated this transition process by focusing on Turkish causatives. Previous research examining spontaneous and elicited production of Turkish causatives with familiar verbs attested the onset and early stages of productivity at ages 2 to 3 (Aksu-Koç & Slobin, 1985; Nakipoğlu et al., 2021). So far, however, we know very little about children's understanding of causatives with novel verbs. In the present study, we asked: (1) When does the generalization of causative morphology in a novel context emerge? and (2) What role does child-directed input play in this development? To answer the first question, we conducted comprehension-judgment experiments with children aged 2;6–6;1¹ using pseudo-verbs (Study 1 & 2). Results showed that children preferred the Turkish causative suffix -DIr over an unrelated or no suffix to denote caused events earliest at age 4;10. To answer the second question, we analyzed child-directed speech from a longitudinal corpus of Turkish language acquisition (Study 3). Results showed that when addressing children younger than age 3, caregivers used the -DIr suffix with little variation considering the overall variability of verbs they could utter. Overall, these findings suggest that productivity with morphological causatives in a novel context emerges in a later stage of acquisition. This later development might partly be accounted for by the insufficient variation of morphological causatives in the early input.

Keywords: causatives, Turkish morphology, comprehension, child-directed speech, corpus

¹ Age notated in years:months.days

1 Introduction

Language acquisition heavily relies on two factors, language exposure (input), and the learning mechanisms that ultimately enable children to use grammatical categories independent of individual items. This is commonly referred to as productivity. Here, we suggest that productivity develops gradually. We focus on Turkish children's understanding of causative morphology and the relationship between the developmental process and language input.

Productivity in language acquisition has long been a major topic in cognitive science. Many studies have attempted to capture children's productivity with grammatical categories with various measures, yielding inconsistent results (Akhtar & Tomasello, 1997; Berko, 1958; Brown, 1973; Kuczaj, 1978; Lieven & Behrens, 2012; Lignos & Yang, 2016; Maratsos, 2000; Matthews & Theakston, 2006; McKercher & Jaswal, 2012; Stoll, 2015; Wagner et al., 2009). These inconsistent results may not merely be an artifact of the different measures used, but an indication that productivity manifests at different levels on a continuum of development (Behrens, 2015; Dromi et al., 2003; Gábor & Lukács, 2012; Stoll, 2005; Theakston et al., 2015). In other words, it may not be useful to categorize children either as productive or not productive at a given age. Rather, children may be productive to a certain degree under certain circumstances, and only gradually over time become fully productive. Along this route, children go through several years and stages of experience supported by language exposure (Brooks & Tomasello, 1999; Dittmar et al., 2008; Tomasello & Kruger, 1992) as well as broader cognitive developments such as statistical learning, perception, memory, and executive functions (Kidd et al., 2020). Here, we focus on the gradual route to productivity with verbal morphology.

Take the example of mastering the use of the English past tense suffix -ed. A child will not immediately display full productivity, that is, she will not be able to form the past tense for all verbs in all contexts. Initially, she may utter verbs inflected by -ed as rote-learned, unanalyzed chunks, with no productivity involved (Bowerman, 1974, 1982; Clark, 2014; Lieven, 2010; Tomasello, 2003). Later, she starts uttering a limited number of verbs correctly inflected with -ed when describing events in the past. At this time, she also over-generalizes the schema of the -ed suffix to the point of using it incorrectly as in “go-ed” instead of “went” (first stage of

productivity; Bowerman, 1982; Bybee, 1995; Maratsos, 2000; Marcus et al., 1992; Maslen et al., 2004; Pinker & Ullman, 2002; Plunkett & Marchman, 1993). The child then becomes more flexible in the use of the -ed marker on a wider variety of verb types (second stage of productivity; Kuczaj II, 1977; Matthews & Theakston, 2006). Finally, she can correctly and productively describe past events with -ed in all proper scenarios in an adult-like way, reaching full productivity. This level of full productivity has first been captured in elicited production experiments using pseudo-verbs, the so-called wug test (Berko, 1958). This experiment tested whether children who were taught, for example, that “ricking” stands for swinging can produce “ricked” to indicate that this action happened in the past.

The wug test requires children to produce past tense forms with novel verbs, which they have never heard before. Young children are, however, in general, reluctant to produce or coin novel words or forms they have not heard modeled by another speaker (Akhtar & Tomasello, 1997; Clark, 2014; Olguin & Tomasello, 1993). However, the knowledge of morphology may not only be manifested in the production of speech, but also in comprehension. Hence, we used an adapted version of the wug test to reduce the demand to produce novel forms. Instead of producing a novel form, we let children choose from two alternatives, only one of which is grammatical (Jaswal et al., 2008). Therefore, in this study, we probe productivity by assessing comprehension and grammaticality judgments rather than production.

In sum, we attempted to reconcile the various methods to assess morphological productivity and the differing findings derived from these methods. We hypothesized that productivity can be best described as a continuum. In the following, we illustrate this continuum by focusing on causative morphology.

1.1 Causative Verbs

Causality is one of the cornerstones of human cognition and it emerges early in ontogeny. Even 6-month-old infants perceive causality in events (Cohen & Oakes, 1993; Leslie & Keeble, 1987). An intriguing yet unresolved issue is how children learn to represent this early emerging concept of causation in language.

Here, we use the term causatives for “verbs [or verbal constructions] which refer to a causative situation, that is, to a causal relation between two events, one of which [effect event] is believed by the speaker to be caused by another [cause event]” (Kulikov, 2001, p. 886). The two main types of causatives found in the languages of the world are lexical and morphological causatives (Comrie, 1989; Dixon, 2000; Shibatani & Pardeshi, 2002; J. J. Song, 2014). In lexical causatives, the notion of cause is embedded in the predicate itself without a formal marker of causality, such as in “I **feed** the cow”. Here, the lexical causative “feed” indicates both the cause event of feeding and the effect event of cow’s eating. In many morphologically complex languages, the causal meaning is marked with a causative morpheme. For instance, in Turkish, attaching the -DIr suffix to the transitive verb stem *ye*, ‘to eat’, turns the verb into the causative verb *yedir* [eat-CAUS], ‘to feed’.

1.2 Acquisition of Causative Morphology

Previous research on children’s spontaneous speech suggests a gradual development of morphological causatives over the first three years of life in several languages including Turkish, Hebrew, Inuktitut, Quechua, and Japanese (Aksu-Koç & Ketrez, 2003; Allen, 1998; Berman, 1993; Courtney, 2002; Ketrez, 1999; Murasugi et al., 2003). It has been suggested that children’s understanding of morphological causatives evolves from verbs being perceived as unanalyzed chunks in their second year of life to the emergence of causativized verbs in their third year (Berman, 1993; Nakipoğlu et al., 2012). Elicited-production studies show that children improve their causative understanding continuously with age (Berman, 1993; Nakipoğlu et al., 2021). For example, given *Bebek muz yiyor*, ‘The baby is eating a banana’, Turkish-learning children can produce *yediriyor* ‘feeding’ when prompted with *Anne bebeğe muz ...* ‘The mom is ... a banana to the baby’ (Nakipoğlu et al., 2021). However, 2;6- to 8;7-year-old Hebrew-learning children showed less success in deriving causative forms from pseudo-verbs than from familiar verbs (Berman, 1993). This gap in success between pseudo-verbs and familiar verbs decreased with age, indicating that children change from merely relying on lexical familiarity and contextual cues to becoming fully productive with morphology. What remains largely unknown is whether and when children start to comprehend the grammatical necessity of a verbal causative suffix.

Here we test when Turkish children comprehend the causative by allowing them to choose the correct (i.e., causative) suffix over an alternative.

1.3 Turkish Causatives

Turkish causative morphology stands out as a good candidate for probing morphological productivity for two reasons. First, Turkish has both morphological and lexical causatives, that is, there is both lexical and grammatical learning involved. Due to the existence of lexical causatives, not every causative is systematically derived with morphological suffixation. This might pose a challenge for the acquisition of morphological derivation of causatives that extends beyond familiar items and contexts (Bates & MacWhinney, 1989). For instance, for some causative actions, children need to learn non-derived verbs² such as *kes* ‘to cut’, *at* ‘to throw’, and *katla* ‘to fold’. These would be classified as lexical causatives (Kulikov, 2001; Shibatani, 2002; Shibatani & Pardeshi, 2002). For other causative actions, children need to learn verbs derived with the causative marker -Dİr such as *doldur* ‘to fill (tr.)’ and *güldür* ‘to make laugh’.

Second, the causative marker -Dİr is highly regular and prevalent. There are four other forms, -t, -İr, -Ar, and -It, but they are less frequently used. -Dİr may surface as “-dir, -dır, -dür, -dur, -tir, -tır, -tür, -tur” based on harmony rules of Turkish. Here we focus on -Dİr because it better suits our aim of examining whether productivity shows a gradual development, than other affixations that involve many exceptions. The morphological derivation of causatives is highly productive (Comrie, 1989; Kornfilt, 1997; Shibatani & Pardeshi, 2002). When a causative marker is affixed to a non-causative verb, the derived verb denotes the caused version of the action or event depicted by the non-causative verb. Even if a verb is a lexical causative and therefore already causal in the stem form, a causative marker can still be affixed to make a double causative (i.e., making someone do something that affects something or someone else). In

² The term ‘non-derived verbs’ in this context refers to root or stem verbs that have not been attached with a causative marker. This category of verbs would require an anticausative marker (e.g., -il, -in) to derive the anticausative form, namely the intransitive verb indicating the event that affects the subject with the cause not involved. For example, *kes-il* would mean ‘to be cut’ and *katla-n* would mean ‘to be folded’.

addition, in Turkish, there are almost no verbs that can be used both causally and non-causally (labile verbs), and only a few verbs whose causative alternatives are not derived but are different verbs (Haspelmath, 1993). For instance, the causative of the intransitive verb *yan* ‘to be on fire (anticausative)’ is not **yandır*, but *yak* ‘to set on fire (causative)’. This means that there is a directed anticausative-causative alternation, and a non-causative verb, for the most part, *must* take a causative marker to become causative. Hence, the relationship between non-causative verbs and their causative counterparts is highly transparent (Shibatani & Pardeshi, 2002). Moreover, although lexical causatives need to be anticausativized with an anticausative marker, Turkish displays a greater preference for causative derivation than anticausative derivation (Haspelmath, 1993).

1.4 Acquisition of Turkish Causatives

So far, the acquisition of causatives in Turkish has mainly been studied in spontaneous speech data (Aksu-Koç & Ketrez, 2003; Aksu-Koç & Slobin, 1985; Ketrez, 1999; Sofu, 1995), and a few studies experimentally tested children’s elicited production and comprehension of causative forms with familiar verbs (Ammon & Slobin, 1979; Nakipoğlu et al., 2012; Nakipoğlu et al., 2021). Hence, much has been researched before the stage of full productivity in the continuum. As attempts to measure productivity in general, these studies claim that children show productivity with morphological causatives as early as 2 years of age. Children were considered productive when they used at least one verb stem and its derived causative form appropriately at the same measurement point (session) and shifted between them. For example, Ketrez (1999) found contrastive use of causative and anti-causative forms in correct syntactic frames and appropriately shifting between them in spontaneous speech as early as age 1;9. The author thereby considered the Turkish-learning child to show evidence of productivity in causative morphology by this age. These results certainly suggest that children show some early signs of productivity with the morphological derivation of causatives in the second year of life. Yet, they mainly target the early stages in the continuum of productivity, and the measured level of productivity is very much limited to highly frequent forms that are encountered in the input. To test whether children are indeed fully productive we need to show that they can produce

causatives independent of individual lexemes. There is no previous experimental study on Turkish causatives conducted with pseudo-verbs, therefore, we fill this gap by carrying out such an experiment here.

1.5 The Present Study

In the present study, we asked at what age children reach the stage of full productivity with causative morphology. To test this, we used a *comprehension-judgment* task: Children first learned a pseudo-verb for an action, and subsequently viewed an action describable by the causativized version of the pseudo-verb. They then had to choose the causative derived form over another alternative derived form – an existing but unrelated suffix attached to the pseudo-verb (or with no suffix in Study 2) – for its expression. In this comprehension-judgment task, children needed both to comprehend the caused version of the action and judge the grammatically correct use of the causative morpheme. With this methodology, we aimed to assess children's understanding that the causative morpheme can and must be productively attached to verbs to express the caused version of an event.

In addition to revealing when children on average show evidence for full productivity with causative morphology, shedding light on why this level of productivity might emerge at that age is also important. Although we know that the stored exemplars play a fundamental role in children's abstraction of schemas which they can productively apply to any given verb (Ambridge, 2020), the source of these exemplars remains to be more closely examined. A major source is undoubtedly the language input directed to children. Especially, the variation of verb types with which the causative morphemes are used in the child-directed input may provide important insights into the developmental timeline of children's abstraction process in the route to full productivity (Bybee, 1995; Plunkett & Marchman, 1993).

In sum, the present paper aims to answer the following questions: (1) When do Turkish-learning children display abstract generalization of morphological causatives in a pseudo-verb-learning context, and (2) Does the variation of morphological causatives in child-directed input play a role in this developmental timeline. To investigate these questions, we combined experimental and corpus work. In Studies 1 and 2, we used experimental designs with pseudo-

verbs in comprehension-judgment tasks to determine the age when Turkish-learning children reliably understand the -DIr causative marker. To account for the possibility that this understanding might be influenced by children's overall stage of language development, given robust links between young children's grammar complexity and vocabulary size (Bates et al., 1988; Dale et al., 2000; Hoff et al., 2018; Marchman & Bates, 1994), we measured their vocabulary as a proxy for their linguistic knowledge. In the corpus study, we examined naturalistic speech (i.e., everyday speech) to account for children's acquisition of causative marking. More specifically, we looked at the input from caregivers directed to children in an attempt to find relationships between the richness of the input, in terms of causatives, and the experimental results regarding the development of abstraction of causative marking in children. With the combination of experimental and corpus evidence, we aimed to shed light not only on the question of *when* children generalize morphological derivation of causatives, but also *why then?*.

2 Study 1

In Study 1, we asked at what age children acquire an abstract understanding of causative morphology and thereby approach full productivity. We tested Turkish-learning children in a comprehension-judgment task using pseudo-verbs. We focused on the most productive causative marker in Turkish, -DIr, and assessed at what age children were able to reliably judge the use of this causative marker over a suffix that exists in the language but is unrelated to causativization. Previous studies which explored the acquisition of causatives in Turkish (Aksu-Koç & Ketrez, 2003; Aksu-Koç & Slobin, 1985; Ketrez, 1999; Nakipoğlu et al., 2012; Nakipoğlu et al., 2021) and other languages (Allen, 1998; Courtney, 2002; Murasugi et al., 2003) suggest that the onset of productivity with the morphological causatives emerge sometime between 2 and 3 years of age. However, although we do not know much about the developmental timeline in pseudo-word contexts, it may extend to much older ages considering the previous research in Hebrew (Berman, 1993). Therefore, we tested children starting at age 2;7 up to 6;1. In addition, to check the validity of the task, we also tested adults.

2.1 Method

2.1.1 *Participants*

One-hundred-six typically developing, native Turkish-speaking children (52 females, 54 males) within the age range of 2;7 to 6;1 ($M = 4;4$, $SD = 0;11$) participated in the study. They were recruited from a total of 11 kindergartens located in various districts of Istanbul, Turkey. Seven additional children were tested but excluded from the analyses (2 had developmental problems, 3 did not respond in at least three out of the four trials, and 2 because of experimental error). Demographic information forms were returned by 81% of the participants. Based on this data, 50% of the children had at least one sibling, 74% of the mothers and 94% of the fathers were full-time employed (and another 1% worked part-time for each parent), 12% of mothers and 8% of fathers completed 5 or 8 years of compulsory education (primary school), 13% of mothers and 27% of fathers completed secondary education (high-school), 62% of mothers and 53% of fathers completed university education, 14% of mothers and 2% of fathers completed higher education (master's or Ph.D. degree). All procedures were approved by the local research committee and performed in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments. Children received a sticker and a book for their participation.

Furthermore, 42 native Turkish-speaking adults (27 females, 15 males) within the age range of 18-33 years ($M = 24$, $SD = 3;2$) participated in an adult-appropriate online version of the task (see 2.1.3 for the details of the procedure). Participation was on a voluntary basis and was not compensated.

2.1.2 *Materials*

For the testing of adults, we created and carried out the online questionnaire on SoSci Survey (Lenier, 2019). For the testing of the children on both the language judgment task and the receptive vocabulary task, we used a 14-inch touchscreen laptop. Touchscreen functionality was only employed for the receptive vocabulary task. Both tasks were run with the software PsychoPy (Version 1.90.1, Peirce & MacAskill, 2018). We used two puppets, which were each

given a name, for the language judgment task. All video materials and the Python script of the tasks used in Studies 1 and 2 can be found at: <https://osf.io/dyarg/>.

2.1.3 Procedure and Design

All children were tested by an experimenter who was accompanied by another experimenter who operated the puppets. There were a total of four experimenters involved in testing, with any two interchangeably taking part as the main experimenter and the one operating the puppet at different testing sessions. Children were individually tested in a separate room in their kindergarten. They were first introduced to the experimenter by their kindergarten teacher. Then the experimenter conversed with the child for a few minutes as a warm-up and subsequently introduced the task. Each session lasted about 10 minutes. Children's responses were coded online but the sessions were also videotaped to allow further analyses.

To assess the abstract understanding of the causative marker in Turkish, children were tested in a grammaticality judgment task (similar to Jaswal et al., 2008; Kanero et al., 2016). Children first heard a simple instruction explaining their task: "Now, we're going to play a game with you. Look, there are two puppets here, called Omer and Ferhat. Omer and Ferhat are learning how to talk about movies. Your task is to teach this to them. We will watch a short movie together and then I will ask Omer and Ferhat what happened in the movie. They will try to tell what happened in the movie in the best way they can. Sometimes Omer will tell it better and sometimes Ferhat will tell it better. Your task is to point to the one who told it better. Deal?". The subsequent test included four trials. In each trial, first a teaching phase and subsequently a language judgment phase took place. In the teaching phase, children watched a video along with the puppets in which an inanimate object moved in a certain way. Simultaneously, an audio recording of a native female speaker described the action with a pseudo-verb. For example, a balloon hanging on a rope swung from one end to the other and the audio described: "Oh look. The balloon is VERB-ing. Look, the balloon is VERB-ing". When the video stopped the speaker used the past form of the sentence "The balloon VERB-ed", while a frozen frame of the end of the video was on the screen (see Table 1 for the actions, the pseudo-verbs, and the entire sentences in the accompanying auditory stimuli, and puppets' descriptions; see Appendix A for

snapshots from the causal videos in Figure A1, and for detailed descriptions of the actions in Table A1; see the link in the 2.1.2 section for viewing the videos). The teaching phase was played twice in total, allowing children to hear the novel pseudo-verb modeled four times in the present progressive tense and twice in the past tense. These two tenses were chosen because they are known to be the earliest acquired verbal tense morphemes for Turkish-speaking children (Aksu-Koç & Ketrez, 2003; Aksu-Koç & Slobin, 1985).

In the language judgment phase, children were reminded that the puppets would each describe the upcoming video and that they had to choose the puppet providing a better description. Then, the children watched the causal video in which a male actor caused the original inanimate object to move in a way that was comparable to the movement observed during the teaching phase. For example, the actor poked the balloon with his finger and caused it to swing to the sides. Then the experimenter asked the puppets to describe the videos. The videos were presented in a fixed order. Which puppet was worn on which hand, which spoke first, and which was the correct puppet were all pseudo-counterbalanced (see Appendix B). One of the two puppets (henceforth labeled “the correct puppet”) used the accurate causative marker attached to the pseudo-verb and the other puppet (henceforth labeled the “incorrect puppet”) used an existing but unrelated suffix (henceforth labeled “incongruent suffix”) ungrammatically attached to the pseudo-verb (see Table 1 for puppets’ descriptions in each trial). Finally, the experimenter turned to the child and asked “Which puppet described it better?” prompting the child to point to one of the puppets (See Figure 1 for a sketch of the procedure). If children hesitated to point after the question, they were prompted a second time. If they again did not respond, the experimenter moved on to the next trial. In every trial, children were given a score of 1 if they chose the correct puppet, and 0 if they chose the incorrect puppet or did not respond. The total score ranged between 0 and 4. Children who did not respond to at least three out of 4 trials were excluded from the analyses.

Table 1*Video, Audio, and Puppet Descriptions of Each Trial*

Trial	Object and action	Auditory Stimuli	Correct puppet	Incorrect puppet
1	Balloon swinging	Aa buraya bak. Balon şımıyor. Gördün mü? Balon şımıyor. Balon şımdı. (Oh look here. The balloon is VERB-ing. Did you see? The balloon is VERB-ing. The balloon VERB-ed.)	Adam balonu şımDIRdı. (The man VERB-CAUS-ed the balloon-ACC.)	Adam balonu şımLAŞtı. (The man VERB-IS*-ed the balloon-ACC.)
2	Book turning	Aa buraya bak. Kitap lasıyor. Gördün mü? Kitap lasıyor. Kitap lastı. (Oh look here. The book is VERB-ing. Did you see? The book is VERB-ing. The book VERB-ed.)	Adam kitabı lasTIRdı. (The man VERB-CAUS-ed the book-ACC.)	Adam kitabı lasLAŞtı. (The man VERB-IS*-ed the book-ACC.)
3	Flower swaying	Aa buraya bak. Çiçek füsüyor. Gördün mü? Çiçek füsüyor. Çiçek füstü. (Oh look here. The flower is VERB-ing. Did you see? The flower is VERB-ing. The flower VERB-ed.)	Adam çiçeği füsTÜRdü. (The man VERB-CAUS-ed the flower-ACC.)	Adam çiçeği füsLEŞtı. (The man VERB-IS*-ed the flower-ACC.)
4	Mouse ramp-walking	Aa buraya bak. Fare nukuyor. Gördün mü? Fare nukuyor. Fare nuktu. (Oh look here. The mouse is VERB-ing. Did you see? The mouse is VERB-ing. The mouse VERB-ed.)	Adam fareyi nukTURdu. (The man VERB-CAUS-ed the mouse-ACC.)	Adam fareyi nukLAŞtı. (The man VERB-IS*-ed the mouse-ACC.)

* Incongruent suffix

Figure 1*Schematic Representation of the Procedure in Study 1*

The phonological properties of the pseudo-verbs could only accept the -Dİr suffix. That is, the pseudo-verbs were monosyllabic verbs (consonant-vowel-consonant) ending with non-liquid consonants and the only causative suffix that is attached to such existing verbs in Turkish is -Dİr (Nakipoğlu & Üntak, 2008). Moreover, these pseudo-verbs were ensured to have no similar-sounding real verb roots in Turkish that are causativized with a non-default (non-Dİr) suffix (Nakipoğlu & Üntak, 2008). The harmony rules were also applied to the pseudo-verbs.

For the descriptions of the incorrect puppet, we used an incongruent suffix, -LAş, which is normally used to derive verbs from nouns or adjectives. This was done for two reasons. First, we aimed to avoid any familiarity/novelty preference as the children would have heard the pseudo-verb marked with the past tense modeled in the teaching phase, and second, we aimed to equalize the length of the marked pseudo-verbs. Note that the number of verbs ending with the -LAş suffix listed in the Turkish verb lexicon is comparable to that of -Dİr (Nakipoğlu & Üntak, 2008). Furthermore, we kept the syntactic frame of both the correct and the incorrect sentence the same, such that both had the same arguments and nominal markers (see Table 1).

Children's vocabulary was subsequently tested with the BILEX (Gampe et al.,

2018), a touchscreen-based receptive vocabulary measure. The test consisted of 48 trials. In each trial, children heard an object name (e.g. some animals or furniture items) and had to tap on the corresponding image out of 6 images (For all items see the link: <https://osf.io/x5wcj/>). They were given a score of 1 if they chose the correct image corresponding to the word, and 0 if not. Therefore, the scores ranged from 0 to 48. Note that the BILEX provides a relatively rough estimate of children's vocabulary size because it is limited to nouns.

Adults were tested in an online and adult-appropriate version of the same comprehension-judgment task. In this online version, to make it appropriate for adults, the two puppets and the cover story were not used. Adults were instructed as follows: "In this questionnaire, you will watch some videos and hear some sentences regarding what happens in those videos. In these sentences, you will hear some nonsense verbs. You will then be asked to choose one of two descriptions that you think best explains what happens in a subsequent connected video. Please watch the videos with sound and pay attention to the nonsense words used." Accordingly, participants first watched the video in the teaching phase. Then they watched the video in the language judgment phase, which was followed by the written question "Which of the two sentences would you use to describe what happened in the video?" and the two forced-choice alternatives. The order of presentation of the two choice alternatives (first or second row) was randomized in each trial.

2.2 Results and Discussion

The data and analysis scripts of both Studies 1 and 2 can be found at:
<https://osf.io/smpuj/>.

In Study 1, we asked at what age Turkish-learning children reliably showed an abstract understanding of the causative morphology. To answer this question, we analyzed children's choices of the correct puppet, in which they used the causative marker in its description, over the incorrect puppet, in which they used an incongruent suffix. Before analyzing this, we first examined the adult participants' data to check the validity of the task. Forty-one out of the 42 participants chose the correct alternative for all 4 trials. A one-proportion z-test showed that this was well above chance [50%] ($\chi^2(1) = 36.21, p < .0001$, leading to the

conclusion that the task was valid. To analyze children's choices, we applied a Bayesian Generalized Linear Mixed Model (GLMM) with the `brm` function of the `brms` package in R (Bürkner, 2017). A Bayesian GLMM analysis was preferred over a standard GLMM to be able to interpret the uncertainty intervals in terms of probability. In other words, for the case of a 95% uncertainty interval chosen, a Bayesian interval would tell us that the interval contains the true value of an estimated effect with 95% probability, whereas a frequentist GLMM interval would tell us that in 95% of the repeated sampling we expect the true value of an estimated effect to fall within the resulting interval (with 100% probability) (Hespanhol et al., 2019). We fitted a model with a binomial logit link function (family = `bernoulli`) with uninformative priors. In our model, we predicted the probability of choosing the correct puppet by entering sex, age, trial number, and receptive vocabulary (BILEX) as fixed effects and allowing the intercept to vary for each child participant. Before we describe the results of the model, we report the descriptive statistics for the receptive vocabulary scores ($M = 35.5$, $SD = 5.29$, $\min = 10$, $\max = 45$).

The model used the default No U-Turn Sampling (NUTS) with 4 chains. Visual inspection of convergence plots showed no evidence of non-convergence. Figure 2 shows the density plots of the model parameter estimates. Note that the estimates of 'sex' and the 'SD of participants (random effect)' are separately given in a second figure to better show the intervals, because the latter two span a larger interval. The dark blue lines represent the point estimates (coefficients) and the shaded areas under the curves represent the 95% uncertainty (credible) intervals. This means that, with 95% probability, the estimate of the corresponding effect will be between the values under the shaded area. When this credible interval does not contain zero, it means that with 95% probability, there is a non-zero influence of the given parameter, which we indicate as a meaningful effect. As can be seen in the density plot in Figure 2, only age had a meaningful influence, as its 95% credible interval did not contain 0. Age had a small but positive influence such that with each increasing month of age, the likelihood of choosing the correct puppet increased by 1.05 times (exponential of the point estimate of 'age' (= 0.05) which is in the logit scale). The random effect term, `sd(Intercept)`, was away from zero, validating the addition of random intercepts for participants. Figure 3a shows the total score of individual children (jittered) across age, to illustrate the raw scores. Figure 3b shows the model prediction

for the probability of correct puppet choice as a function of age, at the mean level of the other predictors. This probability increased across age, and reliably exceeded the chance level around the age of 4;10, which is indicated by the arrow in Figure 3b where the lower bound of the 95% quantile-based credible interval of the model prediction crosses 50% chance probability line. This result indicates that the age at which Turkish-learning children start to reliably choose the causative marker for a caused event in a pseudo-verb-learning environment is around 4;10. Please note that the pattern of results did not change when we re-ran the model by excluding children who persevered in choosing the same puppet in all four trials ($n = 11$), which also meant persevering in choosing the puppet to their right ($n = 6$) or their left ($n = 5$). However, in this model, the age at which causative choice was above chance shifted to around 5;0. The pattern of results, including the age of above-chance performance, did not change when we re-ran the model by excluding children who persevered in choosing the puppet who spoke first ($n = 4$) or last ($n = 2$) in all four trials.

Previous corpus studies looking at Turkish-speaking children's spontaneous production proposed that children acquired productivity with the causative marker as early as 2 years of age (Aksu-Koç & Ketrez, 2003; Aksu-Koç & Slobin, 1985; Ketrez, 1999). The comprehension of the productivity of the causative marker seemed to emerge much later in our task. Nevertheless, a limitation of the current study is that it is not clear whether the younger children simply failed to comprehend the causative marker because they have not yet abstracted it, or because they had difficulty processing some components of the task itself. In Study 2, we addressed the latter possibility.

Figure 2

Posterior Distributions in Study 1 and 2 with Estimates and 95% Credible Intervals

Note. The x-axes show the estimate values of variables in the models, the y-axes show the different variables in the models.

3 Study 2

Study 1 showed that Turkish-learning children chose the causative marker -DIr for caused events only at age 4;10. However, the task required children to process several components to succeed, which might have been too difficult. In Study 2, we modified the task addressing these components and tested a younger and narrower age group of 3;6- to 4;6-year-olds. Below we describe these components and how we modified the task in Study 2 to tackle the problems in Study 1.

Figure 3*Total Score and Probability of Correct Puppet Choice*

Note. a) Total score of children's correct puppet choice across age in Study 1 and 2. b) Probability of correct puppet choice as a function of age in Study 1 and 2. The horizontal dotted line at 0.50 on the y-axis represents the chance level. c) Probability of correct puppet choice as a function of age in Study 1 when a model is fitted with only the children within the age range of Study 2.

First, in the teaching phase of Study 1, children had to learn a novel pseudo-verb for the action of the inanimate object. It is possible that children did not achieve this fast-mapping because they thought the actions could have simply been labeled with existing Turkish verbs. Consequently, they may have rejected to map these novel pseudo-verbs onto the depicted actions. In Study 2, to tackle this limitation, we told the children that the people making these videos were speaking a different, funny Turkish language and that their task was to teach this funny Turkish to the puppets.

Second, in the teaching phase of Study 1, children saw the action twice and heard the pseudo-verb six times in total (four times marked in the present progressive tense and twice marked in the past tense). It is possible that the number of repetitions for the actions and novel verbs did not suffice for children to map the pseudo-verbs onto the observed actions. Despite testing a younger age group, many word-learning studies using pseudo-words modeled these words at least ten times (e.g., Akhtar & Tomasello, 1997; Brooks & Tomasello, 1999; Grassmann & Tomasello, 2007). Moreover, as part of this component, children had to segment the conjugated pseudo-verbs into their roots and conjugations. We modeled the pseudo-verbs with the earliest acquired tense markers in Turkish, which are the present progressive and the past tense, in order to make the segmentation easier for children as they would be likely to recognize these markers in the verbs. Yet, young children are shown to learn verbs better for approaching or completed actions rather than ongoing actions, due to a better focus of attention or readiness on the learning of the verb in the former two conditions (Tomasello & Kruger, 1992). Therefore, in Study 2, we used the pseudo-verbs additionally marked with the future tense in each repetition of the videos in the teaching phase. This way, we aimed to achieve two things: First, to increase the number of repetitions of the pseudo-verbs and provide yet another opportunity for segmentation of their root. Second, to facilitate the fast-mapping by preparing the child to attend to an upcoming action corresponding to the novel verb. Additionally, we repeated the videos 3 times instead of 2 times, resulting in 10 repetitions of the pseudo-verb in the teaching phase. To check whether children can at least phonologically reproduce the pseudo-

verbs, after each repetition of the video we asked children to produce the pseudo-verb themselves by asking them what happened in the video.

Third, in the language judgment phase of Study 1, children had to segment the pseudo-verbs into their root and the new suffixes (“the causative suffix and the past tense” by the correct puppet and “the incongruent suffix and the past tense” by the incorrect puppet), and then decide that the correct suffix is the causative marker. Although this incongruent suffix cannot be affixed to verbs and does not denote causality, it still is an existing derivational suffix in Turkish. It may be attached to adjectives to denote the meaning of “to turn into or become”, or to nouns to denote mutual activity (Göksel & Kerslake, 2004). The use of this suffix with a derivational meaning might have been confusing for children given that a particular change took place between the non-causal and causal videos and that this derivational suffix also denotes some form of change (i.e., change of state, with the meaning “to turn into, to become”), albeit not a causal change. To circumvent the potential confusion this might have caused, in Study 2 we used the pseudo-verbs only marked with the past tense in the incorrect puppet’s description, omitting the incongruent suffix. That is, the correct puppet said “The man VERB-CAUS-PAST the object” whereas the incorrect puppet said “The man VERB-PAST the object”. The latter was still ungrammatical given that labile verbs are quite rare in Turkish and an intransitive verb must be marked with a causative marker for causativization (Haspelmath, 1993; Ketrez, 1999).

In sum, Study 2 examined whether 3;6- to 4;6-year-old children understood the use of causative morphology. We used a modified version of the task in Study 1 that aimed to circumvent potential difficulties that may have masked children’s true understanding. We expected that children could then reliably choose the description with the causative marker over no suffix for caused events.

3.1 Method

3.1.1 *Participants*

Thirty-eight typically developing, native Turkish-speaking children (16 females, 22 males) within the age range of 3;6 to 4;6 ($M = 4;0$, $SD = 0;3$) participated in the study. One more child was tested but his data was not included in the analyses because he failed to finish the task. Children were recruited from 7 kindergartens located in various districts of Istanbul and one kindergarten in a smaller city in Turkey. The participants from the two cities did not differ with respect to socio-economic status. Children were thanked with a sticker and a book for their participation. Demographic information was obtained from all of the participants. Based on this data, 58% of the children had at least one sibling, 50% of the mothers and 97% of the fathers were full-time employed (and another 8% of mothers worked part-time), 18% of mothers and 21% of fathers completed 5 or 8 years of compulsory education (primary school), 32% of mothers and 29% of fathers completed secondary education (high-school), 42% of mothers and 42% of fathers completed tertiary education (university), 8% of mothers and 8% of fathers completed higher education (master's or Ph.D. degree).

3.1.2 *Materials, Design and Procedure*

The materials and the design were the same as in Study 1 except that there were 8 pseudo-counterbalanced orders instead of 4 (see Appendix C). The procedure and scoring were the same as in Study 1, except for the changes described at the beginning of section 3 ("Study 2").

3.2 Results and Discussion

Study 2 examined whether Turkish-learning children aged 3;6 to 4;6 were able to correctly judge the use of the causative marker -DIr in a modified version of the task used in Study 1. All children could repeat the pseudo-verbs intelligibly in the teaching phase. Preliminary analyses showed neither sex of the children nor the city of data collection influenced the language judgment ($p = .63$, $.07$; respectively) or the receptive vocabulary scores ($p = .15$,

.23; respectively), so we collapsed the data for the main analysis. We then compared children's total score (it ranged from 0 to 4, where 4 represents success in all 4 test trials) against chance ($\mu = 2$) in the language judgment task, to see whether children consistently chose the correct puppet that used the causative marker. We used a Wilcoxon-signed-rank test, as a Shapiro-Wilk test showed that the scores were non-normally distributed ($p < .001$). We found that children's mean score ($M = 2.21$, $SD = 0.91$, $CI[95\%] = 1.89\text{--}2.53$) was not different from chance ($V = 105.5$, $p = .16$), indicating that, at this age, they could not correctly judge the use of the causative marker for causativization. Moreover, children's receptive vocabulary score was not related to their score in the language judgment task ($Estimate = -0.009$, $SE = 0.036$, $t = -0.25$, $p = .80$).

A Bayesian Generalized Linear Mixed Model with the same specifications as in Study 1 confirmed the findings of the frequentist analyses reported above. Figure 2 shows the density plot of the model parameter estimates. Sex, age, trial number, or receptive vocabulary did not have a meaningful influence, given that all of the variables' credibility intervals contained 0, as can be seen in the density plot in Figure 2. The variance of the random intercept of participants was .13, however, the lower bound of its credibility interval was very close to 0. This suggests that including random intercepts may not have been necessary. Note that the pattern of results remained similar in a model without the random intercepts. Figure 3a shows the total score of individual children (jittered) across age, to illustrate the raw scores. Figure 3b shows the model prediction for the probability of correct puppet choice as a function of age, at the mean level of the other predictors. This probability did not increase across age and did not reliably exceed the chance level in this age range of 3;6-4;6. This is indicated by the fact that the lower bound of the 95% quantile-based credible interval of the model prediction for the probability did not exceed the 50% chance level at any age. Please note that the pattern of results did not change when we re-ran the model by excluding children who persevered in choosing the same puppet in all four trials ($n = 5$), which also meant persevering in choosing the puppet to their right ($n = 3$) or their left ($n = 2$), or by excluding children who persevered in choosing the puppet who spoke first ($n = 5$) or last ($n = 2$) in all four trials. Binomial tests showed that none of these idiosyncratic choice patterns were greater than expected by chance (all $ps > .05$).

We also fitted a model with the same specifications to the data of Study 1 by only including the children within the age range of Study 2 to compare the results. As Figure 3c shows, the model prediction for the probability of correct puppet choice did not increase within this age range and did not reliably exceed the chance level. Although non-significant, it showed a negative trend similar to Study 2.

Although we made several changes to the task used in Study 1 to reduce potential task-related extraneous variables, children still did not reliably choose the -DIr marker for caused events at this younger age period. The past tense-inflected version of the pseudo-verbs was used to familiarize the child with the pseudo-verbs in the teaching phase, although only in a sentence with an intransitive frame. Still, this may raise the possibility that children went for the incorrect option because they heard this pseudo-verb + past tense combination, without really paying attention to the rest of the syntactic structure of the sentence (transitive vs. intransitive frame). But this possibility is ruled out by the finding of Study 1 where children of the corresponding age range also responded at the chance when pseudo-verb + past tense was not one of the response options.

Together with the results of Study 1, the findings strengthened the claim that Turkish-learning children do not display an abstract understanding of the causative marker in a novel context until around the age of five. A possible explanation for this late abstraction might be that children lack the necessary variation in the morphological causatives in the input directed to them. The language input directed to children is a crucial element in children's gradual acquisition of verbs. Studies show that children's use of certain verbal constructions closely parallels their caregivers' use (e.g., Rubino & Pine, 1998) and are confined by the input. For instance, children younger than 3 years of age cannot use pseudo-verbs in a different syntactic frame than the one in which they heard it modeled by the experimenters (Abbot-Smith et al., 2001; Wittek and Tomasello, 2005; for a review of studies, Ambridge and Lieven, 2011). For morphology in particular, the variation of the types with which an inflection is used in the input is tightly linked to abstraction (Bybee, 1995; Plunkett & Marchman, 1993). This variation might

even prove more crucial when it comes to understanding the derivation from a pseudo-verb, requiring even greater flexibility with the grammatical categories.

A possible explanation for this late abstraction might be that children lack the necessary variation in the morphological causatives in the input directed to them. The language input directed to children is a crucial element in children's gradual acquisition of verbs. Studies show that children's use of certain verbal constructions closely parallels their caregivers' use (e.g., Rubino & Pine, 1998) and are confined by the input. For instance, children younger than 3 years of age cannot use pseudo-verbs in a different syntactic frame than the one in which they heard it modeled by the experimenters (Abbot-Smith et al., 2001; Wittek and Tomasello, 2005; for a review of studies, Ambridge and Lieven, 2011). For morphology, in particular, the variation of the types with which an inflection is used in the input is tightly linked to abstraction (Bybee, 1995; Plunkett & Marchman, 1993). This variation might even prove more crucial when it comes to understanding the derivation from a pseudo-verb, requiring even greater flexibility with the grammatical categories.

The empirical evidence on the acquisition of causatives in several languages that have morphological causatives advocates a gradual acquisition (Allen, 1998; Berman, 1993; Courtney, 2002; Family & Allen, 2015; Murasugi et al., 2003). Nevertheless, we know much less about the role of input in this development. If children do generalize an abstract schema of causatives through the input, they need sufficient exemplars with these markers provided by adults (Brooks et al., 2006; Bybee, 1995; Kempe & Brooks, 2001; Kuhl et al., 1997; Plunkett & Marchman, 1993; Snow, 1972; Theakston et al., 2001). Children need to learn the expressions for causal events item by item and retrieve the common patterns in the expression of these similar items to come up with a schema for causatives. This process might be particularly difficult for learners of languages such as Turkish, where some of these causal events are expressed with lexical causatives. Therefore, in Turkish, morphological causatives will not always be used for any given causative situation. Consequently, the generalization for the causatives might depend on the input characteristics. If adults use a limited variation of morphological causatives when addressing their children, children might be rather late to abstract a schema for the

morphological derivation of causatives. To find out about the distribution of causative verbs in the input we analyzed the use of -DIr causatives in child-directed speech (henceforth CDS) from a naturalistic longitudinal corpus of Turkish language acquisition.

4 Study 3 - Corpus Analysis of morphological causatives in CDS

Study 3 asked first, whether -DIr causatives show sufficient variation with different verbs in CDS, and second, whether this variation significantly increases as a function of child age.

4.1 Data

We used a longitudinal corpus of naturalistic speech of Turkish children and their caregivers (Küntay et al., 2015). Data and analysis scripts can be found at: <https://osf.io/m7wxz/>. The corpus is comprised of the transcribed speech of eight children between the ages of 0;8–3;0 and their caregivers (e.g. mother, grandmother, babysitter) in their homes during daily activities. The home visits took place for 1 hour twice a month for 29 months. We examined the data of seven children (5 females, 2 males)

Table 2

Details of the Turkish Longitudinal Corpus

Child	Sex	Hours of recordings	CDS		CS	
			Utterances	Words	Utterances	Words
1	F	57	15,121	53,073	12,061	23,224
2	M	40.5	25,272	81,484	17,118	32,526
3	F	51	27,610	105,653	17,472	32,601
4	F	56	34,241	105,966	19,561	30,473
5	M	41.75	20,600	67,259	15,547	25,755
6	F	46	30,192	103,689	15,495	32,342
7	F	51	31,371	102,033	16,107	23,725

in this study, because the recording of one child was terminated at the age of 1;9. Table 2 shows more details of the data of these seven children in the corpus. Four of the children came from families of low socio-economic status (SES) with parents who completed 5 or 8 years of education, and three came from families of high SES with parents who completed 11 or 15 years of education. At the start of the data collection, the mean age of mothers was 25;6 ($SD = 4;8$, range = 21–34) and the mean age of fathers was 29 ($SD = 3;6$, range = 26–35). Note that the data for the age of the parents of one child is missing. None of the children had siblings.

4.2 Automatic Parsing and Manual Correction

The corpus is partially annotated, lacking complete parsing for part-of-speech (POS) tags and causative morphology. To find verbs and detect the -Dİr markers, we employed an automatic parser, namely the ITU Turkish Natural Language Processing Pipeline (Eryiğit, 2014), which automatically tagged the words for parts of speech, operated the stemming, and parsed the morphological markers. After the POS tagging, we extracted all the tokens tagged as verbs (840 stem types) that appeared in the child-directed speech and extracted those with a -Dİr suffix attached to them. Further, the first author, a native Turkish speaker, examined all verb stems to rule out wrongly tagged words (non-verbs, 49 out of 840) and corrected the ones that were inflected forms but were tagged as stems (50 out of 840, of which 48 were existing stems while 2 introduced new stems, resulting in 743 remaining stem types). We also scrutinized the eligibility of taking the -Dİr marker for the remaining 743 stem types. Stems that are ineligible to take -Dİr include polysyllabic stems with a vowel or a liquid consonant ending (-t taking stems), monosyllabic stems that take -İr, -Ar, or -It, equipollent or suppletive pairs, and some reflexive verbs (e.g., *toparlan* *put oneself together*, *hazırlan* *get prepared*, *temizlen* *clean oneself*). Ruling out these stems left us with 328 stem types that are theoretically eligible to take the -Dİr marker. Note that lexical causatives also exist within these eligible stems, which would constitute “double causatives” when causativized, hence providing types for the child’s abstraction. We further validated these theoretically eligible stems in another context of naturalistic conversations, namely tweets. For this, we extracted morphological causatives with -Dİr from a large corpus of Turkish tweets (Sezer, 2016) comprising 12.5M word tokens. We found 755 stem

types that occurred at least once with -DIr. We then filtered the 328 theoretically eligible stems to include those that were also attested in the 755 stems from the tweet corpus, which left us with 242 stems. With this further filtering by the tweet corpus, we ensured that the eligible stems can and do take -DIr in speech that represents a rather colloquial language that approximates adults' natural spontaneous speech. These 242 stem types formed the inventory of stems that can both theoretically and naturalistically take the -DIr marker, henceforth referred to as "eligible stems".

4.3 Entropy Estimation

We investigated the development of the use of morphological causatives with -DIr in child-directed speech. To achieve this, we collected the occurrences of all causative constructions with -DIr in CDS at each child age and examined the entropy of the verb roots.

Specifically, we used the Nemenman-Shafee-Bialek (NSB) entropy estimator (Nemenman et al., 2001) to measure the variation of causative use. NSB is a Bayesian entropy estimator that takes an infinite mixture of Dirichlet distributions as its prior distributions. The posterior entropy estimate NSB produces has proven to compensate for the under-sampling issue commonly existing in acquisition corpora (Nemenman et al., 2001; You, Rüst, et al., 2021). In addition, these Dirichlet distributions require a known cardinality, we therefore further employed the Smoothed Good-Tuning estimator (SGT) (Orlitsky et al., 2016) to estimate the cardinality. In our study, this cardinality is the number of types of eligible stems. We used SGT to estimate the number of types of unseen stems based on observed stem tokens pertaining to the category of eligible stems, and this number of unseen types was added to the number of observed types to infer cardinality.

We measured the entropy for two categories, namely (i) the verb stem tokens with -DIr and (ii) the verb stem tokens that were eligible stems. We were thus able to detect the development of the use of -DIr as compared to the general development of verbs in CDS.

4.4 Results and Discussion

We first examined the CDS in terms of the development of -Dlr marker addressed to every individual child, compared with the development of eligible stems. As shown in Figure 4, although -Dlr constructions are expressed in most sessions, the entropy level of their use is lower ($M = 1.69$, $SD = 0.97$) than the use of the eligible stems ($M = 2.84$, $SD = .15$)³.

Figure 4

Development of -Dlr Constructions and Eligible Stems in CDS

³ Since entropy is a logarithmic index, a difference of 1 should not be underestimated. For example, an entropy measure of 1 with base e is reached when 3 types are evenly distributed, 2 is reached when 7 types are evenly distributed, and 3 is reached when 20 types are evenly distributed. Also, we even applied entropy correction for negative bias, which makes up for the unsampled data, resulting in a higher measure. Nonetheless, the entropy of -Dlr constructions still stays “low”.

Note. The ribbon band for each category is the range of one standard deviation on each side. The standard deviation was rendered by the Bayesian estimator.

To answer our second question regarding the development of -D_{Ir} use in CDS, we regressed entropy on child age with a Bayesian mixed model, where child-caregiver pairs were treated as a random factor. We fitted such a model for both categories respectively, namely morphological causatives with -D_{Ir} and the eligible stems that can take -D_{Ir}. Figure 5 shows the comparison of the posterior predictive developmental trajectories between these two categories. It is clear here that the use of -D_{Ir} in CDS has not become highly varied by the age of three years, whereas the variation of eligible stems has reached a relatively high level. However, the developmental rate does not differ between these two categories. We looked closer into the coefficient of age in the regression models, as shown in Figure 6. The coefficient in the model for the use of -D_{Ir}, compared with the model for eligible stems, exhibits a similar level. This indicates that the increase of entropy by the use of -D_{Ir} might be heavily associated with the development of eligible stems, while the gap between them stays invariant. It should be noted that by the age of three, the variation of -D_{Ir} constructions has not reached the initial level of eligible stems in children's first year (the mean predicted entropy of the use of -D_{Ir} in the end only slightly surpasses the lower bound of the 95% credible interval of the predicted entropy of eligible stems at the start, see Figure 5). We thus suggest that the -D_{Ir} marker has not been pervasively used in child-directed speech in children's early years, lacking flexibility in its constructions.

We also checked the development of -D_{Ir} in child speech. Since the data on child speech was lacking -D_{Ir} constructions, the entropy measure was not fully reliable and tended to overestimate the true variation. We thus did not analyze the developmental trajectories with entropy measures; alternatively, we observed the onset of the variable use of -D_{Ir} (i.e., the first session where -D_{Ir} is recorded with two different verb stems) in child speech. The onset ages are: 2;9.24, 2;3.29, 2;2.12, 2;5.10, 2;4.14, 2;0.10, 2;2.2, respectively. Children start to produce causative morphology with multiple verb stems from this age on, marking the onset of productivity. We also observed the numbers from the corpus for the verb stem types and those

marked with -DIr for both CDS and child speech. These numbers for each parent-child pair are reported in Appendix D.

5 General Discussion

In this study, we examined the acquisition of morphological causatives in Turkish-learning children by focusing on the generalization of the most productive causative marker in Turkish, namely, -DIr. In particular, we targeted the stage of development approaching full productivity, using a comprehension-judgment task. The experiments in Studies 1 and 2 showed that children acquired an abstract command of the productive use of the -DIr marker to derive causal meanings in novel contexts only towards the end of the fifth year. This late stage of productivity indicated by the abstract understanding of the morpheme was supported by an investigation of child-directed speech in a corpus scanning the ages between 0;8–3;0. The corpus analyses showed that overall children did not hear a rich variety of verbs causativized with the -DIr marker in the early input compared with verb stems that can theoretically and naturalistically take the -DIr marker, despite a slow but significant rate of growth of such variation over time. Together, the findings speak for gradual development of productivity with causative morphology in Turkish, demanding variation of causatives in CDS to reach a fully abstract stage. Children reach this stage somewhat late, possibly because the exemplars needed for this abstraction from the input are still insufficient by at least 3 years of age.

Importantly, our results show a much later age of productivity with causative morphology than claimed in previous studies of children's spontaneous speech (Aksu-Koç & Ketrez, 2003; Ketrez, 1999). We suggest that the early evidence indicates the first stage of the productivity continuum, indicating some contrastive causative use and some overgeneralizations in spontaneous speech. Our observation of the onset of the variable use of causative morphology in child speech in the corpus study also confirms the age of this first stage of productivity at around 2 years. The productivity, however, continues to improve between the ages of 2 and 4 years, incorporating a wider variety of anticausative-causative counterparts, as evidenced by elicited

Figure 5*Developmental Trajectories of DIr and Eligible Stems*

Note. The shaded bands represent 95% quantile-based intervals. The two-dash line draws the mean estimate of entropy in the end for the use of -DIr.

production studies of deriving causatives from familiar anticausative verbs (Nakipoğlu et al., 2012; Nakipoğlu et al., 2021). Finally, the present experiments suggest that around the end of age 4, children start to show indications of full productivity with causative morphology. That is, they expect the causative derivation to apply to completely novel items they have not encountered before.

This later stage of productivity might in part reflect morphological awareness, which is the metalinguistic ability to appreciate and manipulate the morphemic structures of words (Carlisle, 1995). Morphological awareness is not a separate construct from the acquisition of

Figure 6*Posterior Distribution for Coefficient of Age in the Regression Models*

Note. 95% quantile-based intervals for -DIr: (0.00070, 0.00176); for eligible stems: (0.00064, 0.00121).

morphology. However, it reflects a processing of morphology that is different than that in daily, contextualized language use, such as in conversations (Bialystok & Ryan, 1985; Carlisle, 1995; Kuo & Anderson, 2006; Nagy et al., 2014). Specifically, conversations do not pose a great demand for an analysis of language to understand and produce speech. In contrast, the experimental setups in the current study required children to process and operate on morphology in an unfamiliar context divorced from natural language use and discourse properties. The focus is on the language itself, rather than communication, and the task is, therefore, more abstract. In that respect, successful performance in our language judgment tasks might rely heavily on both

metacognitive representation of the morphological derivation of causatives, and cognitive control to handle the task demands to learn, analyze and update pseudo-verbs. This suggestion is further supported by the fact that the age of 4 to 5 – when children showed successful performance in our experiment – nicely overlaps with the age at which children show marked developmental progression in metacognition and cognitive control (for a review; Roebers, 2017). Some authors further distinguish between a more elementary and full-blown level of morphological awareness and label the former as epilinguistic awareness (Diamanti et al., 2018). They suggest the epilinguistic awareness to be captured in judgment tasks, similar to ours, while the full-blown metalinguistic level to be captured in more explicit production tasks. A future study testing both children's judgment and production of the causative marker and looking at potential age-related differences may shed more light on whether such a distinction is warranted for the case of causatives.

The proposal for a later-emerging more flexible productivity with causative morphology evidenced in the experimental studies 1 and 2 is corroborated by the examination of the corpus in Study 3. The use of -DIr causatives in adult speech directed to children was highly limited. An input that provides sufficient exemplars with the -DIr causatives seems particularly important for children to switch from learning individual items with the -DIr to generalizing the schema that this marker can be productively attached to a variety of verbs to express their caused version. There is ample evidence showing that morphological development is closely linked to the input directed to children, coming from both naturalistic data (Aguado-Orea & Pine, 2015; Maslen et al., 2004) and elicited production studies (Engelmann et al., 2019; Leonard et al., 2002; Lukács et al., 2009; Savičiu^{te} et al., 2017) in several different languages. Specifically, these studies show that children's inflection errors are documented to be higher for low-frequency verbs than high-frequency verbs, which indicates that the acquisition of the correct forms is input-dependent. Furthermore, a study focusing on the acquisition of causatives in Persian-learning children aged 1;11–6;7 showed that child speech correlated with child-directed speech with respect to causatives only for older children (Family & Allen, 2015). This evidence supports our

claim that more years of exposure to the input might be necessary for children to collect enough exemplars to systematize schemas governing the use of causatives.

Moreover, we found no relation between the abstract understanding of the causative marker and children's receptive vocabulary. Given that our vocabulary measure only consisted of noun items and did not include verbs, which might have been a better predictor for the ability to abstract causative markers, we refrain from interpreting this null finding further.

Interestingly, the children within the age range of 3;6–4;6 showed an unexpected negative trend in both Studies 1 and 2. Despite not being statistically meaningful, there seems to be a U-shaped trend in trajectory. An overall increase in correct choices of the causative marker takes place between 2.5 to 5 years of age, alongside a slight decrease around the age of 4. One has to be careful not to overinterpret this trend, but it might be a result of how children perceive the task. Around age 3, children might be more willing to accept and pay attention to novel verbs. Around age 4, having a better vocabulary at their disposal, they might be less willing to accept novel verbs for the actions depicted in the task and focus on the syntactic structure of the sentences rather than the verb morphology. In both Studies 1 and 2, both the correct and the incorrect puppets uttered a transitive frame with the corresponding agent in the subject position, and the corresponding patient in the accusative marked object position. In that case, children might have found both options equally likely based on their scene-appropriate syntactic structure without paying attention to the verb morphology. By contrast, older children at the age of around 5 might display a better understanding of the task on a metacognitive level, and understand that the experimenter wants them to focus on these pseudo-verbs and operate on them.

One limitation of the current study is that we only examined the most productive causative marker in Turkish, -DIr. Next to noticing that whenever -DIr is used, a causal meaning is intended, children also need to notice that -DIr is not used every time a causal meaning is intended. This is because there are also other causative markers and lexical causatives in Turkish. At least another causative marker, -t, is considerably productive (causativizing ~1350 verbs), whereas the rest of the markers (i.e., -Ir, -Ar, -It) causativize together a total of 29 verbs (Nakipoğlu & Üntak, 2008). For the -t marker, children need to attend to the ending of verbs as

they attach to vowel-final stems, and for the remaining markers, they need to learn rote as they are irregular. Turkish-learning children are shown to be sensitive to these phonological differences and correctly distinguish the use of -DIr and -t suffixes as early as age 3; but to have difficulties with the irregular stems and to overregularize these with -DIr (Nakipoğlu et al., 2021). In that sense, the abstraction of -DIr requires paying attention to the phonological properties of verb stems but appears to not be highly challenged by the presence of other causative suffixes.

Many lexical causatives also exist in Turkish, although the exact number is unknown. There is no consensus on how lexical causatives are determined. Some require verbs to have the same or an unrelated anticausative alternative to name them lexical causatives (Dixon, 2000). Even then, some of the transitive verbs that others would not define as lexical causatives, still need to be learned by children as verbs that have a causal meaning but do not have a causative marker. Therefore, the presence of such verbs (label them lexical causatives or not) serves as another challenge for children to generalize the productive use of -DIr. Further, although the causative markers are reliable indicators of causality, they may not serve as good cues as long as they are not available (Bates & MacWhinney, 1989), which seems to be the case at least in the early input. Instead, the syntactic frame or the case marking might be a more available cue. In fact, the number of arguments and accusative case marking were found to be good cues to identify transitive and intransitive verbs in Turkish child-directed speech (Ural et al., 2009) and were utilized by Turkish-learning children younger than 6 years old to infer a causal meaning while the causative marker was not (Göksun et al., 2008). In future studies, it might be worthwhile to investigate the distribution of lexical causatives, and morphological causatives with other markers in child-directed speech. This would allow us to get a better understanding of the frequency of these non-DIr forms and help us understand if this might be a driving force for why children might need an extended time to generalize the -DIr causatives.

A second limitation is that the corpus analyses in Study 3 incorporated only a part of the age range tested in Studies 1 and 2. The corpus was only available between the child ages of 0;8–3;0, therefore we were not able to quantify the variation of -DIr causatives in the child-directed speech at child age older than 3;0. Particularly, it would be very informative to have corpus data

between the ages 3;0 and 5;0 to be able to capture any change in CDS that might potentially drive the abstraction to emerge around age 4;10. It is conceivable that during this period the variation of -DIr causatives in CDS reaches, or at least approaches, the level of the variation of all verb stems that are eligible to take -DIr. It should be noted that the eligible verb stems also included lexical causatives. The presence of lexical causatives among the eligible stems may play a role in the lower entropy of -DIr causatives. For example, the lexical causative *kır* ‘break’ is included in eligible verb stems. Lexical causatives can also be causativized with a causative marker to make double causatives, as in *kırdır* ‘make someone break something’. In principle, for the -DIr category to reach the eligible verb stem category in variation, *kırdır* should also be in the input along with *kır*. Nonetheless, an utterance involving a double causativized lexical causative might be more sophisticated, both formally and semantically (cognitively). Evidence shows that caregivers adjust the sophistication level of their speech based on their child’s cognitive and language development (Fusaroli et al., 2019; Huttenlocher et al., 2010; Ketrez, 2003; L. Song et al., 2014; You, Daum, et al., 2021). For example, You, Daum, et al. found that adults adapted their speech to their child’s speech regarding the semantics of lexical causatives. Thus, the appearance of such double -DIr causatives in child-directed speech might come at a later child age, when caregivers grant their children the prerequisite knowledge.

In conclusion, Turkish-learning children generalized the morphological derivation of causatives only toward the end of age 4. Moreover, the variation of morphological causatives with -DIr in Turkish CDS in the first 3 years remained low compared to the variation in eligible verbs, suggesting that the insufficient variation in the input might be one factor that leads to this late generalization. Previous examinations of children’s spontaneous speech and elicited production studies with familiar verbs suggested that Turkish-learning children showed the onset and early stages of productivity with the morphological causatives around the ages of 2 to 3. The current findings reveal a later stage of productivity, which is context-independent, at the age of 5. Together, these findings suggest that productivity does not emerge all at once, but rather shows a gradual development composed of several stages. Variation of forms in child-directed input appears even more important to reach the later stages of productivity.

Acknowledgements

We thank the participants, their parents, and the kindergartens for their participation. We thank Larissa Stuber, Sura Ertas, Sena Gezici, and Merve Duran for their thoughtful contribution and help in data collection and coding. Many thanks to Prof. Ben Ambridge for his feedback on the findings and the conceptualization of the study. Thanks also to Dr. Andrew Cowton for proofreading. This work was funded by the Swiss National Foundation (100015_169712, PIs: Sabine Stoll, Moritz M. Daum). Both PIs were also funded by the ‘Evolving Language’ part of the ‘National Centers of Competence in Research (NCCRs)’ project of Swiss National Science Foundation (<http://www.snf.ch/en/researchinFocus/nccr/evolving-language/Pages/default.aspx>).
Declarations of interest: ‘none’.

References

- Abbot-Smith, K., Lieven, E., & Tomasello, M. (2001). What preschool children do and do not do with ungrammatical word orders. *Cognitive Development*, 16(2), 679–692.
[https://doi.org/10.1016/S0885-2014\(01\)00054-5](https://doi.org/10.1016/S0885-2014(01)00054-5)
- Aguado-Orea, J., & Pine, J. M. (2015). Comparing different models of the development of verb inflection in early child Spanish. *PLoS One*, 10(3), e0119613.
<https://doi.org/10.1371/journal.pone.0119613>
- Akhtar, N., & Tomasello, M. (1997). Young children's productivity with word order and verb morphology. *Developmental Psychology*, 33(6), 952.
<https://doi.org/10.1037/0012-1649.33.6.952>
- Aksu-Koç, A., & Ketrez, F. N. (2003). Early verbal morphology in Turkish: Emergence of inflections. In D. Bittner, W. U. Dressler, & M. Kilani-Schoch (Eds.), *Development of verb inflection in first language acquisition: A cross-linguistic perspective* (pp. 27–52). Walter de Gruyter. <https://doi.org/10.1515/9783110899832.27>
- Aksu-Koç, A., & Slobin, D. I. (1985). The acquisition of Turkish. In D. I. Slobin (Ed.), *The Cross-linguistic Studies of Language Acquisition* (pp. 839–876). Lawrence Erlbaum Associates.
- Allen, S. E. M. (1998). Categories within the verb category: Learning the causative in Inuktitut. *Linguistics*, 36, 633–677. <https://doi.org/10.1515/ling.1998.36.4.633>
- Ambridge, B. (2020). Abstractions made of exemplars or 'You're all right, and I've changed my mind': Response to commentators. *First Language*, 40(5-6), 640–659.
<https://doi.org/10.1177/0142723720949723>
- Ambridge, B., & Lieven, E. V. (2011). *Child language acquisition: Contrasting theoretical approaches*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511975073>
- Ammon, M. S., & Slobin, D. I. (1979). A cross-linguistic study of the processing of causative sentences. *Cognition*, 7(1), 3–17. [https://doi.org/10.1016/0010-0277\(79\)90007-6](https://doi.org/10.1016/0010-0277(79)90007-6)
- Bates, E., Bretherton, I., & Snyder, L. (1988). Acquisition of a novel concept at 20 months. *From First Words to Grammar: Individual Differences and Dissociable Mechanisms*, 124–134.
- Bates, E., & MacWhinney, B. (1989). Functionalism and the competition model. In E. Bates &

- B. MacWhinney (Eds.), *The crosslinguistic study of sentence processing* (pp. 3–76). Cambridge University Press.
- Behrens, H. (2015). The acquisition of grammatical categories. In N. L. Bavin E (Ed.), *The Cambridge handbook of child language* (pp. 250–270). Cambridge University Press.
<https://doi.org/10.1017/CBO9781316095829.012>
- Berko, J. (1958). The child's learning of English morphology. *Word*, 14(2-3), 150–177.
<https://doi.org/10.1080/00437956.1958.11659661>
- Berman, R. A. (1993). Marking of verb transitivity by Hebrew-speaking children. *Journal of Child Language*, 20(3), 641–669. <https://doi.org/10.1017/S0305000900008527>
- Bialystok, E., & Ryan, E. B. (1985). Toward a definition of metalinguistic skill. *Merrill-Palmer Quarterly*, 31(3), 229–251. <https://www.jstor.org/stable/23086295>
- Bowerman, M. (1974). Learning the structure of causative verbs: A study in the relationship of cognitive, semantic, and syntactic development. *Papers and Reports on Child Language Development*, 8, 142–178.
- Bowerman, M. (1982). Reorganizational processes in lexical and syntactic development. In W. Eric & L. R. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 319–346). Cambridge University Press.
- Brooks, P. J., Kempe, V., & Sionov, A. (2006). The role of learner and input variables in learning inflectional morphology. *Applied Psycholinguistics*, 27(2), 185–209.
<https://doi.org/10.1017/S0142716406060243>
- Brooks, P. J., & Tomasello, M. (1999). How children constrain their argument structure constructions. *Language*, 720–738. <https://doi.org/10.2307/417731>
- Brown, R. (1973). Development of the first language in the human species. *American Psychologist*, 28(2), 97. <https://doi.org/10.1037/h0034209>
- Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software*, 80(1), 1–28. <https://doi.org/10.18637/jss.v080.i01>
- Bybee, J. (1995). Regular morphology and the lexicon. *Language and Cognitive Processes*, 10(5), 425–455. <https://doi.org/10.1080/01690969508407111>
- Carlisle, J. F. (1995). Morphological awareness and early reading achievement. In L. Feldman (Ed.), *Morphological aspects of language processing* (pp. 189–209). Lawrence Erlbaum Associates, Inc.

- Clark, E. V. (2014). Acquisition of derivational morphology. In R. Lieber & P. Štekauer (Eds.), *The Oxford handbook of derivational morphology*. Oxford University Press.
<https://doi.org/10.1093/oxfordhb/9780199641642.013.0024>
- Cohen, L. B., & Oakes, L. M. (1993). How infants perceive a simple causal event. *Developmental Psychology*, 29(3), 421–433.
- Comrie, B. (1989). *Language universals and linguistic typology: Syntax and morphology*. University of Chicago Press.
- Courtney, E. H. (2002). Child acquisition of quechua causatives and change-of-state verbs. *First Language*, 22(1), 29–71. <https://doi.org/10.1177/014272370202206402>
- Dale, P. S., Dionne, G., Eley, T. C., & Plomin, R. (2000). Lexical and grammatical development: A behavioural genetic perspective. *Journal of Child Language*, 27(3), 619–642. <https://doi.org/10.1017/S0305000900004281>
- Diamanti, V., Benaki, A., Mouzaki, A., Ralli, A., Antoniou, F., Papaioannou, S., & Protopapas, A. (2018). Development of early morphological awareness in greek: Epilinguistic versus metalinguistic and inflectional versus derivational awareness. *Applied Psycholinguistics*, 39(3), 545–567.
- Dittmar, M., Abbot-Smith, K., Lieven, E., & Tomasello, M. (2008). German children's comprehension of word order and case marking in causative sentences. *Child Development*, 79(4), 1152–1167. <https://doi.org/10.1111/j.1467-8624.2008.01181.x>
- Dixon, R. M. W. (2000). A typology of causatives: Form, syntax and meaning. In R. M. W. Dixon & A. Y. Aikhenvald (Eds.), *Changing valency: Case studies in transitivity* (pp. 30–83). Cambridge University Press Cambridge.
<https://doi.org/10.1017/CBO9780511627750.003>
- Dromi, E., Leonard, L. B., & Blass, A. (2003). Different methodologies yield incongruous results: A study of the spontaneous use of verb forms in Hebrew. *Language competence across populations: Toward a definition of specific language impairment*, 273–289.
- Engelmann, F., Granlund, S., Kolak, J., Szreder, M., Ambridge, B., Pine, J., Theakston, A., & Lieven, E. (2019). How the input shapes the acquisition of verb morphology:

- Elicited production and computational modelling in two highly inflected languages. *Cognitive Psychology*, 110, 30–69. <https://doi.org/10.1016/j.cogpsych.2019.02.001>
- Eryiğit, G. (2014). ITU Turkish NLP web service. *Proceedings of the Demonstrations at the 14th Conference of the European Chapter of the Association for Computational Linguistics (EACL)*.
- Family, N., & Allen, S. E. M. (2015). The development of the causative construction in Persian child language. *Journal of Child Language*, 42(2), 1–42. <https://doi.org/10.1017/S0305000915000057>
- Fusaroli, R., Weed, E., Fein, D., & Naigles, L. (2019). Hearing me hearing you: Reciprocal effects between child and parent language in autism and typical development. *Cognition*, 183, 1–18. <https://doi.org/10.1016/j.cognition.2018.10.022>
- Gábor, B., & Lukács, Á. (2012). Early morphological productivity in Hungarian: Evidence from sentence repetition and elicited production. *Journal of Child Language*, 39(2), 411–442. <https://doi.org/10.1017/S0305000911000110>
- Gampe, A., Kurthen, I., & Daum, M. M. (2018). Bilex: A new tool measuring bilingual children's lexicons and translational equivalents. *First Language*, 38(3), 263–283. <https://doi.org/10.1177/0142723717736450>
- Göksel, A., & Kerslake, C. (2004). *Turkish: A comprehensive grammar*. Routledge. <https://doi.org/10.4324/9780203340769>
- Göksun, T., Küntay, A. C., & Naigles, L. R. (2008). Turkish children use morphosyntactic bootstrapping in interpreting verb meaning. *Journal of Child Language*, 35(02), 291–323. <https://doi.org/10.1017/S0305000907008471>
- Grassmann, S., & Tomasello, M. (2007). Two-year-olds use primary sentence accent to learn new words. *Journal of Child Language*, 34(3), 677–687. <https://doi.org/10.1017/S0305000907008021>
- Haspelmath, M. (1993). More on the typology of inchoative/causative verb alternations. In B. Comrie & M. Polinsky (Eds.), *Causatives and transitivity* (pp. 87–121). John Benjamins. <https://doi.org/10.1075/slcs.23.05has>

- Hespanhol, L., Vallio, C. S., Costa, L. M., & Saragiotto, B. T. (2019). Understanding and interpreting confidence and credible intervals around effect estimates. *Brazilian Journal of Physical Therapy*, 23(4), 290–301.
- Hoff, E., Quinn, J. M., & Giguere, D. (2018). What explains the correlation between growth in vocabulary and grammar? New evidence from latent change score analyses of simultaneous bilingual development. *Developmental Science*, 21(2), e12536.
<https://doi.org/10.1111/desc.12536>
- Huttenlocher, J., Waterfall, H., Vasilyeva, M., Vevea, J., & Hedges, L. V. (2010). Sources of variability in children's language growth. *Cognitive Psychology*, 61(4), 343–365.
<https://doi.org/10.1016/j.cogpsych.2010.08.002>
- Jaswal, V. K., McKercher, D. A., & VanderBorght, M. (2008). Limitations on reliability: Regularity rules in the english plural and past tense. *Child Development*, 79(3), 750–760. <https://doi.org/10.1111/j.1467-8624.2008.01155.x>
- Kanero, J., Hirsh-Pasek, K., & Golinkoff, R. M. (2016). Can a microwave heat up coffee? How English-and Japanese-speaking children choose subjects in lexical causative sentences. *Journal of Child Language*, 43(5), 993–1019.
<https://doi.org/10.1017/S0305000915000331>
- Kempe, V., & Brooks, P. J. (2001). The role of diminutives in the acquisition of Russian gender: Can elements of child-directed speech aid in learning morphology? *Language Learning*, 51(2), 221–256. <https://doi.org/10.1111/j.0023-8333.2005.00297.x>
- Ketrez, F. N. (1999). *Early verbs and the acquisition of Turkish argument structure* (Master's thesis). Boğaziçi University, Istanbul.
- Ketrez, F. N. (2003). Variation in turkish mothers' style. In A. Özsoy, D. Akar, M. Nakipoğlu Demiralp, E. Erguvanlı-Taylan, & A. Aksu-Koç (Eds.), *Studies in Turkish linguistics* (pp. 447–452). Boğaziçi University Press Istanbul.
- Kidd, E., Bidgood, A., Donnelly, S., Durrant, S., Peter, M. S., & Rowland, C. F. (2020). Individual differences in first language acquisition and their theoretical implications. In C. F. Rowland, A. L. Theakston, B. Ambridge, & K. E. Twomey (Eds.), *Current perspectives on child language acquisition: How children use their environment to learn* (pp. 189–219). John Benjamins Publishing Company.
<https://doi.org/10.1075/tilar.27.09kid>

- Kornfilt, I. (1997). Turkish. London and New York: Routledge.
- Kuczaj, S. A. (1978). Children's judgments of grammatical and ungrammatical irregular past tense verbs. *Child Development*, 319–326. <https://doi.org/10.2307/1128693>
- Kuczaj II, S. A. (1977). The acquisition of regular and irregular past tense forms. *Journal of Verbal Learning and Verbal Behavior*, 16(5), 589–600.
- Kuhl, P. K., Andruski, J. E., Chistovich, I. A., Chistovich, L. A., Kozhevnikova, E. V., Ryskina, V. L., Stolyarova, E. I., Sundberg, U., & Lacerda, F. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science*, 277(5326), 684–686. <https://doi.org/10.1126/science.277.5326.684>
- Kulikov, L. I. (2001). Causatives. In L. I. Kulikov, M. Haspelmath, E. König, W. Oesterreicher, & W. Raible (Eds.), *Language typology and language universals. An international handbook* (pp. 886–898). Walter de Gruyter.
- Küntay, A., Koçbaş, D., & Taşçı, S. (2015). Koç University longitudinal language development database as a part of the 'ACQDIV Corpus'.
- Kuo, L.-j., & Anderson, R. C. (2006). Morphological awareness and learning to read: A cross language perspective. *Educational Psychologist*, 41(3), 161–180. https://doi.org/10.1207/s15326985ep4103_3
- Lenier, D. J. (2019). Sosci survey (version 3.1.06). <https://www.soscisurvey.de>
- Leonard, L. B., Caselli, M. C., & Devescovi, A. (2002). Italian children's use of verb and noun morphology during the preschool years. *First Language*, 22(3), 287–304. <https://doi.org/10.1177/014272370202206604>
- Leslie, A. M., & Keeble, S. (1987). Do six-month-old infants perceive causality? *Cognition*, 25(3), 265–288. [https://doi.org/10.1016/S0010-0277\(87\)80006-9](https://doi.org/10.1016/S0010-0277(87)80006-9)
- Lieven, E. (2010). Input and first language acquisition: Evaluating the role of frequency. *Lingua*, 120(11), 2546–2556. <https://doi.org/10.1016/j.lingua.2010.06.005>
- Lieven, E., & Behrens, H. (2012). Dense sampling. In E. Hoff (Ed.), *Guide to research methods in child language*. Wiley-Blackwell. <https://doi.org/10.1002/9781444344035.ch15>
- Lignos, C., & Yang, C. (2016). Morphology and language acquisition. In A. Hippisley & G. Stump (Eds.), *The Cambridge handbook of morphology* (pp. 765–791). Cambridge University Press. <https://doi.org/10.1017/9781139814720.027>
- Lukács, á., Leonard, L. B., Kas, B., & Pléh, C. (2009). The use of tense and agreement by

- Hungarian-speaking children with language impairment. *Journal of Speech, Language, and Hearing Research*, 52(1), 98–117. [https://doi.org/10.1044/1092-4388\(2008/07-0183\)](https://doi.org/10.1044/1092-4388(2008/07-0183))
- Maratsos, M. (2000). More overregularizations after all: New data and discussion on Marcus, Pinker, Ullman, Hollander, Rosen & Xu. *Journal of Child Language*, 27(1), 183–212. <https://doi.org/10.1017/S0305000999004067>
- Marchman, V. A., & Bates, E. (1994). Continuity in lexical and morphological development: A test of the critical mass hypothesis. *Journal of Child Language*, 21(2), 339–366. <https://doi.org/10.1017/S0305000900009302>
- Marcus, G. F., Pinker, S., Ullman, M., Hollander, M., Rosen, T. J., Xu, F., & Clahsen, H. (1992). Overregularization in language acquisition. *Monographs of the society for research in child development*, i–178.
- Maslen, R. J., Theakston, A. L., Lieven, E. V., & Tomasello, M. (2004). A dense corpus study of past tense and plural overregularization in english. *Journal of Speech, Language, and Hearing Research*, 47(6), 1319–1333. [https://doi.org/10.1044/1092-4388\(2004/099\)](https://doi.org/10.1044/1092-4388(2004/099))
- Matthews, D. E., & Theakston, A. L. (2006). Errors of omission in english-speaking children's production of plurals and the past tense: The effects of frequency, phonology, and competition. *Cognitive Science*, 30(6), 1027–1052. https://doi.org/10.1207/s15516709cog0000_66
- McKercher, D. A., & Jaswal, V. K. (2012). Using judgment tasks to study language knowledge. In E. Hoff (Ed.), *Guide to research methods in child language* (pp. 149–161). Oxford: Wiley-Blackwell. <https://doi.org/10.1002/9781444344035.ch10>
- Murasugi, K., Hashimoto, T., & Kato, S. (2003). On the acquisition of causatives in Japanese. *Boston University conference on language development*, 28.
- Nagy, W. E., Carlisle, J. F., & Goodwin, A. P. (2014). Morphological knowledge and literacy acquisition. *Journal of Learning Disabilities*, 47(1), 3–12. <https://doi.org/10.1177/0022219413509967>
- Nakipoğlu, M., Sarıgül, Ö., Yıldız, E., & Yumrutaş, N. (2012). Frequency of use and the acquisition of the turkish causative. *Boston University Conference of Language Development* 35.

- Nakipoğlu, M., & Üntak, A. (2008). A complete verb lexicon of turkish based on morphemic analysis. *Turkic Languages*, 12, 221–80.
- Nakipoğlu, M., Uzundag, B. A., & Sarıgül, Ö. (2021). Young minds' quest for regularity: Evidence from the Turkish causative. *Journal of Child Language*, 1–28.
- Nemenman, I., Shafee, F., & Bialek, W. (2001). Entropy and inference, revisited. arXiv preprint physics/0108025.
- Olguin, R., & Tomasello, M. (1993). Twenty-five-month-old children do not have a grammatical category of verb. *Cognitive Development*, 8(3), 245–272.
[https://doi.org/10.1016/S0885-2014\(93\)80001-A](https://doi.org/10.1016/S0885-2014(93)80001-A)
- Orlitsky, A., Suresh, A. T., & Wu, Y. (2016). Optimal prediction of the number of unseen species. *Proceedings of the National Academy of Sciences*, 113(47), 13283–13288.
<https://doi.org/10.1073/pnas.1607774113>
- Peirce, J., & MacAskill, M. (2018). Building experiments in PsychoPy. Sage.
- Pinker, S., & Ullman, M. T. (2002). The past and future of the past tense. *Trends in Cognitive Sciences*, 6(11), 456–463.
- Plunkett, K., & Marchman, V. (1993). From rote learning to system building: Acquiring verb morphology in children and connectionist nets. *Cognition*, 48(1), 21–69.
[https://doi.org/10.1016/0010-0277\(93\)90057-3](https://doi.org/10.1016/0010-0277(93)90057-3)
- Roebers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental Review*, 45, 31–51.
- Rubino, R. B., & Pine, J. M. (1998). Subject–verb agreement in Brazilian Portuguese: What low error rates hide. *Journal of Child Language*, 25(1), 35–59.
<https://doi.org/10.1017/S0305000997003310>
- Savičiute, E., Ambridge, B., & Pine, J. M. (2017). The roles of word-form frequency and phonological neighbourhood density in the acquisition of lithuanian noun morphology. *Journal of Child Language*, 45(3), 641–672. <https://doi.org/10.1017/s030500091700037x>
- Sezer, T. (2016). Tweets corpus: Building a corpus by social media. *Journal of Milli Eğitim Education and Social Sciences*, 621–633.
- Shibatani, M. (2002). Introduction: Some basic issues in the grammar of causation. In M. Shibatani (Ed.), *The grammar of causation and interpersonal manipulation* (pp. 1–22). John Benjamins.

- Shibatani, M., & Pardeshi, P. (2002). The causative continuum. In M. Shibatani (Ed.), *The grammar of causation and interpersonal manipulation* (pp. 85–126).
<https://doi.org/10.1075/tsl.48.07shi>
- Snow, C. E. (1972). Mothers' speech to children learning language. *Child Development*, 43(2), 549–565. <https://doi.org/10.2307/1127555>
- Sofu, H. (1995). Acquisition of lexicon in Turkish [Unpublished Doctoral Dissertation].
- Song, J. J. (2014). Causatives and causation: A universal-typological perspective. Routledge.
- Song, L., Spier, E. T., & Tamis-Lemonda, C. S. (2014). Reciprocal influences between maternal language and children's language and cognitive development in low-income families. *Journal of Child Language*, 41(2), 305–326.
<https://doi.org/10.1017/S0305000912000700>
- Stoll, S. (2005). Beginning and end in the acquisition of the perfective aspect in Russian. *Journal of Child Language*, 32(4), 805–825. <https://doi.org/10.1017/S0305000905007142>
- Stoll, S. (2015). Inflectional morphology in language acquisition. In M. Baerman (Ed.), *The Oxford handbook of inflection*.
- Theakston, A. L., Ibbotson, P., Freudenthal, D., Lieven, E. V., & Tomasello, M. (2015). Productivity of noun slots in verb frames. *Cognitive Science*, 39(6), 1369–1395.
- Theakston, A. L., Lieven, E. V., Pine, J. M., & Rowland, C. F. (2001). The role of performance limitations in the acquisition of verb-argument structure: An alternative account. *Journal of Child Language*, 28(1), 127–152. <https://doi.org/10.1017/S0305000900004608>
- Tomasello, M. (2003). *Constructing a language: A usage-based theory of language acquisition*. Harvard University Press.
- Tomasello, M., & Kruger, A. C. (1992). Joint attention on actions: Acquiring verbs in ostensive and non-ostensive contexts. *Journal of Child Language*, 19(2), 311–333.
<https://doi.org/10.1017/S0305000900011430>
- Ural, A. E., Yuret, D., Ketrez, F. N., Koçbaş, D., & Küntay, A. C. (2009). Morphological cues vs. number of nominals in learning verb types in Turkish: The syntactic bootstrapping mechanism revisited. *Language and Cognitive Processes*, 24(10), 1393–1405.
<https://doi.org/10.1080/01690960902775525>
- Wagner, L., Swensen, L. D., & Naigles, L. R. (2009). Children's early productivity with verbal morphology. *Cognitive Development*, 24(3), 223–239.

<https://doi.org/10.1016/j.cogdev.2009.05.001>

- Wittek, A., & Tomasello, M. (2005). German-speaking children's productivity with syntactic constructions and case morphology: Local cues act locally. *First Language*, 25(1), 103–125. <https://doi.org/10.1177/0142723705049120>
- You, G., Daum, M. M., & Stoll, S. (2021). Adults adapt to child speech in causative semantics [in revision].
- You, G., Rüst, O., Stoll, S., & Baroni, M. (2021). Entropy correction in corpus studies [in preparation].

Appendix A

Causal and Non-causal Versions of Actions

Figure C1

Snapshots from the Causal Version of Actions in Each Trial

Table C1

Detailed Descriptions of the Actions

Trial	Version	Action
1	Non-causal	A balloon attached to a rope gently swung from side to side.
	Casual	A man poked the balloon with the index finger once, which caused the balloon to gently swing from side to side.
2	Non-causal	A story book spined around on a table.
	Causal	A man spined the story book on a table with his hand.
3	Non-causal	A plastic rose gently swung to the front and back.
	Causal	A man held the plastic rose on the bottom of its pedicle with one hand and held the tip of its pedicle with the other hand and gently swung the rose to the front and back.
4	Non-causal	A wooden mouse-shaped toy waddled down a wooden ramp.
	Causal	A man held the wooden toy with his fingers and moved it down the ramp in a waddling manner.

Appendix B

Pseudo-counterbalancing Details of Study 1

Order	Which puppet on left hand	Trial	Which puppet speaks first	Correct puppet
1	Ferhat	1	Omer	Omer
		2	Omer	Ferhat
		3	Ferhat	Omer
		4	Ferhat	Ferhat
2	Ferhat	1	Ferhat	Ferhat
		2	Ferhat	Omer
		3	Omer	Ferhat
		4	Omer	Omer
3	Omer	1	Omer	Omer
		2	Omer	Ferhat
		3	Ferhat	Omer
		4	Ferhat	Ferhat
4	Omer	1	Ferhat	Ferhat
		2	Ferhat	Omer
		3	Omer	Ferhat
		4	Omer	Omer

Appendix C

Pseudo-counterbalancing Details of Study 2

Order	Which puppet on left hand	Trial	Which puppet speaks first	Correct puppet
1	Omer	1	Omer	Omer
		2	Omer	Ferhat
		3	Ferhat	Ferhat
		4	Ferhat	Omer
2	Omer	1	Ferhat	Ferhat
		2	Ferhat	Omer
		3	Omer	Omer
		4	Omer	Ferhat
3	Omer	1	Ferhat	Omer
		2	Omer	Ferhat
		3	Omer	Omer
		4	Ferhat	Ferhat
4	Omer	1	Omer	Ferhat
		2	Ferhat	Omer
		3	Ferhat	Ferhat
		4	Omer	Omer
5	Ferhat	1	Omer	Omer
		2	Omer	Ferhat
		3	Ferhat	Ferhat
		4	Ferhat	Omer
6	Ferhat	1	Ferhat	Ferhat
		2	Ferhat	Omer
		3	Omer	Omer
		4	Omer	Ferhat
7	Ferhat	1	Ferhat	Omer
		2	Omer	Ferhat
		3	Omer	Omer
		4	Ferhat	Ferhat
8	Ferhat	1	Omer	Ferhat
		2	Ferhat	Omer
		3	Ferhat	Ferhat
		4	Omer	Omer

Appendix D**Numbers of Verb Stem Types in Recording Sessions in Study 3**

Child	Number of verb stem types		Number of verb stem types with -Dlr	
	Child speech	CDS	Child speech	CDS
1	185	297	10	26
2	226	392	19	44
3	250	414	18	43
4	200	413	8	38
5	181	358	11	39
6	245	400	16	35
7	178	359	7	41