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Does child-directed speech facilitate language development in all domains? A study space analysis of the existing evidence

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ABSTRACT

Because child-directed speech (CDS) is ubiquitous in some cultures and because positive associations between certain features of the language input and certain learning outcomes have been attested it has often been claimed that the function of CDS is to aid children's language development in general. We argue that for this claim to be generalisable, superior learning from CDS compared to non-CDS, such as adult-directed speech (ADS), must be demonstrated across multiple input domains and learning outcomes. To determine the availability of such evidence we performed a study space analysis of the research literature on CDS. A total of 942 relevant papers were coded with respect to (i) CDS features under consideration, (ii) learning outcomes and (iii) whether a comparison between CDS and ADS was reported. The results show that only 16.2% of peer-reviewed studies in this field compared learning outcomes between CDS and ADS, almost half of which focussed on the ability to discriminate between the two registers. Crucially, we found only 20 studies comparing learning outcomes between CDS and ADS for morphosyntactic and lexico-semantic features and none for pragmatic and extra-linguistic features. Although these 20 studies provided preliminary evidence for a facilitative effect of some specific morphosyntactic and lexico-semantic features, overall CDS-ADS comparison studies are very unevenly distributed across the space of CDS features and outcome measures. The disproportional emphasis on prosodic, phonetic, and phonological input features, and register discrimination as the outcome invites caution with respect to the generalisability of the claim that CDS facilitates language development across the breadth of input domains and learning outcomes. Future research ought to resolve the discrepancy between sweeping claims about the function of CDS as facilitating language development on the one hand and the narrow evidence base for such a claim on the other by conducting CDS-ADS comparisons across a wider range of input features and outcome measures.

Introduction

Current consensus in the field of language development research asserts that child-directed speech (CDS) facilitates language learning. This idea was first prominently expressed by Ferguson (1964), who suggested that aiding language acquisition may be a universal function of CDS. He based this conclusion on a comparison of CDS intonation patterns, word form modifications and use of

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specific lexical items comprising diminutives and reduplications across six typologically diverse languages (English, Spanish, Arabic, Marathi, Comanche, and Gilyak). These modifications and CDS-specific lexical items were hypothesised to make the task of language learning easier. Ferguson's ground-breaking proposal contrasted with a widely held belief at the time that "the use of baby talk inhibits learning of the language" (Ferguson, 1964; p. 112), and launched a prolific line of research into the special way in which children are addressed by caregivers. Over the past six decades, this body of research has cemented the view that CDS[1] is indeed tailored to facilitate language development. This claim has been reiterated in statements found in several recent prominent review papers, at first somewhat tentatively, e.g. *"many of the lexical and phonological properties of ID speech seem beneficial for language development."* (Soderstrom, 2007, p. 508) but as time went by ever more assuredly, e.g., *"The linguistic modifications [of IDS]… are designed to facilitate comprehension and aid in language acquisition."* (Saint-Georges et al., 2013, p. 11), *"…there is now enough research to support infants' use of IDS as a language-learning tool…"* (Golinkoff et al., 2015, p. 393) and *"Over the past few decades, a plethora of studies have shown that features of CDC [child-directed communication]…support language acquisition by infants both in comprehension and production."* (Schick et al., 2022, p. 5).

Statements like these typically summarise a limited number of studies on certain features of CDS and their putative effect on language development yet give the impression of generality in the sense that the effect applies to most, if not all, aspects of language. As a result, the idea that CDS serves the function of aiding language development *in general* appears to have become entrenched in the field. In this review we ask whether research on CDS to date has collected sufficiently broad evidence to warrant such a general conclusion. We argue that to better understand the mechanisms by which CDS can affect language development it is important to determine whether this claim is restricted to just a subset of CDS features and learning outcomes or whether it holds more generally across many linguistic (and perhaps even some extra-linguistic) domains. If systematic testing across linguistic domains were to reveal that facilitative effects of CDS hold only for some domains and outcomes but not others, this would help to clarify the mechanisms by which CDS can facilitate learning and the mechanisms by which these beneficial features are generated by caregivers. The distribution of facilitative effects of CDS across domains and outcomes has therefore implications for theories of language development but also for the scope of practical interventions and recommendations. We return to this point in the Discussion.

To gain an overview of the existing evidence we employed a study space analysis, an approach that involves mapping the frequency of studies across specific combinations of independent and dependent variables in an entire research literature. Study space analysis has been introduced in areas of applied psychology (e.g., eye-witness testimony) to scrutinise whether the available research literature holds enough evidence to support policy recommendations that are adequate for a range of conditions (Malpass et al., 2008). Here, we employ this method of synthesising research studies to scrutinise support for a claim that has not just applied but also theoretical relevance. The applied relevance is evident because many educational and policy programmes expend considerable effort at trying to enrich caregiver language directed at young children (e.g., as part of the Head Start programme launched by the US Department of Health and Human Services in 1965). However, study space analyses may also be used to ascertain the strength of the empirical basis for theoretical claims: To date, there has not been a systematic assessment of the extent to which the claim that CDS facilitates language development holds across different linguistic domains of CDS and for different learning outcomes. We seek to clarify whether most or only some aspects of CDS facilitate language development, and whether most or only some aspects of language development benefit from these input modifications. Obtaining an overview of the current landscape of research efforts can reveal which areas have so far been underexplored and may help direct future research efforts towards filling current gaps in knowledge to be theoretically more impactful as well as more empirically grounded with respect to practical interventions and recommendations.

Study space analyses have been conceptualised as a sub-category of scoping reviews (Munn et al., 2018), as they share with the latter the goal of identifying gaps in the research literature. Yet study space analyses go beyond scoping reviews: Obtaining the frequency of studies that address specific combinations of independent and dependent variables offers insight into which independent and dependent variable combinations are over- or under-represented in a research field. In contrast to systematic reviews and *meta*-analyses, study space analyses do not attempt to answer specific research questions but to ascertain whether and to what extent such questions are answerable in principle given the available research literature. In this sense, the goal of the present study space analysis is not to answer the question of whether CDS facilitates language development at all but to determine whether there exist sufficiently broad empirical grounds to assess this claim in the generality – that is, with respect to all or most aspects of language development – with which it is often stated. As a result, we hope to be able to pinpoint the linguistic domains and learning outcomes for which the evidence base for potential conclusions is strong and the ones for which it is weaker, potentially warranting further research efforts.

In order to scrutinise the existing evidence, it is important to clarify first what exactly the notion of facilitation implies. In the most trivial sense, CDS facilitates language development simply by virtue of constituting the language input on which much of language learning operates: Children learn when processing the input they receive. In many (but not all) cultures this input happens to be CDS. Yet in most cases the described benefits of linguistic input pertain to natural language input in general, not just input that is specifically tailored for children (Bergelson et al., 2023). Indeed, a vast amount of research supports the notion that the more language input children receive and the richer this input is the faster language development progresses. For example, greater numbers of words and conversational turns in child-directed communication have been shown to positively predict children's receptive and expressive language skills (Wang et al., 2020). Similarly, higher number of word types, an indicator of lexical richness in CDS, were positively

[1] For ease of explanation and to maintain consistency with the literature we will use the term CDS as an umbrella term to refer to language addressed to all children, including infants (i.e., infant-directed [ID] speech or IDS). We acknowledge that CDS is a reductive term that does not include different modalities (e.g., child-directed sign language or child-directed non-verbal gestures termed 'motionese'). In future, the field may wish to more broadly adopt the terms 'child-directed language' or 'child-directed communication' to incorporate a wider range of modalities.

linked to vocabulary knowledge in 1–3-year-old children (Pan et al., 2005). However, a simple link between input quantity and learning outcomes is not what led Ferguson (1964) to propose a special role of CDS in facilitating language development. He suggested that it is the features that are added or modified in CDS compared to non-CDS that exert the facilitative effect. Consequently, for the claim that CDS plays a facilitative role in language development to hold there needs to be evidence that learning from CDS is more successful than learning from non-CDS would be.

The typical non-CDS control employed in this literature is speech directed at another adult – adult-directed speech (ADS). Thus, at a minimum, the claim that CDS facilitates language development requires evidence of learning benefits from CDS over and above ADS. The present study space analysis seeks to establish what proportion of the extant literature on CDS has attempted to attain such evidence and can therefore speak to the question of whether CDS does indeed facilitate language learning, as opposed to answering other questions such as whether CDS is a human universal or how children learn language from the input they receive. It could be argued that facilitative effects of CDS can be demonstrated by de-coupling the comparison of CDS and ADS features from the testing of the effects of these CDS-features on learning outcomes. In other words, researchers may try to postulate facilitative effects of CDS based on evidence from separate studies, e.g. studies that only examine the difference between CDS and ADS in certain features of interest on the one hand, and a second set of studies that only examines the correlation between the prevalence of these features and some learning outcomes on the other hand. This, however, would not constitute suitable evidence for facilitative effects of CDS because unless learning outcomes from CDS and ADS are compared directly, it cannot be ruled out that the correlation between feature prevalence in CDS and learning outcomes is merely due to larger inter-individual variation in the CDS-only studies. Crucially, within the proportion of the research studies that fulfil the criterion of comparing learning outcomes between CDS and ADS we aim to establish how the available evidence is distributed across linguistic input domains and language development outcome variables. Knowing the distribution of research efforts across this study space can inform the field about whether the current broad-based claims about facilitative effects of CDS are warranted or whether conclusions about the function of CDS at present need to remain more circumspect and bound to the specific aspects of language development for which facilitation has directly been demonstrated.

Dissecting arguments for the claim that CDS facilitates language development

Before presenting the results of our study space analysis we start by critically evaluating arguments that are frequently advanced in favour of the claim that CDS 'aids', 'facilitates' or 'is tailored to support' language development. To this end, it may be helpful to adopt principles from behavioural ecology that involve explaining a behaviour in terms of its ultimate and proximate causes (Tinbergen, 1963), where 'ultimate' refers to evolutionary explanations that highlight the adaptive value and the phylogenetic history of a behaviour (the 'why') and 'proximate' explanations refer to the underlying physiological and psychological mechanisms as well as to the behaviour's ontogeny (the 'how'). In the context of CDS, it is often not clear whether claims about a facilitative effect refer to its ultimate adaptive function or to the proximate mechanisms that generate it. Do claims about facilitation pertain to CDS as a human universal that has evolved to enable child language development? Or do these claims pertain to specific socio-cognitive mechanisms by which caregivers alter their language and communicative strategies in an effort to support child language development? In the former sense, facilitation of children's language development can be construed as an ultimate cause of CDS, which implies that its characteristic features have evolved because they are adaptive for this purpose. What matters, then, is the learning outcome, regardless of whether the proximate mechanisms that bring about the characteristic features of CDS are deployed by caregivers with the aim to support child language development or not. In the latter sense, facilitation of language development can be seen as a proximate mechanism for generating CDS, which implies that CDS features are manifestations of caregivers' intent to support the child's language development, which may exist regardless of whether a beneficial learning outcome is being achieved or not. Even though the language development literature is rarely explicit about whether it construes facilitation of language learning through CDS in the ultimate or the proximate sense, the various lines of argument that have been advanced can roughly be grouped by whether they are more compatible with the former or the latter: arguments that emphasise links between CDS features and language learning outcomes implicitly seem to refer to the ultimate function of CDS (e.g., Saint-Georges et al., 2013) while arguments that emphasise links between caregiver intent to support language development and CDS features seem more concerned with its underlying mechanisms (e.g., Eaves et al., 2016).

Argument 1: A positive link between CDS features and language learning outcomes is evidence that the function of CDS is to facilitate language development.

A prominent argument that the ultimate function of CDS is to facilitate language development emphasises a positive link between features of CDS and language learning outcomes (Saint-Georges et al., 2013). This link pertains to features of CDS across all domains. For example, features like increased average pitch height or expanded pitch range are thought to attract the attention of pre-linguistic infants to speech as a socially important source of information (e.g., ManyBabies Consortium, 2020) and to increase the salience of intonation patterns that convey information about speaker intention (e.g., Fernald, 1989). Linguistic features of CDS comprise features like slow speech rate, which may ease the processing load for the language learning child (e.g., Graf Estes & Hurley, 2013), hyperarticulation, which may aid discriminability of vowels due to expanded vowel space and low vowel variability (e.g., Kuhl et al., 1997; Hartman et al., 2017), exaggeration of Voice Onset Time (VOT) contrasts, which may enhance discriminability of stop consonants (e.g., McMurray et al., 2013), or frequent use of derivations like diminutives or reduplications, which may aid word learning (e.g., Ota & Skarabela, 2016) and the discovery of morphosyntactic regularities (e.g., Kempe et al., 2003).

Correlations between availability of CDS features at one point in time and learning outcomes at a later point in time have been reported for several linguistic domains. However, links are not always positive. For example, while there is evidence for positive associations between more hyperarticulated versions of speech sounds in caregiver speech and infants' ability to discriminate these sounds from acoustically similar ones (Cristia, 2011), clearer speech is not always associated with better learning: A recent study has

shown that greater phonological complexity associated with hypoarticulation due to coarticulation and extended word duration in CDS is associated with more advanced phonological processing in children while hyperarticulation predicts increased vocabulary size, showing that effects of simplicity vs. complexity can differ depending on outcome measure and child age (Cychosz et al., 2021). Similar effects seem to hold with respect to morphosyntactic and lexico-semantic features of CDS where there is controversy about whether morphosyntactically and semantically simpler vs. more complex CDS is related to better language learning outcomes (Newport et al., 1977; Gleitman et al., 1984; Furrow et al., 1979; 1986). These heterogeneous results may reflect a developmental trajectory by which complexity of CDS in various domains exert different effects depending on the current linguistic competence of the child in each domain.

Crucially, whatever their direction, links between features of the language input and language learning outcomes do not constitute evidence that CDS facilitates (or, for that matter, hinders) language development. They merely show that variability in the way children are being addressed is linked to variability in how children learn. That correlational evidence of this kind is not relevant for the argument of a facilitative role of CDS can be illustrated by a *Gedankenexperiment* in which caregivers address infants in much the same way as they would address other adults. To the extent that there is variability in the relevant features, all the observed correlations would still hold – greater speech clarity would initially benefit phonological category discrimination but subsequently hinder the learners' ability to extract phonological information from more complex or noisy input and morphosyntactic and semantic simplifications would aid early learning of words and grammatical categories but would subsequently stifle the expansion of learners' morphosyntactic skills and semantic knowledge. Such associations would be expected with respect to any language input that is processed by the child and, in the absence of a comparison to ADS, are thus not evidence for CDS as a facilitator of language development.

Argument 2: Adjustments of CDS in response to children's linguistic needs are evidence for an intent to support language development.

Another argument in favour of the claim that CDS facilitates language learning is that it changes with the linguistic needs of the child (Saint-Georges et al., 2013). Assumed linguistic needs of the child are inversely related to the child's linguistic competence, which caregivers extrapolate from the child's age or neuro-developmental status (e.g., Down Syndrome, Autism Spectrum Disorder, hearing loss etc.). For the sake of argument, we will mention just a few examples of this kind of adjustment across linguistic domains: CDS pitch and vowel length reduce, and articulation rate increases gradually over the course of the first 2–3 years of children's life (Cox et al., 2023a), a trajectory that is assumed to reflect caregivers' sensitivity to changes in children's attentional preferences and to their developing processing capacities. Caregivers also reduce frequency and salience of sound-symbolic words over the first two years of their children's life, a period during which reliance on sound-symbolism becomes less important for children's world learning (Jo & Ko, 2018). Similarly, caregivers modify the lexical diversity and syntactic complexity of their utterances between children's ages of 3 and 12 months, albeit not always in linear fashion (Genovese et al., 2020). Whatever the trajectory of change of CDS with children's age, the central assumption is that modifications of CDS based on children's linguistic needs are evidence that caregivers attune their language to the cognitive and linguistic maturity of the child by scaffolding input in a way that aids language development.

It is remarkable that explicit discussion of potential proximate mechanisms that drive caregivers' speech adjustments is rare in the language development literature. In contrast, mechanisms of speech adjustment are frequently discussed in the context of information-theoretical views of language use, construed as signal transmission through a noisy channel that ensures listener comprehension while at the same time conserving speaker effort (Zipf, 1949; Aylett & Turk, 2004). This view distinguishes broadly between speaker-oriented and listener-oriented approaches to this trade-off. Speaker-oriented approaches assume that language production is egocentric and that what appear like adjustments to listeners' needs are essentially epiphenomena that arise from processing constraints of the speaker. For example, speakers have been found to provide prosodic disambiguation in instances of syntactic ambiguity. e.g., through placement of pauses in sentences like *Touch the cat with the ball.*, regardless of listener need (Kraljic & Brennan, 2005; Schafer et al., 2000; Speer et al., 2011). In other instances, speakers can exaggerate voice onset time contrasts not because a minimal-pair competitor occurs in the same utterance and requires disambiguation but because speakers are aware of a competitor's presence in the phonological neighbourhood of the target word. This indicates that automatic speaker-internal processes take precedence over listener needs (Bease-Berk & Goldrick, 2009). Under a speaker-oriented approach to speech and language production, adjustment of CDS to the child's linguistic needs should therefore not be considered the result of an effort to facilitate language development.

Instead, speaker-oriented approaches are compatible with interpretations of CDS features as by-products of speaker-internal processes such as threat minimisation or positive affect expression. Indeed, the hyperarticulation of vowels is likely a side-effect of shortening of the vocal tract by raising the larynx to appear less threatening (Kalashnikova et al., 2017), with the goal to appease and build rapport with the listener. Moreover, CDS prosody has been shown to be indistinguishable from the prosody of 'happy' speech (Singh et al., 2002) and bears similarity with other affective speech registers like lovers' speech (Bombar & Littig, 1996) or pet-directed speech (Burnham et al., 2002) in its characteristic use of pitch, pitch range and voice quality. Interestingly, pet-directed speech lacks phonetic and phonological adjustments to improve speech intelligibility, such as hyperarticulation, even though many pet owners spend considerable time trying to teach their pets to engage or not engage in certain behaviours. Thus, while a teaching intent towards pets may be commonplace, speech adjustment is not the way to express it.

Listener-oriented approaches to speech production (e.g., Lindblom, 1990; Moon, 1995; Galati & Brennan, 2010), on the other hand, postulate that speakers adjust prosodic, phonological, morphosyntactic and lexical features of their speech in accordance with a continuously updated mental model of listener knowledge (Turnbull, 2019). These adjustments require perspective taking on the part of the speaker and are therefore associated with a capacity for Theory of Mind. Consequently, individual differences in signal enhancement are – at least in part – linked to individual differences in Theory of Mind: better scores on Theory-of-Mind-tests are associated with more intelligible clear speech, i.e., speech modifications that can help overcome transmission obstacles such as noise or listener processing limitations (Turnbull, 2019). If applied to the production of CDS, listener-oriented approaches would predict that

caregivers should adjust their speech based on their mental model of the child's comprehension abilities, and that caregivers who are better at constructing such mental models should produce more pronounced CDS features when they judge the child's comprehension abilities to be low. Even though a link between CDS features and Theory of Mind has to our knowledge not been tested directly, some indirect evidence points in this direction: higher pitch and more pronounced pitch excursions in CDS are associated with having grown up with siblings (Ikeda & Masataka, 1999), and growing up with siblings is known to foster Theory of Mind (McAlister & Peterson, 2007). However, this indirect link is open to alternative interpretations so whether greater Theory of Mind-capacity shapes CDS will have to be tested in future research. Still, even under a listener-oriented approach to speech and language production, creating mental models of the listener and exercising Theory of Mind would not be considered manifestations of an intent to teach language, something that has been acknowledged before in the language development literature by suggesting that CDS is merely a way of communicating with linguistically immature interlocutors (Newport et al., 1977; Soderstrom, 2007).

The question of whether adjustment of CDS to the listener's linguistic needs can be taken as an indicator for the intent to facilitate language learning is not unique to CDS but has also been raised with respect to other clear speech registers (Smiljanić & Bradlow, 2009) that share features with CDS. One such clear speech register is foreigner-directed speech (FDS), used to address non-native listeners. The fact that speakers adjust their speech to the listener's perceived linguistic competence has been interpreted as evidence for a didactic function of FDS, i.e. that FDS serves the purpose of teaching a second language and that it has an impact on language learning (Piazza et al., 2022). However, a didactic function is not implied in another clear speech register that shares similarities with CDS, namely, speech directed at elderly interlocutors (Kemper et al., 1998). Like CDS (and FDS), elderspeak is characterised by clear speech features and simplifications, in acknowledgment of addressees' diminishing perceptive and processing capacities (e.g., Thimm et al., 1998). In caring contexts, elderspeak may arguably even exhibit affective features not dissimilar to CDS. Yet, despite these remarkable overlaps between speech directed at very young and very old interlocutors, claims that such adjustments are motivated by an intent to teach language would be inconceivable for the latter. To construe clear speech registers like CDS, FDS and elderspeak as didactically motivated behaviour, i.e., a way of teaching language, would logically render teaching indistinguishable from any signal enhancements that improve intelligibility and listener comprehension. Even though definitions of teaching vary widely by discipline (Kline, 2015), postulating that *any* kind of adjustment to the needs of listeners constitutes teaching does not do justice to the functional distinctiveness of this human capacity (Gurven et al., 2020; Brandl et al., 2023). Unless one wants to equate speech adjustment with teaching there is no need to invoke the intent to teach language as an explanatory construct for clear speech registers. Trying to settle the question of what distinguishes speech adjustment from teaching would require examining whether speech features that serve the purpose of adjustment to listener needs are different from speech features that serve the purpose of teaching. At present it is still an outstanding empirical question whether speaking to clarify and speaking to teach linguistic competence are similar in their underlying mechanisms, observable features and in their impact on comprehension and learning. Therefore, we argue that modifications in CDS in response to perceived linguistic competence of the child do not constitute evidence for caregivers' intent to support language development.

The present study space analysis

Because the frequently advanced arguments discussed above do not hold up to scrutiny, we aimed to evaluate how the evidence for facilitative effects of CDS compared to ADS is distributed across multiple input domains and learning outcomes. To this end, our study space analysis coded the number of available studies for each combination of the following variables: (a) *CDS-ADS Comparison:* whether the study contained a comparison between CDS and ADS, (b) *Primary CDS Domain:* the primary linguistic domain of CDS under scrutiny, e.g. whether a study was concerned with prosodic, phonological, morphosyntactic, lexico-semantic, pragmatic or associated extra-linguistic features, and (c) *Learner Response Domain:* the learning outcome or domain of learner response, if any, that is being investigated, e.g. register discrimination, word segmentation, phonological or lexical development etc.

One fundamental problem with comparing learning outcomes between CDS and ADS is that this comparison cannot be performed using observational studies, simply because in cultures where CDS has been documented children tend not to be addressed with speech registers that are normally used amongst adults. Thus, a CDS-ADS comparison requires an experimental design which can either be implemented with adult learners to provide proof of concept for the effects of the input manipulation of interest or with children to compare short-term learning gains from CDS. Another research strategy involves the use of computational modelling by applying various learning algorithms to either CDS or ADS input. To capture these methodological choices, we also coded (d) *Learner type*: whether learning was measured in children, adults, or by performance of a computational model. Finally, although not directly related to the primary aim of this analysis, we also coded (e) the *language(s)* investigated in each study, to get a sense of the cross-linguistic scope of the literature on CDS.

This coding scheme allowed us to determine the proportion of studies in the CDS-literature that contain comparisons between CDS and ADS without investigating differences in learning outcomes. While informative about the nature of CDS, these kinds of studies do not permit conclusions about facilitative effects on language development as learning outcomes are not examined directly. Still, they do serve the purpose of identifying candidate features characteristic of CDS that could potentially facilitate learning. It is therefore important to know how these comparison studies are distributed across linguistic domains. The coding scheme also allowed us to identify the proportion of studies that examine learning outcomes from CDS without a comparison to ADS. Such studies are informative with respect to specific language learning mechanisms which may differ depending on linguistic input and outcome domains. Finally, the coding scheme allowed us to identify the crucial proportion of studies that can provide evidence for facilitative effects from CDS by comparing learning outcomes to ADS. Scrutinising the distribution of this latter type of studies across input domains and learning outcomes is crucial for assessing the generality of the claim that CDS facilitates language development.

Method

Article selection

Our article selection followed PRISMA-ScR, the PRISMA checklist extension for scoping reviews (Tricco, 2018). Searches were conducted on Web of Science and PubMed Central using the keywords 'child-directed speech' OR 'infant-directed speech' OR 'baby talk' OR 'babytalk' OR 'motherese' OR 'maternal speech' OR 'paternal speech' OR 'mother–child-conversation*' OR 'mothers' speech to' OR 'fathers' speech to'. A separate search using the search terms 'child-directed language' NOT 'child-directed speech' was added when we became aware that some studies used the former term exclusively and may therefore have been missed in the initial search. Eighty papers originally not retrieved were added as they were discovered while scanning the selected articles. This search protocol resulted in retrieval of articles with a publication date up until 22 October 2022, including 19 articles published ahead of print which might now be archived with a publication date later than our cut-off date.

Our first inclusion criterion was that studies needed to present empirical evidence subjected to peer review and therefore had to be published in academic journals. To comply, we excluded non-peer-reviewed sources like books, book chapters, and not reliably peer-reviewed sources like conference proceedings as well as theoretical reviews (see Fig. 1). The remaining 1761 articles were retrieved and scanned for relevance and accessibility (20 articles could not be retrieved). Our second inclusion criterion was that child-directed speech and its effects had to be the subject of research. To comply, we had to ascertain when the search terms were mentioned in an ancillary context and exclude those studies. This was the case for the 69 empirical studies on speech directed to other addressees (pets, foreigners, robots or the elderly[2]), where the search terms were mentioned in the context of comparison to CDS. This could also be the case for studies that investigated educational or clinical interventions or various non-linguistic aspects of cognitive development (e.g., childhood amnesia, social or emotional development) where the search terms were used, for example, to describe methods of stimulus construction. Finally, we excluded studies where a CDS corpus was used to obtain word frequency or similar data for stimulus construction in an otherwise unrelated experiment. Following these exclusion criteria 797 studies were removed during the pre-scanning process by the first author (VK); adherence to inclusion criteria was subsequently checked by the third author (SS); one discrepancy was resolved by mutual agreement.

Article coding

To ascertain how much research effort has been dedicated to establishing learning benefits from CDS over and above ADS and how empirical investigations are distributed across linguistic input domains and learning outcomes, we coded the remaining 944 papers with respect to the study variables of CDS-ADS Comparison, Primary CDS Domain, Learner Response Domain, Learner Type, and Language(s). Given the size of this corpus and our goal to establish the distribution of evidence across input domains and outcome measures in the field of research on CDS, the coding was applied to entire articles rather than to individual studies within an article. This is justified given that we were interested in the research questions posed and multiple studies reported within an article tend to try to answer the same research question about a specific aspect of CDS.

CDS-ADS Comparison. For each article we used a binary coding of whether it contained a comparison between CDS and some form of ADS or not, regardless of whether ADS data were obtained through naturalistic observation, pre-existing corpora or elicited in a specific context.

Primary CDS Domain. Because many studies often consider CDS features from multiple linguistic domains without prioritising one domain over the others we had to establish a protocol for determining primary and secondary CDS domains of interest. We decided to base this on the level of abstraction and complexity, starting from the broadest, most context-dependent aspects and moving towards more specific, structural elements of language input thus arriving at the following hierarchy of six features: extra-linguistic → pragmatic → lexico-semantic → morphosyntactic → phonological / phonetic (henceforth abbreviated as Phon + in the figures) → prosodic. For example, if input features such as amount of turn-taking, parental motion patterns (features of 'motionese') or gaze direction were coded in addition to lexical information such as type-token ratio or presence of certain words (e.g., emotion labels) 'extra-linguistic' was selected as the primary CDS domain and 'lexico-semantic' as the secondary CDS domain. Similarly, when pragmatic information such as whether utterances served as requests, queries or recasts was coded alongside morphosyntactic information such as mean length of utterances, 'pragmatics' was selected as primary and 'morphosyntactic' as secondary input domain. This approach was chosen for consistency to ensure that our coding reflected the diversity of CDS domains in this literature, given that domains with lower complexity and context-dependency like phonology or prosody are more frequently included in CDS research. If more than two CDS domains were explicitly or implicitly included in the analyses (e.g., type-token ratio, mean length of utterances and pitch/ pitch range) the catch-all category 'Multiple' was chosen as primary category and no secondary category was coded. 'Multiple' was also employed for studies that did not specify which CDS feature could be responsible for an effect (e.g., studies that employed recording devices like the one used with the Language ENvironment Analysis [LENA] to estimate overall quantity of CDS).

Learner Response Domain. For those articles in which input features were linked to some measure of learner behaviour or emerging language ability, we coded whether the learner response and outcome domain fell into one of the following thirteen categories (listed in alphabetical order). Unlike for CDS input domains articles tended to focus on one outcome domain of interest; only the category

[2] It is interesting to note that in this corpus of literature all studies examining foreigner-directed speech (FDS) did so in conjunction with examining CDS and the one article exclusively devoted to foreigner-directed speech was a review article.

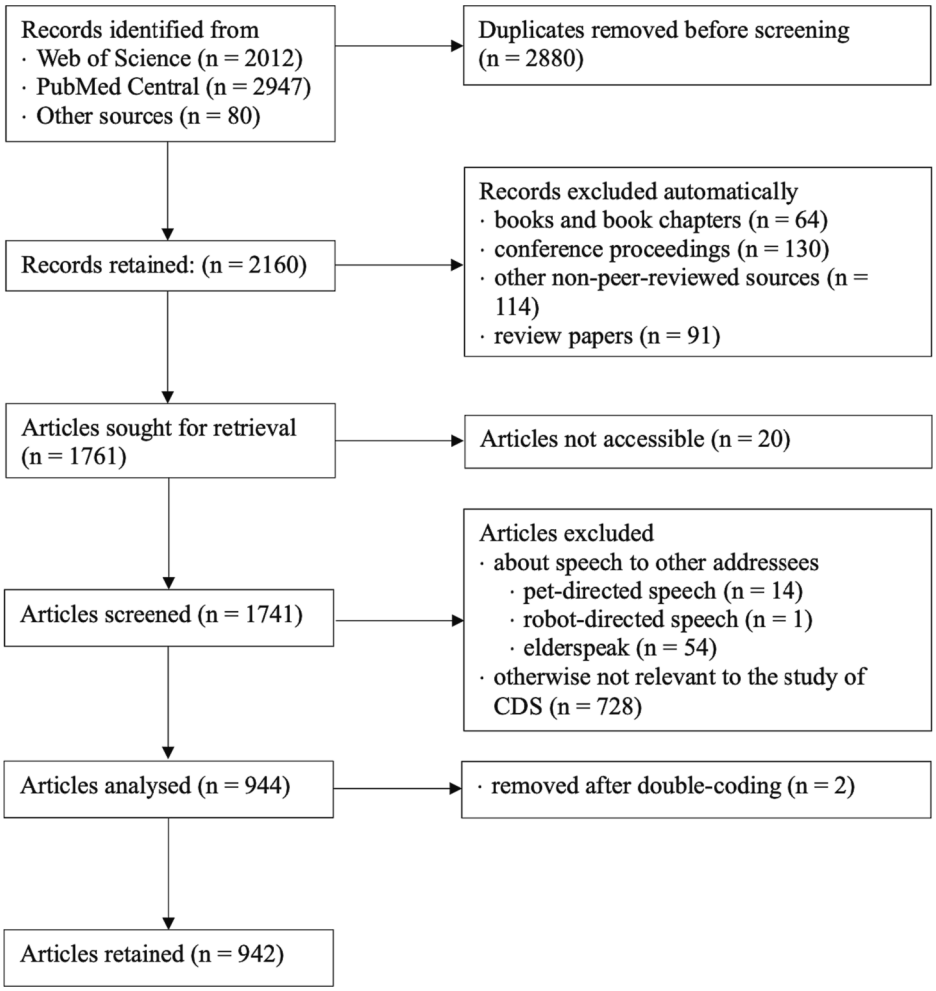

Fig. 1. PRISMA-ScR flow chart of article selection and exclusion.

'Language Development' included studies looking at multiple outcomes.

a) *Extra-linguistic:* measures of non-linguistic communicative behaviour like gaze following (e.g., Hernik & Broesch, 2019) or patterns of turn-taking (e.g., Kajikawa et al., 2004) or of extra-linguistic developmental markers like child attention (e.g., Nencheva et al., 2021) or even infant growth (Monnot, 1999).
b) *Language choice:* measures of participants' selection of one of multiple languages for communication in a multilingual environment based on input features, e.g., to ascertain degree of language mixing or code switching (e.g., Quick et al., 2021).
c) *Language comprehension:* comprehension measures like fixations during eye tracking (e.g., Arunachalam, 2016).
d) *Language development:* either aggregate or standardised measures of language skills across multiple domains, e.g., the Receptive Communication and Expressive Communication subtests of the Bayley Scales of Infant and Toddler Development (Bayley, 2006).
e) *Lexical learning:* measures of vocabulary knowledge or vocabulary size, e.g., based on parental reports like the MacArthur-Bates Communicative Developmental Inventory (Fenson et al., 2007) or on children's naming abilities, e.g., using the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997).
f) *Literacy:* measures of literacy skills, e.g., reading comprehension to measure delayed effects of parental input (e.g., Pratt et al., 1992).
g) *Morphosyntax:* any measure of morphosyntactic development such as mean length of utterances (e.g., Newport et al., 1977; Furrow et al., 1979; Hampson & Nelson, 1993)
h) *Phonology:* measures of phonological development, e.g., presence of certain phonemes or phonetic features in child speech (e.g., Sim & Post, 2022) or tests of phonological memory such as nonword repetition (Czychosz et al., 2021).

i) *Pragmatics:* measures of recognition of a speaker's communicative intent, underlying emotion or speech act evidenced in comprehension (e.g., Bryant & Barrett, 2007) or production of appropriate responses and gestures (e.g., Nakamura & Quay, 2012).
j) *Prosody:* measures of prosodic features produced by the child (e.g., McRoberts & Best, 1997), e.g., children's speech rate (e.g., Guitar & Marchinkoski, 2001) or imitation of interlocutor prosodic contours (e.g., Gratier & Devouche, 2011).
k) *Register discrimination:* Any measure of either discrimination between registers (predominantly between CDS and ADS) or preference for a register. A small minority of studies investigated discrimination or preference with respect to other registers, e.g., affective speech or between different versions of CDS (e.g., addressed to children of different age). Discrimination and preference measures were combined based on the rationale that to prefer a register the addressee needs to be able to distinguish it from the competitor register. Example measures are the amount of gaze following triggered by speech (Outters et al., 2020) or neural measures like oxygenated haemoglobin values obtained from near-infrared spectroscopy (Saito et al., 2007).
l) *Vocalisation:* Measures of the amount of infant vocalisation (e.g., Henning et al., 2005) or of the contingency of parent vocalisation based on infant vocalisation (e.g., Breznitz & Sherman, 1987).
m) *Word segmentation:* Behavioural measures for the ability to discriminate words from non-words e.g., using fixation times indicating novelty preference (e.g., Saffran et al., 1996).

Note that in most but not all cases what is measured are learning outcomes, but in a few instances the studies considered learner variables that interact with CDS features, e.g., when caregiver speech is contingent upon infant vocalisations. In this case, the amount of infant vocalisation is not a learning outcome *per se* but it is still a learner response that reflects some aspect of CDS. Because the categories of *Language Choice*, *Language Comprehension* and *Literacy* each comprised fewer than 5 studies they were combined into one category called *Other*.

Learner Type. For those studies in which a learner response was measured, we also coded the type of learner, i.e., whether learning success was investigated in children, adults, or computational models.

Language. We also coded the language(s) under investigation in each article to get a sense for the degree of cross-cultural and cross-linguistic diversity in this field of research. In those rare cases where the language of the stimuli was different from the participants' native or ambient language(s) we coded participant language rather than language of the stimuli.

Inter-coder reliability

Of the 944 articles selected and coded by the first author, 180 articles (19.1 %) were second-coded by the second and third author (who were randomly assigned the labels 'Coder 2′ [C2] vs 'Coder 3′ [C3]). Each of C2 and C3 coded 80 randomly selected articles; an additional 20 randomly selected articles were coded by both C2 and C3. Two articles, one assigned to C2 and one assigned to C3, were subsequently deemed to be irrelevant to the study space analysis and were excluded from the database, resulting in 99 s-coded articles per coder for a total of 178 (18.9 %) double-coded articles (see Fig. 1). The initial coding by C2 and C3 was discussed and revised to ensure that second coding was based on mutually agreed criteria. After this initial phase of clarification of coding criteria and completion of second-coding, inter-coder reliability was computed using unweighted Kappa coefficients provided in Table 1. The coefficients show that inter-coder reliability ranged from substantial (0.60——0.80) to perfect (>0.80) by the standards of qualitative exploratory research where coding of text responses into multiple categories is common (Burla et al., 2008; O'Connor & Joffe, 2020). For Learner Response Domain – the study variable with the largest number of categories – inter-coder reliability was lowest but still within the range of what is considered substantial.

After the consensus-seeking phase and the establishment of inter-coder reliability, the initial coding of C1 was revised in accordance with coding by C2 or C3 if by consensus the latter was deemed more appropriate. This was done for the 178 of double/triple coded articles to improve overall coding reliability in the corpus. Due to the time-consuming nature of inspecting and coding this large corpus of articles, the original C1-coding was retained for the rest of the corpus. Given that the reliability estimates in Table 1, which present the lower bound of coding reliability achieved before agreed modifications, range from substantial to perfect we can be

Table 1
Inter-coder reliability (indicated by Cohen's Kappa for two coders and Fleiss' Kappa for three coders) for the study variables where a discrepancy after consensus seeking on C2 and C3 coding remained and before C1 coding was revised in the double/triple-coded articles.

study variable	C1 vs. C2 (n = 99)	C1 vs. C3 (n = 99)	C1, C2, C3 (n = 20)
CDS-ADS Comparison (present / absent)	0.95	0.98	0.93
Primary CDS Domain (7 categories)	0.72	0.70	0.79
Learner Response Domain (11 measures and no domain)	0.78	0.69	0.64
Learner Type (child, adult, model)	0.83	0.79	0.83
Participant Language (native / ambient)	0.94	0.95	0.90

confident in our findings. For readers wishing to scrutinise the coding the full list of articles along with the agreed coding is available on https://osf.io/tzv7b/.

Results

We start by illustrating the steady increase in peer-reviewed journal articles on CDS over the past eight decades, and provide, in the interest of transparency, the count of sources that were not included in our corpus such as conference proceedings, book chapters, other non-peer-reviewed sources as well as review articles (Fig. 2). Reference counts are given until the cut-off date of 22. October 2022. It is evident that even if restricted to peer-reviewed journal articles this literature is substantial and has undergone considerable growth, especially in the 21st century.

Next, we determined whether comparisons of CDS to ADS were equally distributed across primary CDS input domains to ascertain how much research effort has been devoted to describing CDS modifications across linguistic domains. Overall, 290 studies (30.8 %) in this corpus contained a CDS-ADS comparison. Fig. 3 shows that CDS-ADS comparison studies were not equally distributed across input domains ($\chi^2 = 231.21$, df = 6, Cramer's V = 0.50, $p < 0.0001$); they comprised 62.2 % of studies investigating prosodic, phonetic and phonological features of CDS compared to only 16.2 % of studies investigating features from other domains. A similar distribution was evident for the 229 studies (24.3 %) for which a secondary CDS input domain was coded; again, 52.6 % of studies which considered prosodic, phonetic and phonological features as secondary input domains contained a CDS-ADS comparison, in contrast to only 6.5 % of studies which considered morphosyntactic, lexico-semantic and pragmatic features as secondary input domains.

The heatmap in Fig. 4 shows the distribution of studies across the variables of CDS-ADS Comparison, Primary CDS Domain and whether a learner response was measured or not. Out of the total of 942 studies, 490 (52.0 %) considered some form of learner response (see bottom row in Fig. 4). Collapsing over all Primary CDS Domains revealed a roughly equal proportion of CDS-ADS comparisons ($p = 0.82$) across studies with or without learner response, with 153 of 490 studies (31.2 %) with learning outcome and 137 of 452 studies (30.3 %) without learning outcome comparing CDS to ADS.

Next, for those studies that did consider a learning outcome, we checked the distribution of CDS-ADS comparisons across Learner Response Domains (see Fig. 5). This distribution was heavily skewed ($\chi^2 = 184.01$, df = 10, Cramer's V = 0.61, Fisher's $p < 0.0001$) with CDS-ADS comparisons most prevalent in studies investigating register discrimination. This learner response category comprised studies investigating ability to distinguish CDS from ADS as well as preference for CDS compared to ADS. Note that the few studies in this category that did not contain a CDS-ADS comparison investigated discrimination of subtypes of CDS, e.g., CDS directed to younger vs. older children (Bozkurt & Solely, 2022).

The heatmap in Fig. 6 provides a comprehensive overview of the study space, i.e. the distribution of studies across the three main

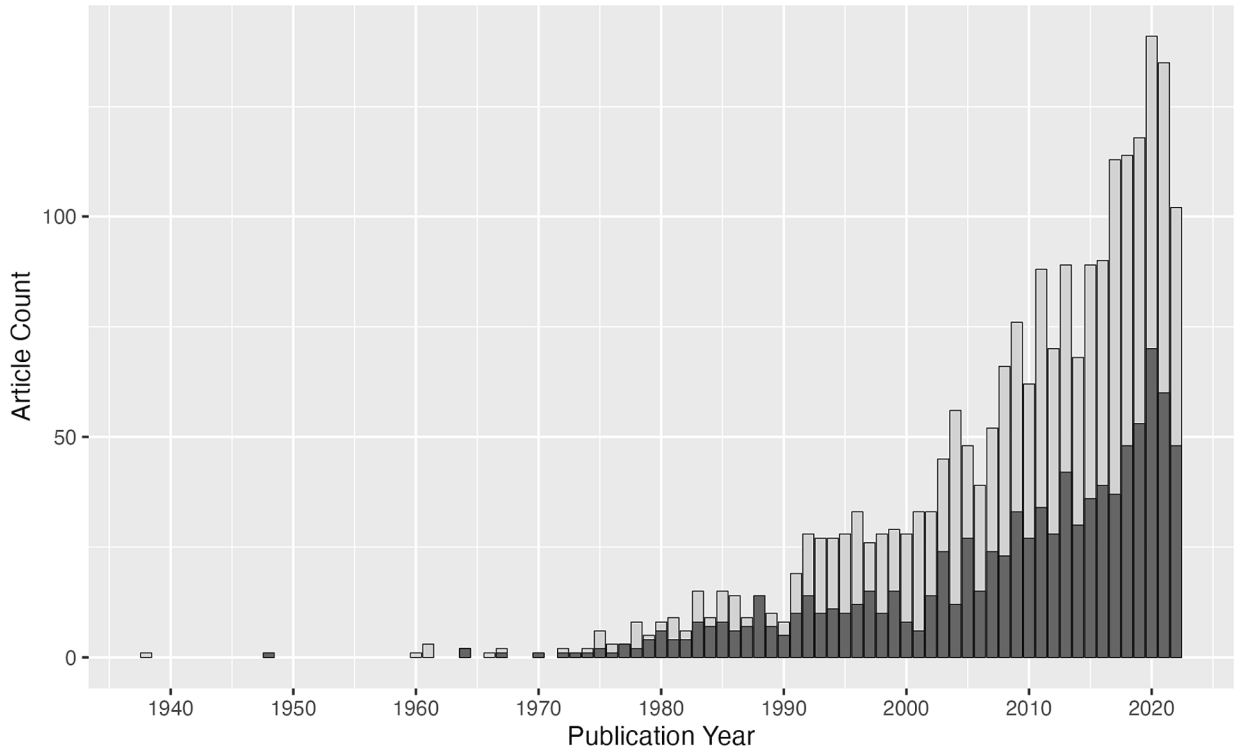

Fig. 2. Number of CDS references by publication year. Dark grey columns indicate peer-reviewed articles; light grey columns indicate all other sources which were not included in the study space analysis (see text for explanation of inclusion and exclusion criteria).

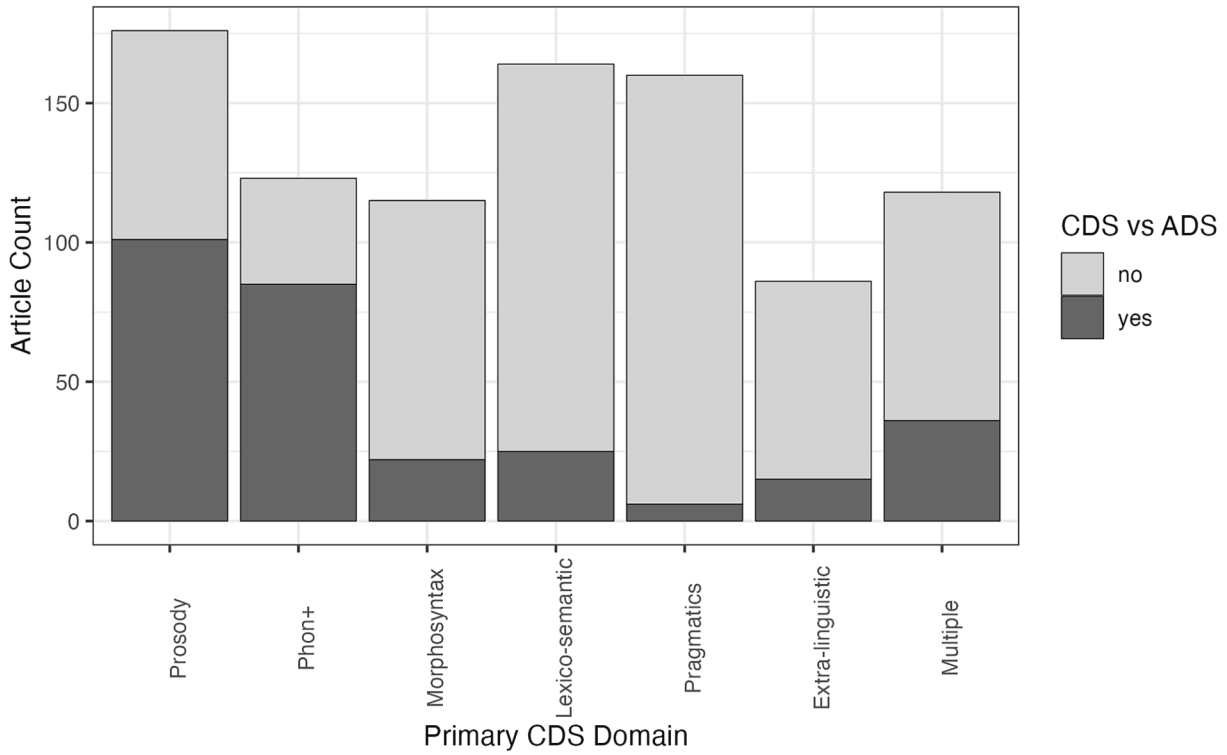

Fig. 3. Number of studies with and without CDS-ADS comparison across primary CDS domains. ('Phon+' signifies both phonetic and phonological features of CDS).

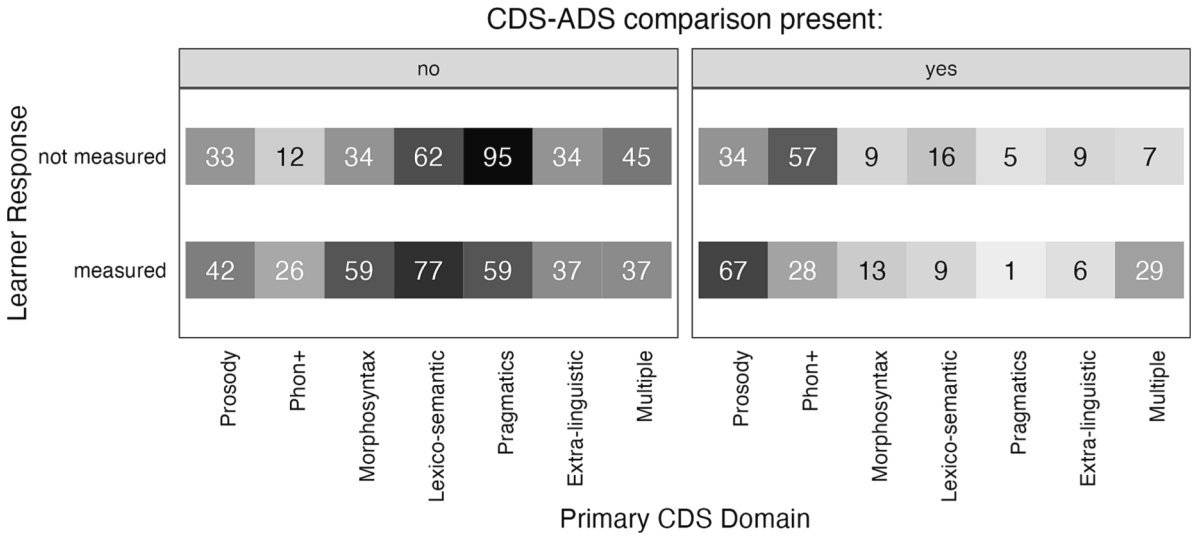

Fig. 4. Distribution of studies across the study variables of CDS-ADS Comparison, Primary CDS Domain and whether a Learner Response was measured or not.

study variables. Two striking observations can be made from this visualisation. Firstly, there are considerable gaps in the research literature with respect to combinations of input and outcome domains. In the Discussion we will address to what extent such gaps are theoretically justified or to what extent they might reflect biases in research effort. Secondly, this visualisation confirms that input and outcome combinations are very differently distributed depending on whether studies compare CDS to ADS or not: While the bulk of studies without a CDS-ADS comparison that correlates CDS features with certain learning outcomes is centred around if and how morphosyntactic and lexico-semantic features of CDS are linked to morphosyntactic and lexical development, respectively (see left

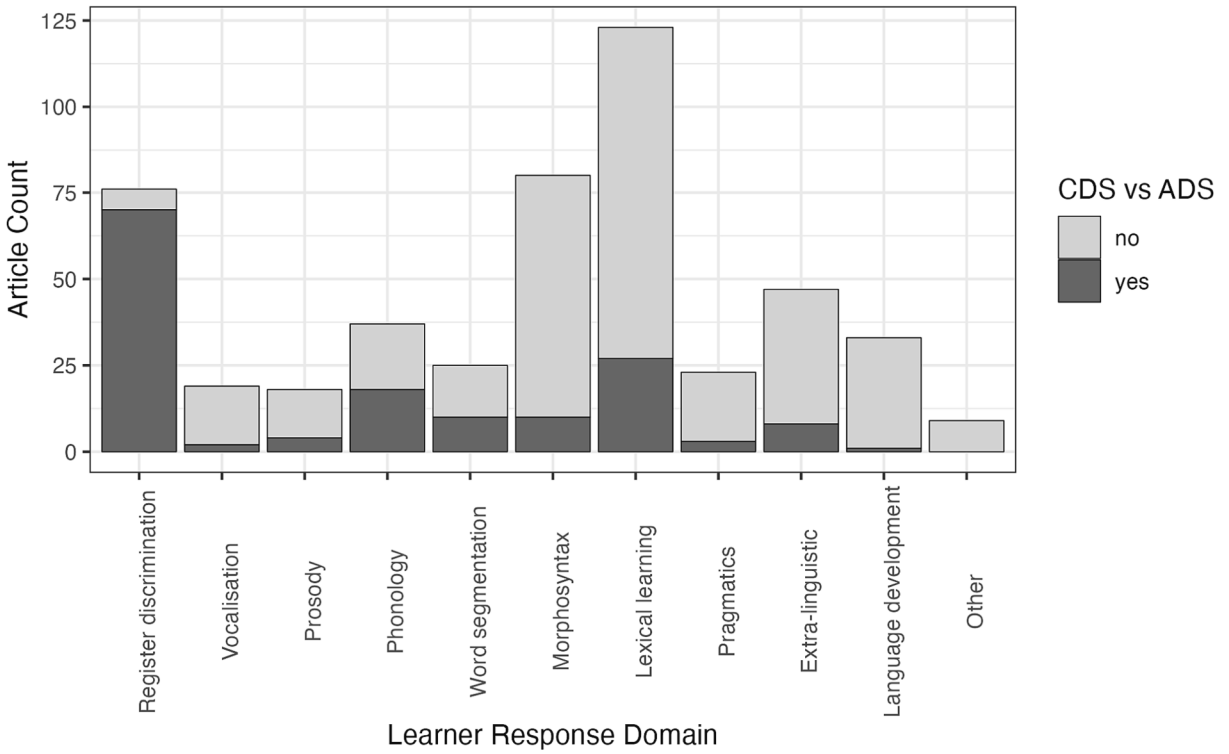

Fig. 5. Number of studies with and without CDS-ADS comparison across learner response domains.

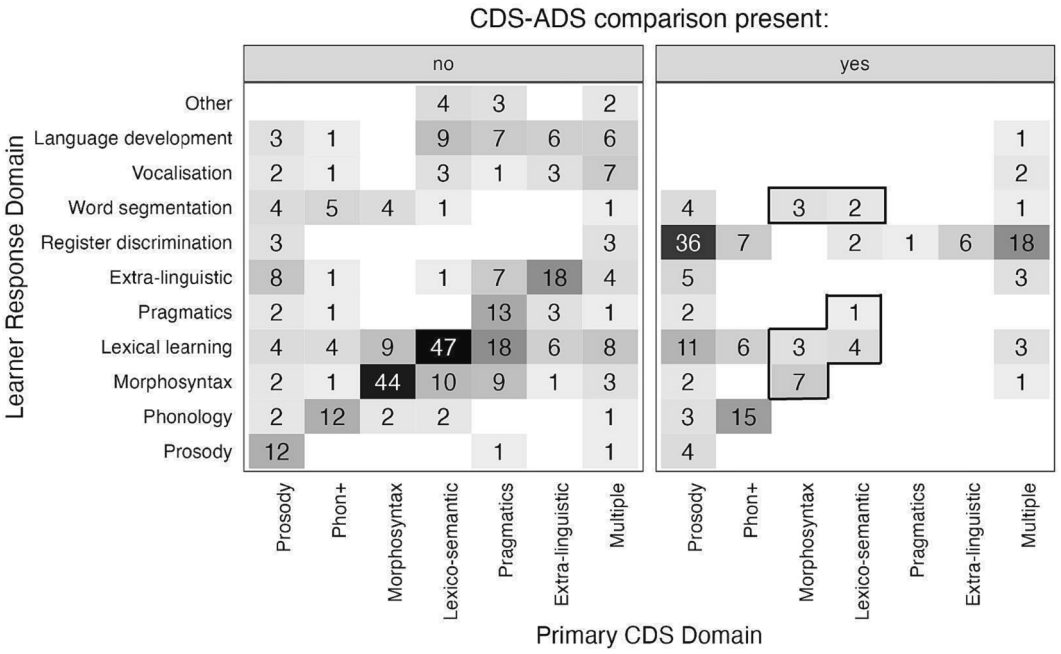

Fig. 6. Distribution of studies with measured Learner Response across the study variables of CDS-ADS Comparison, Primary CDS Domain and Learner Response Domain. Framed cells in the right panel highlight studies comparing learning outcomes other than register discrimination for morphosyntactic and lexico-semantic features.

panel of Fig. 6), studies that do contain a CDS-ADS comparison focus on the effects of CDS features on register discrimination, with 70 studies investigating this outcome. There is also a set of 52 studies that examines effects of prosodic and phonetic / phonological CDS features on learning outcomes other than register discrimination, e.g. phonological or lexical learning. Crucially, out of the 153 studies that qualify as containing potential evidence for facilitating effects of CDS over and above ADS (see right panel of Fig. 6), only 20 studies (framed in black in Fig. 6) are investigating effects of CDS features aside from prosody / phonetics / phonology on a learning outcome other than register discrimination. In other words, there are only 20 studies in total that would potentially allow us to

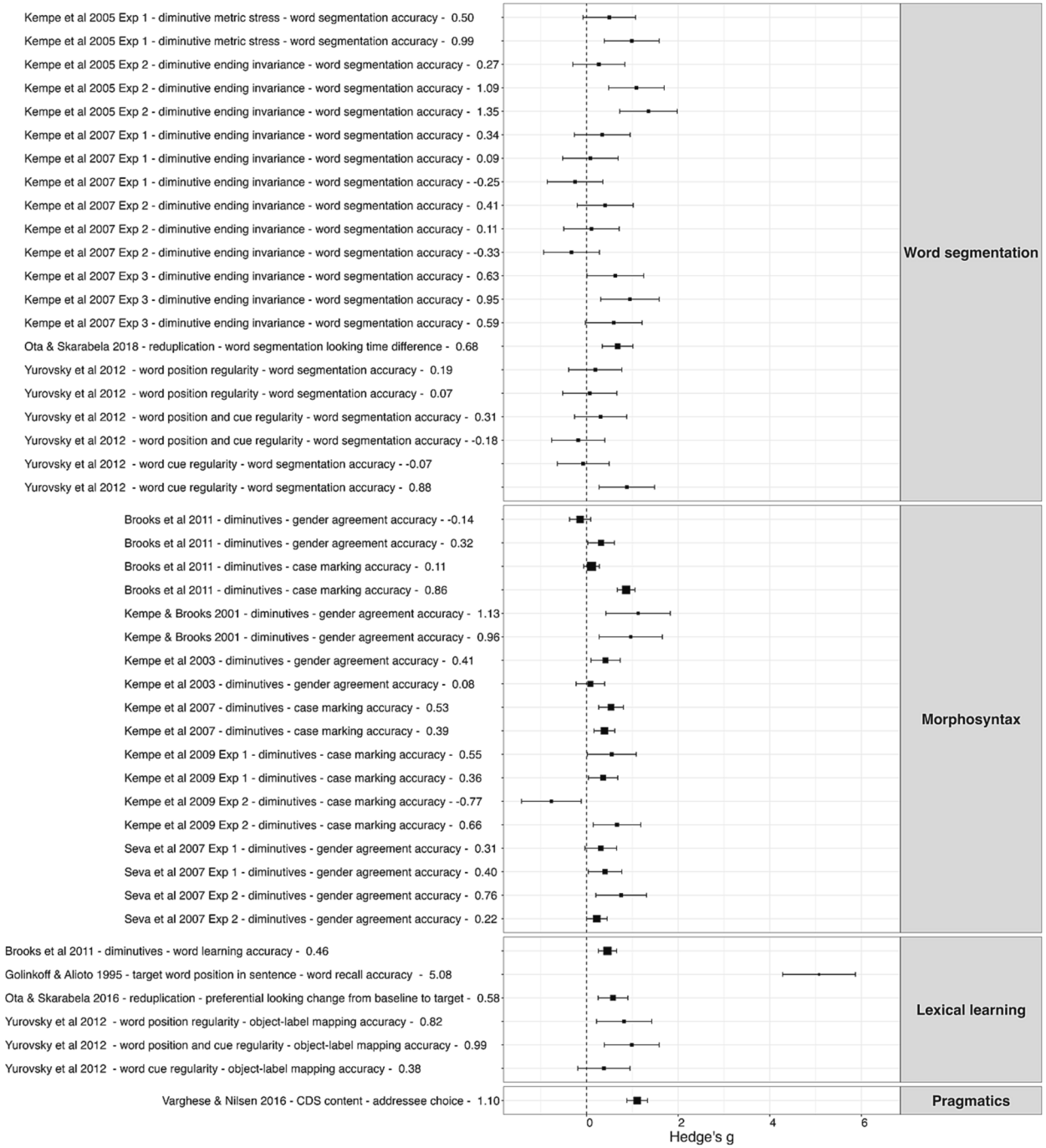

Fig. 7. Forest plot of 46 individual effect sizes (Hedge's g) from 18 experiments within the 13 studies that compared learning outcomes between CDS and ADS based on morphosyntactic and lexico-semantic input features. Point size represents precision, calculated as inverse variance. Effects are sorted by learning outcome indicated by panel labels on the right. Labels on the left denote experiment, independent variable, dependent variable, and Hedge's g.

generalise the claim that CDS facilitates learning over and above ADS to morpho-syntactic, lexico-semantic, pragmatic and extra-linguistic features and to learning outcomes other than register discrimination. In Appendix A, we list the specific CDS features and learning outcomes in this subset of 20 studies, along with the associated references.

Five of these 20 studies that went beyond prosodic, phonetic and phonological CDS features demonstrated greater learning benefits from CDS compared to ADS via computational modelling (see Appendix A for the references to these studies). Two studies (Perry et al., 2018; Rowe, 2008) compared CDS and ADS in a feature of interest but measured only a CDS-related outcome. Thus, only 13 studies directly compared learning outcomes other than register discrimination for morphosyntactic and lexico-semantic features of CDS; there are no studies comparing outcomes for pragmatic and extra-linguistic features. It seems prudent to point out that 11 of these 13 studies have been conducted in collaboration with two authors of the present study (VK and MO). This small set of studies is very heterogeneous in terms of learning outcomes (including word segmentation, morphosyntactic, lexico-semantic, and pragmatic development) and learner types (children and adults). There is also a skewed distribution of studies across sub-areas within these broader domains, such as the concentration of work on the effects of diminutives on word segmentation and morphosyntactic learning. Moreover, one study (Golinkoff & Alioto, 1995) had an effect size of interest that was more than 6 standard deviations above the mean effect size of all other relevant comparisons, presumably because the relevant comparison between sentence-final and sentence-medial position of the novel word – an effect that is often cited in the literature as evidence for how the word order of CDS benefits lexical learning – is contained in different experiments. This considerable methodological and topic-related heterogeneity suggests that *meta*-analytical summaries of this so far very sparse area of the study space will have to wait until more comparable evidence has accumulated and more specific questions can be addressed (Gasparini et al., 2022). To present a snapshot of the limited evidence on effects from CDS compared to ADS beyond prosody, phonetics and phonology, Fig. 7 provides the individual effect sizes with 95 % confidence intervals for all experiments contained within this small set of studies. Along with the results from the five computational studies these behavioural studies lend some preliminary support to the idea that certain very specific morphosyntactic and lexico-semantic features of CDS can have facilitative effects on some learning outcomes.

Finally, although this was not the primary aim of the analysis, we were interested to see how the CDS research literature fares in terms of cross-linguistic diversity. Fig. 8 demonstrates the rank frequency distribution of different languages across the entire corpus. Note that the number of times languages were included in the count does not sum up to the number of articles (942) as several articles investigated multiple languages. Not unexpectedly, English occupies the dominant position with 594 (48.6 %) study instances out of a total study language count of 1223. To ascertain whether study types differed in terms of cross-linguistic diversity we employed a binary coding of study language(s) as English vs. Not Just English. The latter category comprised studies investigating either languages other than English or English and some other language. While there was no significant difference in the distribution of study language (s) with respect to whether a CDS-ADS comparison was performed ($\chi^2 = 2.77$, df = 1, $\varphi = 0.057$, $p = 0.096$) the distribution across primary CDS domains (see Fig. 9) differed such that for the primary CDS domains of phonetics / phonology ('Phon+') and

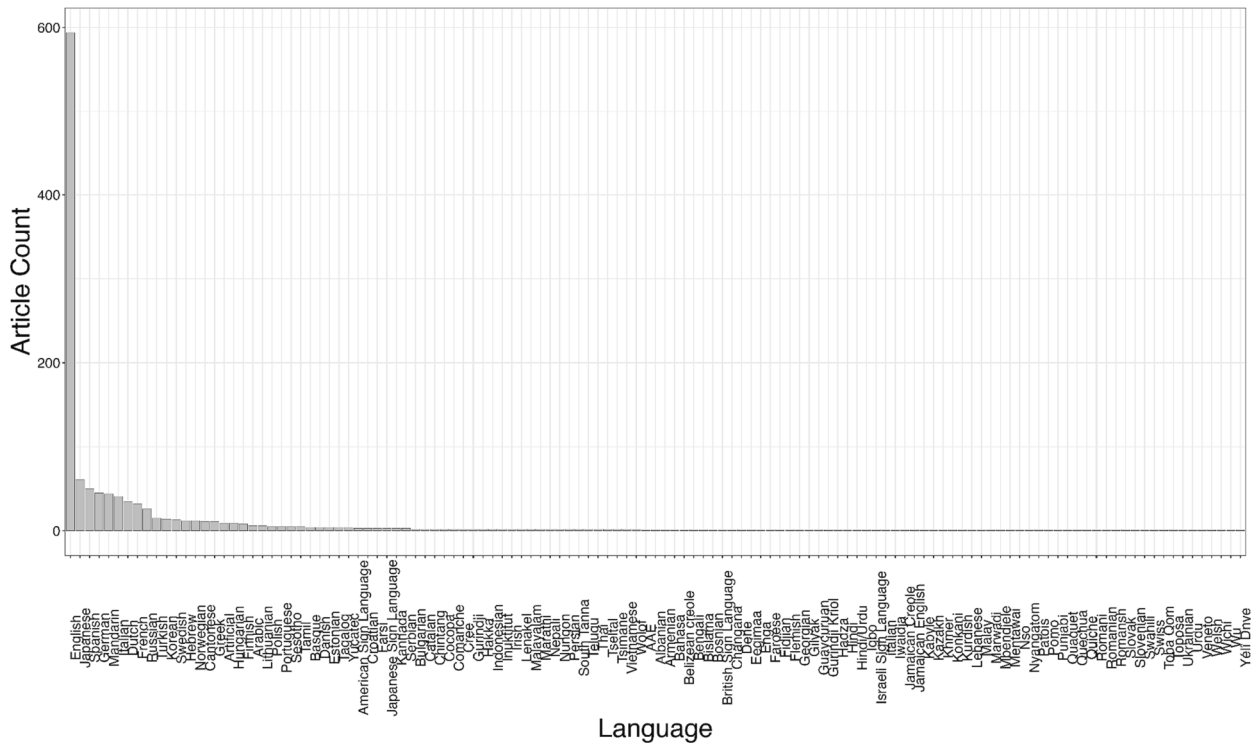

Fig. 8. Rank frequency distribution of 1223 instances of studied languages in the corpus of CDS-studies.

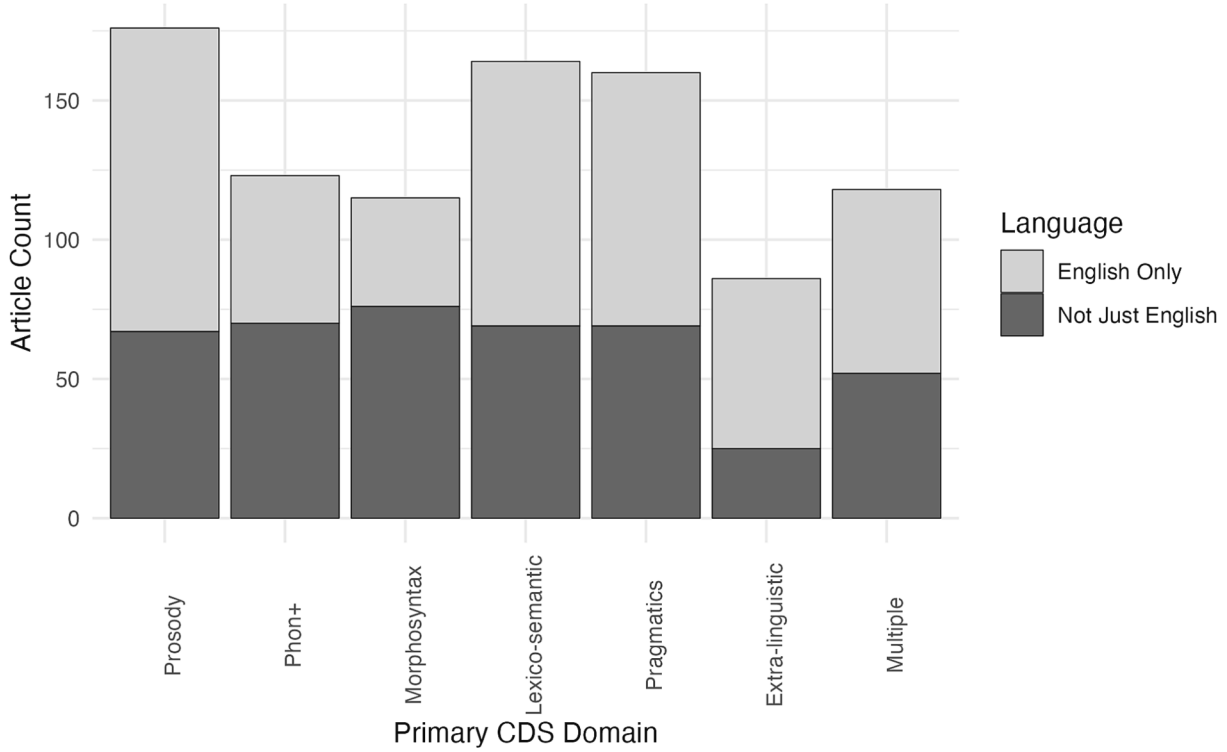

Fig. 9. Number of studies investigating just English vs. not just English for all primary CDS domains.

morphosyntax studies investigating not just English constituted the majority ($\chi^2 = 40.64$, df = 6, Cramer's V = 0.21, $p < 0.0001$), with 56.9 % and 66.1 % of studies, respectively. The latter observation is likely a reflection of the fact that the effects of CDS on morphosyntactic development are best studied in languages that have a richer morphology than English. On the other hand, studies investigating extra-linguistic aspects of child-directed communication have so far been carried out predominantly with children acquiring English.

Discussion

Our aim was to review the extant literature on CDS to evaluate whether there is sufficient evidence to generalise the claim that CDS "aids", "facilitates" or "is tailored to support" language development across different linguistic domains and learning outcomes. We argued that evidence for a facilitative effect of CDS can only come from studies that directly compare learning outcomes between CDS and ADS. We conducted a study space analysis to ascertain what proportion of studies in the field comply with this requirement and how CDS studies are distributed across different input domains, learning outcomes and learner types. We found that while there is a large and continuously growing literature that investigates CDS in various theoretical and applied contexts, the 290 studies containing a comparison between CDS and ADS only constitute a minority of 30.8 % of our corpus of CDS studies. Even more striking, only 153 of these CDS-ADS-comparison studies, i.e. 16.2 % of the entire corpus, also considered some form of learner response or learning outcome, which would be required to conclusively demonstrate a benefit from CDS. This means that obtaining evidence for whether CDS does indeed facilitate language development has so far not been a priority in this field of research, despite presentation of this claim as an established fact in the literature (e.g. Golinkoff et al., 2015, Schick et al., 2022). Instead, research efforts have been devoted to describing features of CDS (315 studies, i.e. 33.4 % of the corpus), linking CDS features to learning outcomes (337 studies, i.e. 35.8 % of the corpus) and comparing CDS features to ADS without considering learning outcomes (137 studies, i.e. 14.5 % of the corpus). Studies falling into these last three categories are often cited in support of the claim that CDS facilitates language development yet do not supply direct evidence for it. For example, in one recent review, only about a quarter of articles cited in support of facilitative effects of CDS report a comparison of learning outcomes to ADS (Schick et al., 2022).

Given the very uneven distribution of CDS-ADS comparisons across input domains and outcome measures, what, then, is known about the origin of modifications that distinguish CDS from ADS and their effect on language development across linguistic domains? With respect to input domains, i.e. CDS features of interest, CDS-ADS comparisons focussed predominantly on prosody, phonetics, and phonology. With respect to learning outcomes, CDS-ADS comparisons focussed predominantly on register discrimination (including register preference) in infants and, to a lesser extent, in adult learners and computational models. Thus, there appears to be a solid evidence base to answer questions about whether CDS can be distinguished from ADS based on its prosodic, phonetic, and phonological features and associated questions like when this capacity emerges in development. A smaller group of studies compared effects

of prosodic, phonetic, and phonological features of CDS vs. ADS on other learning outcomes, predominantly on phonological and lexical learning. In sum, studies that investigate features measurable by their acoustic properties supply the bulk of evidence on which claims about a facilitative role of CDS can be based. Yet there appears to be a dearth of studies investigating facilitative effects of CDS features in other linguistic domains, i.e. with respect to its morphosyntactic, lexico-semantic, pragmatic, and extra-linguistic features. We identified a subset of only 20 experimental and computational studies that tested whether there are learning benefits from CDS features other than its characteristic prosody, phonetics, and phonology. Our summary overview of the 13 behavioural studies within this subset that were suitable for comparison showed some facilitative effect of CDS, but these were confined to just a few very specific CDS features (i.e. diminutivisation, reduplication, distributional characteristics of frequent frames, or child- vs. adult-appropriate semantic content) in a very small set of languages. Most of these features, e.g. diminutives, reduplications, and frequent frames, serve to regularise structural aspects of language thereby supporting statistical learning. Aside from these few studies, we did not find evidence for facilitative effects of CDS with respect to other input features and learning outcomes in domains other than prosody, phonetics, and phonology.

From a methodological point of view, it is unsurprising that studies comparing a wide range of different learning outcomes between CDS and ADS across a wide range of linguistic domains are rare. Unlike register discrimination, which can be tested experimentally in the laboratory, many other learning outcomes typically studied in observational studies are delayed in time, making a manipulation of input features difficult: After all, it seems infeasible to randomly assign children to be exposed to predominantly CDS vs ADS input over a certain period of time and to compare a learning outcome of interest, e.g., morphosyntactic competence or vocabulary size, after some delay. Consequently, the 20 studies that we identified as supplying evidence for a facilitative role of CDS beyond the effect of its prosodic, phonetic, and phonological features on language development employed predominantly experimental studies of short-term learning outcomes or computational models of language learning. Despite these methodological challenges we argue that some of the gaps in this research literature can and should be filled.

The missing evidence

Gap 1: Comparisons between CDS and ADS in morphosyntactic, lexico-semantic, pragmatic and extra-linguistic features.

Traditionally, studies that link morphosyntactic, lexico-semantic, pragmatic features of CDS and extra-linguistic features of child-directed communication more broadly to learning outcomes tend to focus on an established range of input measures of morpho-syntactic and lexical richness and complexity such as mean length of utterances, type frequencies or type-token ratios. Given the centrality of these measures in language development research it is surprising that very few studies have indeed compared them to ADS. For example, for the domain of morphosyntax, we found only nine studies that compared CDS and ADS for features that on theoretical grounds are thought to be of benefit for language learning. Such features included transitional probabilities between words that arise from the syntactic structure of CDS and that elsewhere have been shown to aid word segmentation (e.g., Stärk et al., 2022) or frequency of variation sets (clusters of slightly modified repetitions that render speech more redundant) that have been argued to benefit learning across linguistic levels (e.g., Lester et al., 2022). The pivotal measure of mean length of utterance has only been compared in one study (Ko et al., 2020) which used two ADS registers for comparison, a less formal one directed at a family member and a more formal one directed at the experimenter. Interestingly, this study found that syntactic complexity was lower in CDS compared to informal but not to formal ADS, an intriguing finding suggesting that the familiarity confound plaguing many CDS-ADS comparisons (Weinstein & Baldwin, 2022) may, in fact, have led to an underestimation of differences between CDS and ADS, a suggestion that certainly needs further investigation. A few other studies have focussed on comparing overall utterance length (Kaye, 1980; Lee et al., 2008; Martin et al., 2016; Vigário et al., 2006) but often with the goal of explaining the origins of certain prosodic and phonological characteristics of CDS as a by-product of utterance-length differences. Yet aside from these few studies there is a lack of systematic comparisons between CDS and ADS in many input measures that are considered central to morphosyntactic, lexico-semantic and pragmatic development. Moreover, compared to correlational studies that merely link CDS features to outcome measures, the 20 studies that investigated learning benefits from morphosyntactic, lexico-semantic, pragmatic and extra-linguistic CDS features compared to ADS (see Fig. 7 and Appendix A) tended to focus on very specific aspects of CDS (i.e., certain morphological derivations and lexical items such as diminutives or reduplications) that are different than those typically investigated in correlational studies. There is, therefore, not only a gap in CDS-ADS comparisons for many linguistic domains but also considerable inconsistency with respect to the specific CDS features that are chosen for comparison. We suggest that efforts need to be made to obtain suitable ADS corpora that enable comparisons of CDS features across those linguistic features that have traditionally been considered important for language development like mean length of utterance, type-token ratios, variation sets etc.

Gap 2: Intervention studies testing whether there are facilitating effects of morphosyntactic, lexico-semantic, pragmatic and extra-linguistic features of CDS on language development.

We have already highlighted the methodological difficulty of manipulating certain features that distinguish CDS from ADS to investigate their differential effects on language development. The 20 studies identified in our study space analysis that fulfil these criteria use either experimental designs in the laboratory or computational modelling of learning algorithms assumed to simulate central mechanisms of human learning and, thus, do not capture the complexities of language development that can be studied under naturalistic learning conditions. This means that the evidence base for facilitatory effects of CDS on learning outcome domains other than register discrimination is not just very small but also has limited ecological validity. It is striking that we did not find any intervention studies that would attempt to manipulate input features considered beneficial for language development such as lexico-semantic richness, morphosyntactic complexity, or distributional characteristics like frequent frames (e.g., Chemla et al., 2009) and variation sets (e.g., Onnis et al., 2008) to ascertain their effect over longer periods of time in more naturalistic environments. As far as

we could ascertain, there is not a single study that has, for example, manipulated the amount of word types or the value of type-token-ratios in children's language input to investigate the effect of lexical richness even though the claim that richer input vocabulary supports lexical learning beyond infancy is widely accepted. Such intervention designs could encompass reading of carefully designed picture books that supply text varying in morphosyntactic complexity or lexico-semantic richness over periods of time or engagement in play sessions with sets of toys that allow for manipulation of word type frequencies. In the absence of such studies there is insufficient evidence that morphosyntactic and lexico-semantic features of CDS in general facilitate language development, confirming that this claim is not generalisable across linguistic input domains and learning outcomes.

One possible reason for the scarcity of intervention studies examining the learning benefits of CDS compared to ADS across various linguistic domains and outcomes relates to ethical considerations: Researchers may consider it problematic to expose children in the control conditions to prolonged input that resembles ADS by attenuating certain features hitherto considered beneficial for learning. However, the experimental and computational studies that do exist demonstrate that language learning from input that contains, or mimics ADS features is not impossible, it is, if anything, just slightly less efficient (e.g., Kempe & Brooks, 2005; Ludusan et al., 2016). Researchers may therefore carefully weigh up the potential knowledge gain against the small price of a mildly suboptimal transient intervention.

Where does this leave theories of CDS?

The uneven distribution of research efforts discovered in our study space analysis calls for a revision of the generality of claims about the facilitative effect of CDS on language development. While comparisons of specific learning outcomes like register discrimination based on prosodic, phonetic and phonological features of CDS and ADS are numerous enough so as to permit integration of the evidence (for a *meta*-analytical summary see Dunst et al., [2012]) and this integration confirms facilitative effects of CDS, there is at present little research that would permit conclusions about whether such effects of CDS exist for other domains and learning outcomes. The small set of 20 studies that focus on very specific effects of CDS features like diminutives, reduplications, and frequent frames (see Fig. 7) constitutes an exception in this respect. Even though this small subset of studies demonstrates some facilitative effects of CDS as our overview of effect sizes suggests, the tested features are too limited and specific to permit wider generalisations at this stage. We therefore urge caution with respect to the generality of the claim that CDS serves to facilitate language development given the dearth of evidence across input domains and outcome measures and invite the field to expand research into the study spaces that to date have not received an equal amount of attention. It is important to recognise that not all gaps identified in a study space analysis merit such attention. Certain combinations of input features and outcome domains are simply not theoretically plausible - for example, it may not be reasonable to assume that the characteristic morphosyntactic or lexico-semantic features of CDS benefit prosodic or phonological development. But we suspect that many of the gaps identified in our study space analysis, especially those that pertain to the lack of CDS-ADS comparisons, are probably more a reflection of the popularity of certain research topics rather than the result of considered theoretical reasoning.

To the extent that different mechanisms may govern production of CDS by caregivers and children's language development in different linguistic domains, the distribution of facilitative effects of CDS across domains and outcomes has theoretical and applied implications. A very tentative conclusion from the distribution of evidence found in this study space analysis is that so far facilitative effects of CDS have to a large extent (but not exclusively) been studied for features that tend to be by-products of increased positive affect and reduced threat expression. For example, heightened pitch and exaggerated pitch range associated with positive affect can attract infant attention. Similarly, frequent use of forms of endearment like diminutives (e.g. Kempe et al., 2003) can benefit morphological development by regularising distributional characteristics that support extraction of structure via statistical learning. Finally, modification of formant structure through raising of the larynx, which extends the vowel space (Kalashnikova et al., 2017), can benefit phonological learning. However, we argue that it would be premature to generalise from this to facilitative effects in other domains, and that undue generalisation can potentially lead to flawed applied recommendations. To illustrate, evidence that expanded vowel space in CDS because of a raised larynx can benefit phonological development (e.g. Liu et al., 2003) does not warrant advising caregivers to aim for morphosyntactic simplifications or lexical adjustments in their CDS without explicitly testing whether these other modifications also incur facilitative effects. This is because to date it is not clear about whether other features of CDS (e.g. increased or reduced syntactic complexity and lexical diversity, depending on age of the child) accelerate morphosyntactic, lexical or pragmatic development compared to ADS. At present not knowing the full distribution of facilitative effects of CDS across domains and outcomes should constrain theories of language development but also practical recommendations and interventions.

Not only is the jury still out on how generalisable claims about facilitative effects of CDS will turn out to be once some of the research gaps are filled but it is also problematic that the study of CDS has been confined to a restricted set of languages. While it was encouraging to discover that a total of 121 languages had been studied in the CDS literature it is still the case that 80 % of study instances focussed on English, Japanese, Spanish, German, Mandarin, Italian, Dutch, French, Russian, Turkish, Korean, Swedish, and Hebrew – all languages acquired by children growing up in relatively wealthy industrialised countries. This bias, which echoes the sampling bias in the language development literature in general (Kidd & Garcia, 2022), masks the considerable cross-cultural variation in exposure to CDS that has been highlighted in recent studies conducted in non-industrialised small-scale societies (e.g., Casillas et al., 2021; 2020). A corollary of this narrow cross-linguistic focus is that we know very little about cross-cultural variation in morpho-syntactic, lexico-semantic, pragmatic, and extra-linguistic modifications that caregivers employ when addressing children, as these are the domains for which comparisons between CDS and ADS are generally rare. Moreover, given evidence for potential links between frequency and intensity of certain CDS features and parenting attitudes (Johnston & Wong, 2002; Rowe, 2008) it may be safer to assume that prevalence and specific manifestation of many CDS features are culture-specific and that CDS is, in fact, itself a learned and

culturally transmitted trait. Acknowledging that CDS is itself learned aligns well with the sociolinguistic insight that using registers in a context-specific manner and shifting speaking styles in a conventionalised fashion is an important means of adhering to socio-cultural norms. Speakers are generally very sensitive to the social indexing of subtle variation, down to fine-phonetic detail (e.g., Eckert & Labov, 2017; Calder & King, 2022) and learn to adopt the relevant variables rapidly to comply with expectations in their speech community. In societies that are abundant with model speakers (i.e. other caregivers employing CDS) speakers will learn what is normative and typical in child-directed communication and can align their speech in the presence of children with these cultural expectations.

How compatible is the notion of CDS as a culturally transmitted trait with the frequently expressed idea that its ultimate adaptive function is to facilitate language development? Given the documented cross-cultural variation in prevalence it would at present be premature to declare CDS a human universal, especially since there appears to be no obvious phylogenetic antecedent (Schick et al., 2022). However, as has been argued in the context of Attachment Theory, adaptive value of a behaviour does not imply universality (Vicedo, 2017). Consequently, as many CDS features appear not to be universal, what requires explanation is why features that can be beneficial for language development emerge in some cultural contexts but not others. A possible explanation is that aside from positive affect expression (including threat minimisation) and speech accommodation as mechanisms of CDS generation some socio-cultural contexts may favour another proximate mechanism, namely, deploying CDS as a tool for teaching language. The concept of teaching here implies a set of behaviours that serve pedagogical and didactic functions but may or may not be produced intentionally (see Kline [2015] for a thorough review of diverse conceptualisations of teaching). Just like teaching itself is best explained not as a universal human adaptation but a cognitive gadget that capitalises on human capacities such as domain-general cognition and mindreading (Brandl et al., 2023; Heyes, 2018) and is adaptive in certain socio-cultural contexts but not others (Gurven et al., 2020) it is plausible that using CDS to facilitate language development is also a culturally transmitted cognitive gadget – one that capitalises on the human capacities for affect expression and speech accommodation. In certain socio-cultural contexts, especially those that promote distal dyadic interactions during child rearing (Keller, 2018), vocal and linguistics features that arise from affect expression and speech accommodation may be consolidated and conventionalised if they have didactic utility (i.e. simplify the task of language learning), subject to language- and culture-specific constraints and affordances. We hypothesise that didactic utility of CDS features is especially adaptive in meritocratic post-industrial societies where verbal skill may be perceived as linked to educational attainment (Aucejo & James, 2016) and, by extension, economic prosperity (Bowles et al., 2001). In such socio-cultural contexts, language-specific manifestations of CDS with didactic utility may accumulate and crystallise in conventionalised templates of CDS that are learned by speakers of a community. Deploying such conventionalised ways of speaking minimises the cognitive effort involved in adapting child-directed language for didactic purpose on the fly. An example is the use of diminutives and reduplications which across languages are often used to express positive affective states like endearment, intimacy, and affection (Ponsonnet, 2018; Kentner et al., 2022). In languages where there are few constraints on the morphological productivity of these derivations, frequent use of diminutives and reduplications may be conventionalised in CDS given that it can facilitate children's word segmentation and learning of morphosyntax, as has been confirmed in several experiments (see Fig. 7). Future research into cross-linguistic differences and diachronic changes in CDS should aim to identify the link between socio-cultural contexts and the range of CDS features with potential didactic utility and employ rigorous tests of their facilitative effects on language development. In addition to cross-cultural studies this could also include the study of historical data on CDS contained in archival records to examine whether contemporary CDS features were in evidence during previous, less meritocratic or child-centric historical periods, and then to test experimentally whether such historical variation in CDS makes a difference to language development outcomes.

Limitations

To minimise confirmation bias we adopted a very broad set of search criteria to unearth the corpus of studies on CDS as comprehensively as possible. We included many studies that investigated the role of CDS in various applied and clinical settings and in neurodiverse populations. These kinds of studies are not typically taken into consideration in literature reviews of mainstream language development research even though they are relevant to our understanding of CDS. We thought it justified to cast a wide net beyond the more narrowly defined language development literature to make sure we captured the full landscape of extant research. Still, these broad inclusion criteria may have led us to underestimate the proportion of studies that can be considered relevant to the claim that CDS facilitated language development. However, our broad inclusion criteria should not have affected the distribution of studies across study variables, which lends confidence to our identification of gaps in this literature.

During the writing of this article we learned about the advent of literature-based discovery systems, which use automated tools to identify gaps in the literature and find research fields that would be expected to be linked but are not (Peng et al., 2017). Such systems can in future take study space analyses to a new level. However, until the use of AI-driven systems of this kind spreads from the biomedical to the social sciences there is no available tool yet that would allow researchers to categorise studies of language development according to a predetermined set of criteria other than the keywords provided by study authors in various databases. However, extracting *meta*-data for study categorisation by human experts is fraught with some ambiguity as encountered in this project. For example, it is sometimes not easy to determine whether some computational model merely serves to describe properties of CDS vs ADS (e.g., whether a network analysis as in Cox et al., [2023b] is a description of qualitative differences in semantic network structure) or whether it constitutes a proxy for some learning mechanism (e.g., a model for lexical growth). Because our corpus of studies was sizable, we lacked the human capacity to have multiple coders scan and categorise all 942 studies and then implement a consensus-seeking procedure. We therefore opted to establish coding reliability for a subset of studies only. Still, the substantial, and for some variables, almost perfect inter-coder reliability gives hope that this study space analysis constitutes an informative survey that will

inspire the field to consider some reallocation of research efforts.

Conclusion

This study space analysis of the extant literature on CDS revealed significant gaps in research efforts that invite caution with respect to the generality of the claim that CDS facilitates language development: Less than a fifth of the entire literature is devoted to comparing learning outcomes between CDS and ADS and these comparisons tend to focus on prosodic, phonetic, and phonological features of CDS. As a result, much less is known about how CDS differs from ADS in more complex structural domains like its morphosyntactic, lexico-semantic, pragmatic, and extra-linguistic features. With respect to learning outcomes, most efforts have been devoted to the study of register discrimination, i.e. whether infants recognise and prefer CDS, while CDS benefits for other learning outcomes have been investigated much more sporadically. Given these limitations of the existing evidence base we suggest that research efforts be extended to fill existing gaps in the study space. Future insights into the generalisability of facilitative effects of CDS across the breadth of input features and outcome measures will foster a more nuanced understanding of the mechanisms that underpin child-directed communication and its role in language development.

CRediT authorship contribution statement

Vera Kempe: Conceptualization, Data curation, Writing – original draft, Visualization, Methodology. **Mitsuhiko Ota:** Data curation, Writing – review & editing, Validation, Methodology. **Sonja Schaeffler:** Data curation, Writing – review & editing, Validation, Methodology.

Declaration of Competing Interest

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

Data availability

A link to the Open Science Framework data repository is in the manuscript.

Appendix A:. References and study features of the 20 studies comparing learning outcomes between CDS and ADS for morphosyntactic, lexico-semantic, pragmatic and extra-linguistic features of CDS. *These studies contained a CDS-ADS comparison but measured a learning outcome only for CDS. **Despite the mention of prosody in the title this study also varied lexico-semantic cues.) ***This study was included as an article ahead of print and is now referenced with a 2023 publication date

Article Reference	Primary CDS Domain	Specific Input Feature	Learner type	Learner Response Domain
*Perry, L. K., Perlman, M., Winter, B., Massaro, D. W., & Lupyan, G. (2018). Iconicity in the speech of children and adults. *Developmental Science, 21*(3), e12572.	lexico-semantic	frequency of iconic words	children	lexical learning
***Cox, C. R., & Haebig, E. (2023). Child-oriented word associations improve models of early word learning. *Behavior Research Methods, 55*(1), 16–37.	lexico-semantic	word associations	model	lexical learning
Kodner, J. (2019). Estimating child linguistic experience from historical corpora. *Glossa: A Journal of General Linguistics, 4*(1), 122, 1–14.	morpho-syntax	past-tense inflection	model	morpho-syntax
Ota, M., & Skarabela, B. (2016). Reduplicated words are easier to learn. *Language Learning and Development, 12*(4), 380–397.	lexico-semantic	reduplication vs. non-reduplication	children	lexical learning
Ota, M., & Skarabela, B. (2018). Reduplication facilitates early word segmentation. *Journal of Child Language, 45*(1), 204–218.	lexico-semantic	reduplication vs. non-reduplication	children	word segmentation
*Rowe, M. L. (2008). Child-directed speech: Relation to socioeconomic status, knowledge of child development and child vocabulary skill. *Journal of Child Language, 35*(1), 185–205.	lexico-semantic	lexical diversity	children	lexical learning
**Varghese, A. L., & Nilsen, E. S. (2016). Guess who? Children use prosody to infer intended listeners. *British Journal of Developmental Psychology, 34*(2),	lexico-semantic	lexical content	children	pragmatics

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Article Reference	Primary CDS Domain	Specific Input Feature	Learner type	Learner Response Domain
306–312.				
Batchelder, E. O. (2002). Bootstrapping the lexicon: A computational model of infant speech segmentation. *Cognition, 83*(2), 167–206.	lexico-semantic	word distributions	model	word segmentation
You, G., Bickel, B., Daum, M. M., & Stoll, S. (2021). Child-directed speech is optimized for syntax-free semantic inference. *Scientific Reports, 11*(1), 16527.	morpho-syntax	word co-occurrences, word class	model	lexical learning
Grimm, R., Cassani, G., Gillis, S., & Daelemans, W. (2017). Facilitatory effects of multi-word units in lexical processing and word learning: A computational investigation. *Frontiers in Psychology, 8*, 555.	morpho-syntax	multi-word units	model	lexical learning
Golinkoff, R. M., & Alioto, A. (1995). Infant-directed speech facilitates lexical learning in adults hearing Chinese: Implications for language acquisition. *Journal of Child Language, 22*(3), 703–726.	morpho-syntax	word order	adults	lexical learning
Brooks, P. J., Kempe, V., & Donachie, A. (2011). Second language learning benefits from similarity in word endings: Evidence from Russian. *Language Learning, 61*(4), 1142–1172.	morpho-syntax	diminutives vs. simplex	adults	morpho-syntax
Kempe, V., Ševa, N., Brooks, P. J., Mironova, N., Pershukova, A., & Fedorova, O. (2009). Elicited production of case-marking in Russian and Serbian children: Are diminutive nouns easier to inflect? *First Language, 29*(2), 147–165.	morpho-syntax	diminutives vs. simplex	children	morpho-syntax
Kempe, V., Brooks, P. J., Mironova, N., Pershukova, A., & Fedorova, O. (2007). Playing with word endings: Morphological variation in the learning of Russian noun inflections. *British Journal of Developmental Psychology, 25*(1), 55–77.	morpho-syntax	diminutives vs. simplex	children	morpho-syntax
Ševa, N., Kempe, V., Brooks, P. J., Mironova, N., Pershukova, A. & Fedorova, O. (2007). Cross-linguistic evidence for the diminutive advantage: Gender agreement in Russian and Serbian children. *Journal of Child Language, 34*, 111–131.	morpho-syntax	diminutives vs. simplex	children	morpho-syntax
Kempe, V., Brooks, P. J., Mironova, N., & Fedorova, O. (2003). Diminutivization supports gender acquisition in Russian children. *Journal of Child Language, 30*(2), 471–485.	morpho-syntax	diminutives vs. simplex	children	morpho-syntax
Kempe, V., & Brooks, P. J. (2005). The role of diminutives in the acquisition of Russian gender: Can elements of child-directed speech aid in learning morphology? *Language Learning, 55*(S1), 139–176.	morpho-syntax	diminutives vs. simplex	adults	morpho-syntax
Yurovsky, D., Yu, C., & Smith, L. B. (2012). Statistical speech segmentation and word learning in parallel: Scaffolding from child-directed speech. *Frontiers in Psychology, 3*, 374.	morpho-syntax	frequent frames	adults	word segmentation
Kempe, V., Brooks, P. J., Gillis, S., & Samson, G. (2007). Diminutives facilitate word segmentation in natural speech: Cross-linguistic evidence. *Memory & Cognition, 35,* 762–773.	morpho-syntax	diminutives vs. simplex	adults	word segmentation
Kempe, V., Brooks, P. J., & Gillis, S. (2005). Diminutives in child-directed speech supplement metric with distributional word segmentation cues. *Psychonomic Bulletin & Review, 12*, 145–151.	morpho-syntax	diminutives vs. simplex	adults	word segmentation

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