Parental Speech to Typical and Atypical Populations: A Study on Linguistic Partial
Repetition

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Abstract

Parents often use partial self-repetitions with variation in successive utterances (e.g., *Want to get your ball? Get your ball? Do you want to get your ball?*). Such 'variation sets' contain latent distributional information about the building blocks of language and are predictive of children's lexical and grammatical structures. Because these properties in parents of atypically developing children are virtually unknown, we compared for the first time variation sets in parental speech directed to toddlers with Autistic Spectrum Disorders (ASD), Down Syndrome (DS), and a baseline group of Typically Developing toddlers (TD). In Study 1, we analyzed transcripts of mothers' child-directed utterances during naturalistic dyadic play interactions. While children's mean developmental age was the same across the three groups, we found that measures of partial repetitions in child-directed speech were larger in the ASD than in the DS and typical groups. In Study 2 we also found that these larger measures in the ASD group were mainly driven by the mother, as opposed to the father. Because partial repetitions decrease with chronological age of the child in typical groups, and the atypical children were older than the TD group, our findings suggest compensating modes of communication in parental speech to atypical populations, especially the ASD group. The study validates the extension of structural/statistical analyses of language to compare parental communication to typical and atypical populations.

Keywords: atypical development; child-directed speech; corpus analyses; language development; statistical learning; variation sets

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Introduction

Caregiver language is a key determinant of children's language acquisition and is crucial for the development of other cognitive and socioemotional skills in children (Garton, 1995; Hampson & Nelson, 1993; Longobardi, 1992; Stern, 1985; Tamis-LeMonda, Bornstein, & Baumwell, 2001; Thiessen, Hill, & Saffran, 2005). For these reasons, parental language directed to typically developing (TD) children has long been a subject of close scrutiny (Cameron-Faulkner, Lieven, & Tomasello, 2003; McDonald & Pien, 1982; Olsen-Fulero, 1982; Snow, 1984, 1995). Maternal language directed to developmentally delayed children has been the subject of far less attention (cf. Longobardi, Caseeli, & Colombini, 1998; Spiker, Boyce, & Boyce, 2002), and only in a few instances has research been focused on comparing different developmental disabilities (see for example Venuti, de Falco, Esposito, Zaninelli, & Bornstein, 2012). Venuti and colleagues (2012) compared the functional features of maternal speech directed to three groups of Italian-speaking children of the same developmental age, namely children with autism spectrum disorder, children with Down syndrome, and typically developing children, also investigating associations between maternal functional speech and child language in each group. The results highlighted similarities in maternal functional language directed to the two groups of children with contrasting developmental disabilities compared to that directed to TD children. Specifically, mothers of children with developmental disabilities, compared to mothers of normally developing children, showed a specific style in their verbal interaction, asking fewer questions and making fewer references to the environment but using more direct statements and references to their children's actions (McDonald & Pien, 1982; Olsen-Fulero, 1982). Moreover, a few characteristics emerged that specifically differentiated maternal speech in the two atypical conditions compared to TD: the tendency to use more affect-salient speech by mothers of children with DS, and the enhanced use of child name and of reference to themselves by mothers of children with

ASD.

While Venuti et al. (2012)’s study focused on a functional linguistic analysis of parental speech, here we are interested in conducting a complementary structural linguistic analysis on their dataset. This analysis could enrich the interpretation of their initial findings and further shed light on the features that distinguish parental speech to typical and atypically developing children. The specific ways in which parental input affects the development of language are yet to be fully understood, in particular in terms of a computationally explicit and psychologically plausible theory of language acquisition (Kolodny, Lotem, & Edelman, 2015a; Waterfall, Sandbank, Onnis, & Edelman, 2010). Previous work began to assess the amount and structural properties of language input that infants receive in their first years of life. Building on computational analyses of samples of child-directed speech, we focus on certain statistically prominent structural properties of child-directed speech, namely partial repetitions, that may facilitate language acquisition. To our knowledge, no study has specifically investigated measures of partial repetition in relation to atypically developing populations.

Partial repetitions in child-directed speech

Parents spontaneously speak in clusters of lexically overlapping utterances which contain partial self-repetitions (e.g., *Want to get your ball? Get your ball? Do you want to get your ball?*). Importantly, such “variation sets” in speech contain latent cross-utterance statistical cues to the building blocks of language (words, lexical categories such as nouns and verbs, syntactic constructions, word order relations). In line with previous work (Brodsky, Waterfall, & Shimon, 2007; Kolodny et al., 2015a; Onnis, Waterfall, & Edelman, 2008), a variation sets is defined as a cluster of caregiver utterances occurring within a conversational turn that share some (but not all) lexical items and structures, as in the example of a mother talking to her child aged 1;2, pushing dolls in a stroller:

Yougottopushthentoschool.

Pushthem.

Pushthemtoschool.

Takethemtoschool.

Yougottotakethemtoschool.

These adjacent utterances in caregiver input exhibit some of the properties that could be used by the processes of language structure induction outlined by Harris (1954) – namely, the *alignment* of repeated parts of the utterances, which in turn may facilitate the *comparison* of those utterances. For example, looking at the example above in detail, simply aligning and comparing the first with the second utterance would yield two candidate phrases (*pushthem*, and *toschool*). Further linguistic units may become self-evident by this simple process of alignment and comparison of word sequences repeated iteratively across adjacent utterances. Aligning and comparing the second and third utterance yields two new lexical unit candidates (*push*, *take*, and *them*). At the end of the five utterances, as many as four phrase constituents (e.g. you got to; push them, take them, to school) may become self-evident to the learning child.

While initially the building blocks (words, frequent word combinations, and phrases) in the first utterance would appear indistinguishable to a naive language learner, by the fifth utterance grouping and differentiation will have occurred. Note that this process can happen recursively to detect grouping within groupings. For example, while *pushthem* appears as a grouping in the first and second utterances, a further sub-grouping is hinted at in the third utterance, with the possibility of inferring an abstract grammatical category of Verb by forming an equivalence class [*push/take*] *them*. Thus, alignment and comparison potentially afford the discovery not only of sequential relations between words, but also of properties of words belonging to the same word categories.

Variation sets similar to those exemplified above in language acquisition — clusters of overlapping utterances in speech addressed to very young children — are the focus of our study. Theorists seeking to understand language learning propose that child-directed variation sets provide robust cues that serve to highlight the structural

regularities of language. In particular, from phrases to morphemes, language learning can proceed by cross-utterance alignment and comparison (Edelman & Waterfall, 2007; Harris, 1954), which signal that the candidate groupings are not occurring by chance, even when infrequent (Goldsmith, 2001; Harris, 1991). Converging evidence from three different methods has corroborated this hypothesis. First, variation sets are prevalent in child-directed speech in all languages that have been analysed for this purpose (Hoff-Ginsberg, 1990; Küntay & Slobin, 1996). Further, in longitudinal studies of parent-child interactions, caregivers' earlier variation of certain syntactic structures in variation sets (e.g., syntactic subjects and direct objects) correlated with earlier child production of those structures (Küntay & Slobin, 1996; Waterfall, 2006). These findings suggest that variation sets not only contribute to the acquisition of specific lexical items, but may also facilitate the acquisition of lexical classes as well as larger syntactic structures (Waterfall et al., 2010).

Second, Onnis et al. (2008) investigated the role of variation sets in acquisition by manipulating their distribution in experiments with miniature artificial languages with adults. They found that participants experiencing more variation sets during training were better able at recognising new words in unsegmented speech, compared to a control group exposed to the same stimuli but where these were pseudo-randomized not to occur in variation sets. Their results were recently extended to tasks involving the discovery of different linguistic units, ranging from phrase structure, to form-meaning pairings, and non-adjacent dependencies, and thus suggesting that tracking statistical structure proceeds in an incremental way and is strongly mediated by the presence of variation sets (Onnis & Edelman, 2019). Recently, the use of variation sets in artificial languages was also shown to lead to better word learning in two-year-olds (Schwab & Lew-Williams, 2016), suggesting that similar learning mechanisms sensitive to variation sets operate across the lifespan.

A third line of evidence for the effectiveness of variation sets in learning language comes from computational modelling applied to the results of the observational and artificial language studies above. Three progressively more psychologically plausible

unsupervised computer algorithms (ADIOS, Solan, Horn, Ruppin, and Edelman 2005; ConText, Waterfall et al. 2010; U-MILA, Kolodny, Lotem, and Edelman 2015b) can bootstrap from completely unsegmented large-scale raw data to words and to phrase structure by recursively identifying candidate constructions in patterns of partial alignment between utterances in the training corpus. Thus, alignment and comparison – the two key computational operations highlighted here – can be used to simulate language learning from realistic samples. Importantly, variation sets are prevalent in child-directed speech in all languages that have been analyzed for this purpose. The amount and quality of variation sets is predictive of children’s lexical and grammatical structures, and may be especially useful to infants and toddlers, who possess limited attentional and memory capacities.

The present study

The purpose of the present paper was to compare maternal and paternal spontaneous use of variation sets in language directed to children with two developmental disabilities – autism spectrum disorder (ASD) and Down syndrome (DS) matched to a third group of typically developing children (henceforth TD). We carried out a secondary analysis on the data of Venuti et al. (2012) of parent-child spontaneous conversations in Italian. The research question was whether parental variation differed significantly across the three groups (Study 1) and between mothers and fathers of ASD children (Study 2). Specifically, in Study 1 we considered three possible outcomes for maternal speech, leading to different interpretations of parental behavior. It is important to note from the outset that our three groups were matched for developmental age, but the atypical groups were older in chronological age by at least one year (for details we refer to the primary data described in Venuti et al., 2012). If parents of the atypical group tallied their speech perceiving the developmental age of their child, we would expect them to produce similar amounts of variation sets, leading to no significant differences across the three groups. We labelled this the *developmental age* hypothesis.

The second possibility was that parents of atypically developing children produced *fewer* variation sets compared to the typical group. This would be consistent with previous findings (Waterfall, 2006) that parents produce fewer variation sets as their child grows older, because speech and communication become more information salient, and lexico-syntactic material richer. Information-salient speech is used to share information about the dyad and the environment and to encourage exploration through fully propositional speech that includes questions, descriptions, and directives (Bornstein et al., 1992; Penman, Cross, Milgrom-Friedman, & Meares, 1983). Variation sets are likely negatively correlated with complexity of information-salient language, which increases with the age of the child. This outcome would be consistent with an interpretation that parents of atypically developing children perceive their children to be matched with their chronological cohort of typically developing children and adapt their speech accordingly. Thus, we labeled this the *chronological age* hypothesis.

The third possibility was that variation sets are more frequent in speech to atypical groups. This would be consistent with a *compensating* hypothesis that parents of atypical children perceive the communicative task as particularly difficult for their child, and perhaps attempt to make up for such difficulty by providing highly repetitive language.

While Study 1 focused on analyses of mother-child interaction, the corpus we had at hand also contained transcripts from 13 fathers in the ASD group interacting in an equivalent situation with their child but in a separate session. This allowed us in Study 2 to test whether mothers and fathers use variation sets differently when communicating to their child. Data on mother versus father child-directed language is lacking in typically developing populations, and even less in atypical groups, and this limits our ability to understand how parental language affects development in detail. One possibility is that mothers and fathers exhibit complementary behaviors when interacting with their children (Rowe, Leech, & Cabrera, 2017; Schwab, Rowe, Cabrera, & Lew-Williams, 2018), with fathers engaging in more complex and information-salient language. As such, we predicted that fathers would produce fewer partial repetitions

compared to mothers of the same child.

Study 1

Method

Participants. Participants were 84 mothers and their children with ASD ($n = 27$), TD ($n = 44$), or DS ($n = 27$). Children's mean developmental age was 24.60 months ($SD = 8.31$) and did not differ across the 3 groups, whereas mean chronological ages of groups differed. The participants' recordings came from the study of Venuti et al. (2012) at the XXX in the University of YYY, which is a clinical University center serving individuals with developmental disabilities. The collection of parent-child interaction for this study was found exempt as deemed of low risk. Parents had signed a consent form authorizing the use of the video recording data for research purposes. Mean maternal age was 35.95 years ($SD = 4.93$) and did not differ across the three groups. Mothers in all groups were ethnically homogeneous of European (Italian) heritage and married. Mothers of children diagnosed with DS and ASD were referred to the project by clinicians at two intervention centers, and mothers of TD children were recruited from daycares. Based on clinical judgment, children with DS who also presented Autistic traits were excluded from the study. The clinical diagnosis of participants with ASD was confirmed by an independent clinician based on the DSM-5 criteria for Autism Spectrum Disorder as well as through the Autism Diagnostic Observation Schedule (ADOS – Lord, Rutter, DiLavore, Risi, 2003). Children in the clinical groups did not show co-morbidity with other psychiatric disorders. The Bayley Scales of Infant and Toddler Development (2nd ed., Bayley, 1993) was used to determine the developmental ages of children with ASD and DS.

No Bayley data were available for TD children, but interviews with parents, examination of health records, and observations during the study all indicated that they were developing typically. We also had two other converging kinds of data on children in the TD sample: (a) data on the Vineland Assessment of Behavioral Adaptation, and children in this group fell within the normal range ($M = 102.7$, $SD = 11.66$), and (b)

children in the TD sample were part of a longitudinal study, and IQ measures at 48 months obtained using the WPPSI showed that TD children had IQs in the normal range ($M = 101.8$, $SD = 6.70$).

Procedure. The corpus we analyzed comprised mothers' child-directed speech recorded during an observation of naturalistic joint play interaction. The original data were collected during 10-min sessions video recorded continuously by a female researcher. Observations took place in a quiet room, which was familiar to the participants. A standard set of toys was provided. The mother was asked to play individually with her child in ways she typically would and to disregard the recorder's presence as much as possible. Mothers and children could use any or all of the toys provided. From the 84 videos of mother-child interaction, verbatim transcripts were made of maternal and child language. Transcripts were then compared with the videorecords by a second transcriber, and any necessary corrections were made (see Johnson-Glenberg & Chapman, 2004). For the analyses in Study 1, we extracted and analysed the maternal child-directed portion of the transcripts.

Measures of variation sets. Brodsky et al. (2007) defined a variation set as two or more contiguous utterances produced by a single speaker in a conversation, such that each successive pair of utterances contains lexical overlap of at least one element (excluding a few highly frequent interjections, words, and clitics: *ah*, *eh*, *oh*, *uh*, *be*, *mm*, *mh*, *amm*, *aia*, *ahi*, *ehi*, *ohi*, *ops*, *mah*, *hop*, *sss*, *eheh*, *ahah*, *a*, *e*, *il*, *lo*, *l'*, *la*, *le*, *no*, *si*, *un*, *ci*, *xxx* – the latter representing unidentified words). Here we use an extended definition, which allows to quantify repetitions of lexical items across intervening utterances (or 'gaps').

We identified all the variation sets in maternal speech in our transcripts and computed four indexes, previously used in a corpus of child-directed speech by Brodsky et al. (2007) and Waterfall et al. (2010): (1) the proportion of utterances in variation sets; (2) the proportion of unique words in variation sets; (3) the diameter of variation sets, quantified in terms of normalized Levenstein edit distance (Ristad & Yianilos, 1998); and (4) the mean length (in number of utterances) of variation sets.

These four measures considered together provide an all-round quantitative profile of repetition with variation in our sample of child-directed language. The proportion of utterances in variation sets is indicative of the general propensity of a parent to use repetition with variation during dyadic communication (this propensity doesn't need to be a conscious effort on the parent). The proportion of word types in variation sets indicates the degree of lexical richness used in variation sets. Generally, a higher proportion indicates that repetition patterns are not merely repetitive but they are used to engage in a variety of linguistic items.

The diameter of variation sets is calculated as mean edit distance between its sentences and is defined as the number of elementary edit operations (insertion, deletion or substitution of individual words) needed to transform one sentence into the other. Brodsky et al. (2007) found that the Levenstein edit distance was significantly smaller for utterances in variation sets than for adjacent utterances not in variation sets. To allow comparison of edit distance across sentences of different lengths, we normalized it by dividing the raw edit distance by the length of the longest of the two sequences, which brings it into the range between 0 and 1. The diameter of variation sets is a useful measure as it indicates whether the trade-off between repetition and variation in a given parent is tipped more toward the former or the latter. Low values of diameter (low edit distance) indicate more repetition than variation of adjacent utterances, while high values of diameter indicate more variation than repetition in adjacent utterances.

Finally, the search for variation sets was controlled by two parameters: (1) the maximum allowed gap between successive utterances with partial lexical overlap, which ranged from 0 (no intervening lexically unrelated utterance) to 2 (at most two intervening lexically unrelated utterances); and (2) the number of lexical items (i.e., the length of the n-gram) shared by the pair of utterances under consideration, which ranged from 1 (a single shared word) to 6 (six words in the same order but possibly with intervening unrelated words).

Results

Figure 1 presents — across the three groups of interest — descriptive statistics of the four indexes of variation sets – the proportion of utterances in variation sets; the proportion of word types in variation sets; the Levenstein edit distance statistics for utterances in variation sets; and the average length of variation sets. Mean values are broken down for values of gap = 0, 1, 2 and values of n-gram $1 \leq n \leq 4$. All analyses were carried out in the R programming language and environment (R Core Team, 2019). We first analyzed each measure of variation set as a dependent variable to find the best distribution fitting the data using the *fitdistrplus* library in R. We then modeled each principal statistics of variation sets using generalized mixed-effect models with the appropriate distribution, using the *lmerTest* library (Bates, Maechler, & Dai, 2008). We started all analyses with a full model that included each variation set statistics as dependent variable, participants as random factors, and experimental group, gap and n-gram as fixed predictor variables, including all interacted predictor variables. We then proceeded to simplify the full model incrementally to see whether the model was improved by removing non-significant terms, beginning from the higher-order interactions. Model simplification was carried out with the *buildmer* function and model fit was assessed using chi-square tests on the log-likelihood values to compare different models.

Proportion of utterances in variation sets. The mean proportion of utterances in variation sets for gap = 0 and n-gram = 1 was respectively .44 ($SD = .12$) for the Typical group, .46 ($SD = .09$) for the DS group, and .51 ($SD = .11$) for the ASD group. Increasing n-gram length resulted in progressively smaller proportions of variation sets, as reported in previous studies (Waterfall et al. 2010).

The most parsimonious mixed-effect model predicting proportion utterances in variation sets included main effects of developmental type, n-gram, and gap. Significant interactions included: a n-gram by gap interaction, and an n-gram by developmental type interaction (see Table 1 for full statistics). Tukey HSD posthoc tests revealed that the ASD group produced significantly more variation sets compared to the Typical

group, as well as the DS group, while the DS group did not differ from the Typical group.

Table 1

Analysis of Variance for Study 1: Proportion of maternal utterances in variation sets as a function of child developmental group, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
n-gram	1623.93	3	0.0000
gap	107.28	2	0.0000
group	10.30	2	0.0058
n-gram:gap	118.86	6	0.0000
n-gram:group	67.34	6	0.0000
gap:group	0.89	4	0.9262
n-gram:gap:group	2.73	12	0.9972

Proportion of unique words in variation sets. We found that the word types that define variation sets are far from rare. The mean proportion of unique words in variation sets for gap = 0 and n-gram = 1 was 0.31 ($SD = .10$) in the Typical group, .41 ($SD = .15$) in the DS group, and .40 ($SD = .13$) in the ASD group. The most parsimonious mixed-effect model predicting proportion of unique words in variation sets included main effects of developmental group, gap, and linear and quadratic effects of n-gram. Significant interactions included an n-gram by experimental group interaction, a gap by experimental group interaction, and a n-gram by gap interaction (see Table 2 of Appendix A for full associated statistics). Tukey HSD posthoc tests revealed that both the ASD and DS groups produced a significantly higher proportion of unique words in variation sets compared to the Typical group, while the DS and ASD group did not differ from each other.

Diameter of variation sets. For the present corpus, across the three experimental groups we found that the average diameter of a variation set in terms of normalized edit distance at gap = 0, n-gram = 1 ranged from .78 ($SD = .07$) for the

Table 2

Analysis of Variance for Study 1: Proportion of unique words in maternal variation sets as a function of child developmental group, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
n-gram	1407.92	3	0.0000
gap	41.20	2	0.0000
group	25.90	2	0.0000
n-gram:gap	35.89	6	0.0000
n-gram:group	143.19	6	0.0000
gap:group	5.43	4	0.2458
n-gram:gap:group	6.53	12	0.8872

Typical and DS group, to .83 ($SD = .05$) for the ASD group. The most parsimonious mixed-effect model predicting diameter of variation sets included main effects of experimental group, n-gram and gap. Significant interactions included linear and quadratic n-gram by experimental group interactions, a gap by experimental group interaction, and a n-gram by gap interaction (see Table 3 of Appendix A for full statistics). Tukey HSD posthoc tests revealed that the ASD group produced significantly larger diameters of variation sets compared to the Typical group and the DS group, while the DS and Typical group did not differ from each other.

Length of variation sets. The mean normalized length of utterances making up a variation set for gap = 0 and n-gram = 1 ranged from 2.61 words ($SD = 0.39$) in the Typical group to 2.71 ($SD = 0.25$) in the DS group, to 2.75 ($SD = 0.29$) in the ASD group. The most parsimonious mixed-effect model predicting length of variation sets included main effects of experimental group, n-gram and gap. There were no significant interactions (see Table 4 of Appendix A for full statistics). Importantly, Tukey HSD posthoc tests revealed that the ASD group produced significantly longer variation sets compared to the Typical group and the DS group, while the DS and Typical group did not differ from each other.

Table 3

Analysis of Variance for Study 1: Diameter in maternal variation sets as a function of child developmental group, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
(Intercept)	2062.23	1	0.0000
n-gram	129.56	3	0.0000
gap	77.55	2	0.0000
group	27.32	2	0.0000
n-gram:gap	27.07	6	0.0001
n-gram:group	35.06	6	0.0000
gap:group	6.68	4	0.1538
n-gram:gap:group	3.58	12	0.9899

Summary of Results of Study 1. Overall, the pattern of results indicated that mothers of Autistic Spectrum Disorder children produced higher proportions of variation sets, higher proportions of unique words in variation sets, larger diameter of variation sets indicative of rich variation within repetition, and longer variation sets compared to mothers of typically developing children. The hypothesis that mothers of atypically developing ASD children simply produce more repetitive language is not warranted by the finding that they also produce a higher number of unique words in variation sets and more varied variation sets (as reflected by larger values of diameter) compared to the typical group, suggesting that they maintain lexically rich variation with repetition. In relation to our initial expected outcomes, because ASD children were chronologically older than typically developing children, and variation set measures diminish in child-directed speech as a function of child age, the patterns of result dovetails with the interpretation that ASD mothers may perceive the communicative task with their child in need of extra scaffolding, and may attempt to make up for it by providing highly informative distributional cues to language. Conversely, our results indicate that parents of Down Syndrome children align more

Table 4

Analysis of Variance for Study 1: Length of maternal variation sets as a function of child developmental group, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
(Intercept)	4080.86	1	0.0000
n-gram	397.38	3	0.0000
gap	458.24	2	0.0000
group	19.62	2	0.0001
n-gram:gap	11.64	6	0.0705
n-gram:group	8.38	6	0.2116
gap:group	6.15	4	0.1880
n-gram:gap:group	5.33	12	0.9461

with child-directed speech of typically developing children, with three out of four indexes of variation sets not differing significantly. Thus, the patterns of results may suggest that there is something unique about ASD that results in differences in parental language than in other atypical populations.

Figure 1. Mean values for the four measures of Variation Sets (‘Varsets’ in the figure) across experimental group, gap and n-gram, in Study 1.

Study 2: Mother vs. Father

Healthy parent–child interaction is as fundamental to the development of special needs children, as it is for typically developing children (Bornstein, Venuti, & Hahn,

2002; de Falco, Venuti, Esposito, & Bornstein, 2011; Sander, 2000; Sroufe, 2000. There is a growing body of literature on fathers' adaptation, stress and coping skills when facing the challenges of parenting a child special needs whatever the etiology (Glidden, Billings, & Jobe, 2006; Shin et al., 2006. There are also studies showing that in typical development paternal involvement in child-rearing exerts a unique positive influence on different aspects of growth and adaptation (Crouter and Booth 2003), and different dimensions of paternal involvement have been related to positive outcomes in child cognitive development, social competence, and academic achievement (Tamis-LeMonda & Cabrera, 2002). In particular, theorists and researchers agree that fathers play a critical role in fostering child development through play (Hewlett 1992). With respect to dyadic interaction, fathers, compared with mothers, spend more time in play activities vis-à-vis caregiving with their typically developing children (Parke 2002).

In Study 2, we focused on the linguistic interaction between parents (both mothers and fathers) and their children with Autism Spectrum Disorders (ASD). Despite the fact that both parents may be emotionally and practically involved in child-rearing (Parke 2002), the majority of studies investigating interactions between parents and children with special needs have been conducted with mothers (i.e., Cielinski, Vaughn, Seifer, and Contreras 1995; Ruskin, Mundy, Kasari, and Sigman 1994). That said, recent investigators have drawn attention to the importance of fathers in the development of children with ASD. The few studies conducted on fathers of children with special needs have shown the differential yet positive effect of fathers on child development (see for example de Falco et al. 2011).

Method

Participants. Participants were a subset ($n = 13$) of the 27 mothers of Study 1 plus 13 fathers from the same families, and their children with ASD (total $n = 26$).

Procedure. The procedure and measures of variation sets were the same as in Study 1.

Results

Statistical analyses were carried out as in Study 1. We modeled each variation set statistics as dependent variable, participants as random factors, and parent (mother, father), gap and n-gram as fixed predictor variables, including all interacted predictor variables in the full model first, and proceeding to model simplification if necessary.

Figure 2 presents — across mothers and fathers — the mean values of the five principal statistics of variation sets: the proportion of utterances in variation sets; the proportion of word types in variation sets; the average length of variation sets; and the Levenstein edit distances for utterances in variation sets. Mean values are broken down for values of gap = 0, 1, 2 and values of n-gram $1 < n < 4$.

Proportions of utterances in variation sets. The most parsimonious mixed-effect model predicting proportion of utterances in variation sets included: linear and quadratic effects of n-gram, and gap, an effect of parent, a n-gram by gap interaction, an n-gram by parent interaction (see Table 5 in the Appendix for associated statistics). Mothers produced a significantly higher proportion of utterances ($M = .52$, $SD = .11$) in variation sets compared to fathers ($M = .40$, $SD = .06$).

Table 5

Analysis of Variance for Study 1: Proportion of utterances in variation sets variation sets as a function of parent, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
(Intercept)	310.59	1	0.0000
n-gram	280.00	3	0.0000
gap	15.91	2	0.0004
parent	33.15	1	0.0000
n-gram:gap	19.38	6	0.0036
n-gram:parent	28.83	3	0.0000
gap:parent	0.56	2	0.7541
n-gram:gap:parent	1.06	6	0.9834

Percentage of unique words in variation sets. The most parsimonious mixed-effect model predicting proportion of unique words in variation sets included: main effects of n-gram, gap, and parent, and a n-gram by parent interaction (see Table 6 in the Appendix for associated statistics). Importantly, mothers produced a significantly higher proportion of unique words in variation sets ($M = .40$, $SD = .13$) compared to fathers ($M = .37$, $SD = .18$).

Table 6

Analysis of Variance for Study 2: Proportion of unique words in maternal variation sets as a function of parent, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
(Intercept)	234.10	1	0.0000
n-gram	193.88	3	0.0000
gap	8.62	2	0.0134
parent	9.80	1	0.0017
n-gram:gap	6.28	6	0.3924
n-gram:parent	11.39	3	0.0098
gap:parent	0.00	2	1.0000
n-gram:gap:parent	0.27	6	0.9996

Diameter of variation sets. The most parsimonious mixed-effect model predicting diameter of variation sets included: main effects of n-gram, and gap; interaction effects of n-gram by gap (see Table 7 in the Appendix for associated statistics). Mothers produced non-significantly larger diameters of variation sets ($M = .83$, $SD = .06$) compared to fathers ($M = .78$, $SD = .08$).

Length of variation sets. The most parsimonious mixed-effect model predicting length of variation sets included: effects of n-gram, gap, and parent (see Table 8 in the Appendix for associated statistics). Importantly, mothers produced significantly longer variation sets ($M = 2.75$, $SD = 0.29$) compared to fathers ($M = 2.49$, $SD = 0.27$).

Table 7

Analysis of Variance for Study 2: Diameter of maternal variation sets as a function of parent, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
(Intercept)	1617.77	1	0.0000
n-gram	77.18	3	0.0000
gap	73.05	2	0.0000
parent	2.82	1	0.0933
n-gram:gap	21.17	6	0.0017
n-gram:parent	5.26	3	0.1537
gap:parent	3.76	2	0.1529
n-gram:gap:parent	2.94	6	0.8167

Table 8

Analysis of Variance for Study 2: Length of maternal variation sets as a function of parent, n-gram, and gap.

	Chisq	Df	Pr(>Chisq)
(Intercept)	2688.26	1	0.0000
n-gram	106.21	3	0.0000
gap	138.68	2	0.0000
parent	10.19	1	0.0014
n-gram:gap	9.49	6	0.1478
n-gram:parent	5.12	3	0.1630
gap:parent	1.94	2	0.3785
n-gram:gap:parent	1.26	6	0.9738

Figure 2. Mean values for the four measures of Variation Sets across parent, gap and n-gram, in Study 2.

Summary of Results of Study 2. Overall, the pattern of results indicates that mothers of Autistic Spectrum Disorder children produced higher proportions of variation sets, larger number of unique words in variation sets, larger diameter of variation sets, and longer variation sets compared to fathers. On the assumption that variation set measures offer implicit distributional cues to language, one interpretation of our findings is that mothers may be more adaptive than fathers in tailoring their language to the child's expected needs. A take-away point for this study is that there needs to be more research on father-child dyads in typically and atypically developing populations, and that this study serves as a preliminary step in that direction.

Discussion

Naturally occurring groupings of related utterances are a well-known property of how parents talk to young children, and such repetitiveness predicts children's later vocabulary (Newman, Rowe, & Ratner, 2016; Waterfall, 2006). These properties in parents of atypically developing children are virtually unknown, such as their effects on atypical language development. In Study 1, we conducted a systematic statistical analysis of partial repetitions (operationalised as 4 measures of variation sets) over transcripts of parent-child naturalistic interactions in three groups of children, including the first comparison of typically and atypically developing children. In Study 2, we conducted the first systematic statistical analysis of variation set structure comparing mother and father speech, in a group of ASD children.

The results in Study 1 revealed that mothers of ASD children produced larger measures of partial repetition compared to the benchmark typical group as well as the Down Syndrome group. Indeed, while parents of children from the DS group showed a structurally similar pattern of communication as their typical control group counterpart, the ASD children in our sample received more implicit distributional cues to language. One possible explanation is that given the very few linguistic interactions found in our transcribed conversations on the part of the parents of the ASD group, such parents may have engaged in 'halfalogues', namely monologues in dialogic

situations where one of the interactants is verbally non-responsive. Reduced responses to parental bids are a known trait of ASD children. As a consequence, parents in the ASD group may have had to resort to more repetitive communication, focusing on the phatic and affect-salient aspects of communication, thus producing the higher levels of variation sets found in our analyses.

This interpretation would be consistent with the parallel functional analyses carried out by Venuti et al. (2012) on the same dataset. Parents of atypical children used higher levels of affect-salient language. Parental language is used to convey a mixture of affect and information to children. Affect-salient language maintains social interaction between child and parent and speech that conveys information to the child. Compared to information-salient language affect-salient communication includes fewer direct statements, questions, or descriptions) and referents (to the environment, the child's actions or internal states, or the parent him/herself). In mothers of typically developing children, these two functional categories of speech follow opposite developmental trajectories from early infancy into toddlerhood (Bornstein et al. 1992); specifically, information-salient speech increases, whereas affect-salient speech decreases. Our findings of high levels of variation sets in maternal speech to the ASD group thus tally well with Venuti et al. (2012)'s findings of higher levels of affect-salient language in the same group, as the latter is more repetitive than information-salient language.

However, mothers of ASD children in our dataset were not merely more repetitive. They also produced more unique words in variation sets, and larger diameters of variation sets, which combined indicate that their partial repetitions were rich in lexical variation. Thus, our results may tally better with the interpretation that ASD mothers perceive the communicative task as particularly challenging for their child, and may attempt to make up for such difficulty by providing highly informative distributional cues to language. This could be labelled the 'compensating' hypothesis, because the levels of partial repetitions appear substantially higher, also considering the older chronological age of the atypical group combined with previous findings that older typically developing children receive fewer partial repetitions. Indeed, the specific

sample we analyzed was composed of children with ASD *and* cognitive delay (currently defined as low-functioning). Future studies should perhaps compare child-directed speech to lower versus higher functioning ASD children, and disentangle whether the results we obtained were related to children's perceived cognitive deficits or not. If they were, one would expect levels of variation sets in speech to high functioning children to be closer to levels in typically developing children, and lower than in low functioning children.

Results of Study 2 further suggest that the effect was driven by the mothers rather than the fathers. Compared to fathers, mothers of ASD children produced higher proportions of variation sets, larger number of unique words in variation sets, larger diameter of variation sets, and longer variation sets. The mother-father difference is consistent with findings that fathers engage in more challenging communication in some instances (e.g., in using more wh-questions and eliciting more speech) relative to mothers, and this seems to benefit children vocabulary (Rowe et al., 2017). Our findings are also consistent with Schwab and Lew-Williams (2016)'s findings that fathers of older infants and toddlers use less repetition, especially when their children have larger vocabularies. Thus, the results of Study 2 with parents of ASD children appear to support the view that mothers and fathers adopt complementary linguistic roles across both typical and atypical development. Future studies should aim to establish a causal relationship with atypical language development, something not available in our data set. In general, limited data on features of fathers' child-directed speech undermine a clearer understanding of the overall effect of parents' language input on both typical and atypical language development.

Another relevant finding emerging from Study 1 is that levels of partial repetition in mothers of DS children aligned more closely with the typically developing group than with the ASD group. This finding is not straightforwardly explainable. On the one side, both the ASD and DS groups produced a significantly higher proportion of unique words in variation sets compared to the typical group, while the DS and ASD group did not differ from each other on this one measure. However, overall, the pattern of results

for the DS group is closer to the typical group, and parents of DS children should produce more variation sets compared to typical group if they perceived communication to the child to be in need of linguistic compensation. Thus, results from the DS group are not readily interpretable with our limited data, but our study nonetheless opens the possibility for further computational analyses of speech directed to atypical populations.

One way for future studies to make progress is to devise longitudinal studies addressing the possible effects of parental speech on atypical language development - a source of information that is missing in our data set. For example, individual differences in parental variation sets to ASD and DS should be able to predict measures of receptive vocabulary in children. In typically developing children, a sustained amount of variation sets in speech is positively associated with language growth (Küntay and Slobin 1996; Schwab and Lew-Williams 2016; Waterfall 2006); recently, socioeconomic status (SES) was shown to affect the amount of variation sets children receive (specifically, parents with higher SES produced higher amounts of variation sets; Tal and Arnon 2017). Our initial corpus analyses suggest that partial repetition may result in compensating parental strategies in an ASD group and to a less extent in a DS group. Future studies should ascertain whether or not this trend affects language development and how in atypically developing children.

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