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Dynamic Linguistic Interconnectedness and Variability in Toddlers

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Abstract
This investigation examined the existence of interconnectedness between developing linguistic subsystems. Spontaneous speech samples were collected from 31 typically-developing Greek-speaking toddlers across two age levels, at 28 and 36 months. Correlational analyses were performed synchronically and predictively, revealing significant positive relationships among all language skills within ages. Phonetic and grammatical skills also showed predictive value for later skills. In addition, a cluster analysis on the basis of performance on each individual skill revealed variable linguistic profiles: Low performers showed multiple interactions within and across ages, while High performers showed minimal such interactions. The current results revealed complex interdependencies among the different language skills with children exhibiting variable linguistic profiles, as supported by dynamic systems theory approaches to language acquisition.

Keywords Language development · Linguistic interconnectedness · Dynamic systems theory

Introduction

Language acquisition constitutes a dynamic process which occurs fast, effortlessly and without any formal instruction (Chomsky 1965; Lenneberg 1967). A typical course of language development demands the existence of certain components, such as an intact biological ability associated with the production of vocal-motor schemes and a cognitive-linguistic system allowing the child to map sound onto meaning (Locke 1993; Hoff 2005). Within

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a short period of time, the young language learner moves gradually from sound to meaning and from jargon to intelligible speech. Despite significant variation in developmental trajectories, certain language milestones are expected to appear during the first and the second year of life (see Crystal 1997 for an extensive overview). These include the production of first words around the age of 12 months, the emergence of a critical lexical mass and its acceleration between the ages of 18 and 24 months as well as a remarkable grammatical advancement after the age of 24 months (Marchman and Thal 2005). Furthermore, during the second and third year of life, word combinations and a gradual mastery of the phonetic, phonological and morphophonological patterns of the ambient language emerge (Berko-Gleason and Rattner 2016; Crystal 1997; Stephany 1997; Vihman 1996).

A long-standing debated regarding the interconnectedness or dissociations of language subsystems is discussed in the literature (Marchman and Thal 2005). Are language subsystems related to each other during the course of early language development in the form of a single-mechanism view (Bates and Goodman 2001) or do they develop autonomously in the form of a dual-mechanism system. A simple answer to this question remains unequivocal as language development constitutes a dynamic process with all its subsystems developing and behaving differently as a function of linguistic demands across various chronological age levels (see Stoel-Gammon 2011). Parallel to the notion of linguistic interdependencies, Dynamic Systems Theory framework (DST hereafter) entertains the idea that several factors affect the language acquisition process at different points in development and that linguistic subsystems interact with one another in various ways (Samuelson and Galligan 2014; Ushioda 2015). Language has also been shown to have certain characteristics core to dynamic systems; most importantly complete *interconnectedness between systems* and *variation within and across individuals* (De Bot et al. 2007). The former suggests that language subsystems, such as the phonetic system, grammar or the lexicon, do not develop independently, but mutually influence each other during development, in various ways. This means that a language subsystem can exert its influence on another at a certain point, but also the behavior of that system can affect the other at a later point in development. The latter suggests that a high degree of variability exists between children at different points in development and also that the same child will not remain the same throughout development, but will be affected by the different real-time factors working in tandem. These two characteristics are the major focus of this work, especially as they manifest in language development in the third year of life.

The plethora of investigations focusing on the interconnectedness among linguistic subsystems provided evidence for the existence of mutual influences which operate synergistically (e.g., lexicon vis-à-vis grammar), in order to facilitate the language acquisition process (Bates and Goodman 2001; Marchman and Bates 1994). This issue in the form of linguistic continuity is traced back to infancy and has been proposed to account for a possible link between early phonetic development, and later lexical acquisition in the sense that early vocal schemes set the foundation for the emergence of early words through the creation of syllable templates (Vihman 1996; Morgan and Wren 2018). The linkage between phonetic/phonological development and lexical development is discussed extensively in a commentary by Stoel-Gammon (2011). Along these lines, certain language subsystems develop in tandem and appear to influence cognitive-linguistic representations (Beckman et al. 2007). For example, expressive vocabulary growth and productive "practice" contributes to the child's gradual development and sharpening of the "fine grained" phonological patterns inherent to the words the child produces over time (Metsala and Walley 1998). As children gain a "critical mass" of lexical items (Marchman and Bates 1994), phonological organization shifts from a "gestalt" to a more analytic form which may impact on the phonological/lexical interphase in the form of *phonological bootstrapping* (Vihman 1992; Vihman et al. 1994).

In his pioneering work, Kagan (1971) proposed the presence of homotypic (within domain) and heterotypic (across domains) correlations observed across time. Specifically, relationships occurring within one linguistic domain (e.g., lexicon) and/or between domains (e.g., lexicon and grammar) support the existence of a complex interconnected language system across time. There has been a keen interest in investigating the relationships of lexical and grammatical skills during the second and third year of the child's life, with findings corroborating towards the existence of significant correlations between early expressive vocabulary and morphosyntactic development with the former constituting a strong predictor of later morphological and syntactic achievements (Bates et al. 1988). It has also been shown that children begin to combine words, and thus their grammatical/syntactic development begins, after they have accumulated a lexicon of around 50 words (e.g. Rescorla 1989). On parallel lines, expressive vocabulary at the age of 20 months has also been found to be a strong predictor of grammatical/syntactic abilities (in the form of Mean Length of Utterance (MLU hereafter)) at age 3, supporting the existence of linguistic interdependencies between subsystems in line with single-mechanism approaches to language development (McGregor et al. 2005; Rosenthal-Rollins et al. 1996). Further studies, mainly from English corpora, provided converging evidence related to interdependencies between morpho-syntactic and lexical abilities. Specifically, Bates and Goodman (2001) investigated the relationship between morpho-syntactic abilities, in the form of MLU, and semantic abilities, in the form of Expressive Vocabulary Size (NDWS hereafter), as these surface at different points in language development (e.g., from age 2 to 5 years). The findings revealed significant relationships between lexical (NDWS) and grammatical (type of word combinations) skills, again supporting a highly interconnected language system. Moyle et al. (2007) investigated longitudinal interactions between lexical and grammatical skills in typically developing (TD hereafter) and late talking (LTs hereafter) children across the ages of 2–5 years. They reported strong relationships between lexical and grammatical skills for all children throughout the span of the study, with LTs however exhibiting less such linguistic interdependencies.

The relationship between lexical and morpho-syntactic development has been studied cross-linguistically as well and shown to exist in languages with rich morphology, such as Italian and Cypriot Greek (CG). Using data from the corresponding adaptations of the MacArthur-Bates Communicative Development Inventory (CDI), Caselli et al. (1999) studied the development of grammatical complexity as a function of the size of the lexicon in English and Italian. They calculated the percentage of function words in children's lexicons, sentence complexity and MLU and showed that all three measures increased as the size of the lexicon increased, suggesting a strong interdependence between lexical and morpho-syntactic abilities. The same pattern was found for CG using the corresponding adaptation of the CDI, suggesting that these interdependencies could be related to universal developmental patterns (Taxitari et al. 2017).

The ways in which linguistic subsystems interact during the course of language learning have mainly been examined through the study of interactions between two subsystems, and mainly in English. A simultaneous interaction among all three skills (sounds, lexicon, grammar) warrants further investigation, thus setting the main goal and novelty of the current investigation. Given the acceleration of language development during the second and third year of life, one of the central research questions addressed by the current study revolves around language interconnectedness and variability beyond the age of 2 years. Furthermore, the study investigated the operation of linguistic interconnectedness beyond the 50-word language landmark, allowing us to observe the interaction among more advanced language skills during a developmental period which is supposed to be characterized by higher developmental stability (Moyle et al. 2007). Additionally, the children's level of performance in their phonetic, lexical and grammatical skills at a certain point was used to differentiate them in groups of high and low performers in order to test whether linguistic interconnections between subsystems are affected by how skilled a child is at a specific language skill.

Despite the plethora of data available from English corpora findings do not necessarily generalize to other languages and/or dialects due to differences in their respective phonetic/phonological, semantic and grammatical properties (Marton et al. 2006). In the current investigation the focus was on Greek, and more specifically the Cypriot Greek (hereafter CG) dialect, a variety with a rich morphological system. Phonetically and morphologically rich languages provide the benchmark for examining cross-linguistic patterns in early language development and shed light on to the existence of language specific and language universal patterns of development. Even though developmental language research in CG has received remarkable attention during the past ten years (for a review see Grohmann 2011; Tsimpli et al. 2016), the different linguistic skills have been examined independently. Studies on phonological development focused on the age and order of acquisition of different phonetic segments (for example Okalidou et al. 2010; Petinou and Okalidou 2006; Petinou and Theodorou 2015), while studies on the development of syntax focused on MLU at different ages (for example Voniati 2016) or the acquisition of dialect-specific morphosyntactic elements (for example, Kambanaros et al. 2013; Tsimpli et al. 2016; Petinou and Terzi 2002). Finally, the development of the lexicon has recently been studied extensively through parental feedback on the CG CDI by Taxitari et al. (2017). Petinou et al. (2011) studied all three language skills (phonological, lexical and grammatical) longitudinally in TDs and late talkers in their third year. However, the focus of the study was the comparison between TDs and LTs, so the three language skills were not compared directly to each other.

The only study examining developmental interdependencies between linguistic subsystems was conducted by Taxitari et al. (2017) using the CG version of the CDI, showing an increase in grammatical elements as the size of their lexicon increased. Apart from this latter study, no other studies have directly examined linguistic interactions in CG-speaking TD youngsters, a fact that adds novelty to the present investigation. Given the sparse data that exist on interactive developmental patterns of CG speaking toddlers, the study attempted to shed light onto the mechanisms that might govern the early stages of the language acquisition process. Thus, examining such relationships might offer an insight into different operations that underlie linguistic interconnectedness between subsystems during the early stages of language acquisition and provide cross-linguistic support of Dynamic Systems Theory approaches to language acquisition.

To sum up, the current study investigated (a) the existence of interconnectedness between language subsystems in the third year of life in a language other than English and (2) the interconnectedness of these subsystems as a function of language variability, by separating children into different groups on the basis of their performance at each language skill under investigation. The following questions were addressed:

1. Are there synchronic links among language skills (e.g., sounds, words and grammar) in two different points in the third year of life?

2. Are there any predictive links among language skills across two age points in the third year?
3. Are there any differences in linguistic interdependencies between groups of children who fall into different clusters based on the variability of their linguistic profiles?

Method

Participants

The participants in this study included 31 toddlers (20 girls, 11 boys). Children's language abilities were studied at two ages: (a) *intake* at age 28 months (M = 28.6 months, range 27.6–29.4, SD: 0.47) and (b) *reassessment* at age 36 months (M = 36.4 months, range 35.7–36.9, SD: 0.27). These children were a subset of participants from a larger cohort of subjects in a longitudinal investigation regarding linguistic milestones in CG. Note that these participants were those who completed all experimental language protocols at the two testing time points. They were all recruited through different private and state pre-schools, and advertisements in local newspapers and newsletters, as well as through flyers posted to local public places, the Cyprus Association of Speech and Language Therapists, Paediatric Offices, and personal contacts. Parents who expressed willingness to participate signed a written consent form. The study and its protocol received approval by the Council Committee of the Cyprus Institute of Neurology and Genetics. All participants came from monolingual CG-speaking households and presented with typical course of language development based on linguistic, hearing and cognitive screenings conducted at intake. All participants were matched for socio-economic status (mid-high) on the bases of maternal education and family income (Cyprus Statistical Service 2005).

Cognitive non-verbal ability was assessed via clinical observations and with the use of a checklist adapted from the Bayley Scales of Infant Development (MDI) (1969) administered at the time of intake (American Speech-Language-Hearing Association 2005). A "pass" or "fail" score was based on the child's performance on 18 non-verbal tasks within the age bracket of 23–28 months. The 80% (correct performance of 14 out of the 18 items) was used as the cut-off point required for a "passing profile" set by the examiners according z-score transformation of raw data performance Petinou et al. (2011). Some of the non-verbal items included the completion of a 5-piece puzzle, the building of a six-block tower, the matching of wooden blocks for shapes and colours, and symbolic play schemes. All participants showed typical non-verbal ability according to this criterion.

Expressive and receptive language screening was performed with the use of the Pre-school Language Scale-3 (PLS-3: Zimmerman et al. 1992) adapted in GC (for details see Petinou and Spanoudis 2014). That is, a number of items from the PLS-3 was adapted to fit child's language characteristics and parameters of the CG dialect. It should be noted that most of the adaptations were performed in the expressive domain of the test and included the linguistic parameters of phonology, plural inflections, definite and indefinite articles, grammatical agreement and the correct use of clitics (for details see Petinou and Spanoudis 2014). All children passed the language screening protocol.

Case history regarding medical issues and developmental milestones was also gathered at intake through developmental questionnaires completed by each child's caregiver. In addition, all passed hearing screenings at 500, 1000, 2000, and 4000 (6000 and 8000) Hz presented at 25 dB HL according to the guidelines suggested by the American Speech-Language-Hearing Association (2005) using a GSI-38 portable audiometer.

Procedures

Spontaneous speech samples of the toddlers who participated in this study were collected at the Speech and Language Research Laboratory housed within the premises of the Cyprus Institute of Neurology and Genetics (CING) in Nicosia, the capital of Cyprus. Two trained research assistants carried out the language screening and data collection. Speech samples were collected at two age points: (a) *intake* at age 28 months (M = 28.6 months, range 27.6–29.4, SD: 0.47) and (b) *reassessment* at age 36 months (M = 36.4 months, range 35.7–36.9, SD: 0.27). Each session lasted approximately 45 min and was audio recorded using a *Marantz PMD-222* digital recorder. Recordings utilized an *Audio-Technica* flat unidirectional microphone placed on the table directly in front of the child. During each experimental session children interacted with the examiner and/or the caregiver (usually the mother) while playing with various sets of toys (plastic food items, dolls, plastic cups and plates, plastic tractors, puzzles, books, and pictures). The toys remained constant across all participants across both screening sessions.

Measures

Selection of utterances for the analyses included all consecutive intelligible, non-imitated glossable targets produced within a fixed time-period of 40 min. Analyses was performed on all consecutive utterances produced 10 min within the screening session. This procedure gave our subjects a period for "expressive language warm-up time". Broad phonetic transcriptions were performed by trained researchers for each child's recorded speech corpus by using transcription guidelines based on the International Phonetic Alphabet (IPA 1999). A total of 62 language samples (31 at each age level) were transcribed with number of utterance production ranging from approximately 20–220. Ill-recorded productions, utterances overlapping with noise, or with the researcher's own speech, as well as softly uttered or whispered productions were excluded.

At each screening session, three language measures were calculated based on the spontaneous language samples collected:

Phonetic inventory size (PIS)

Individual phonetic profiles for each child were constructed on the basis of an independent analysis process during which each production was coded irrespective of its reference to the adult target (Amayreh and Dyson 1998; Petinou and Okalidou 2006; Stoel-Gammon and Dunn 1985). Established consonants were considered those occurring in at least two different words at respective word positions (i.e., "bag", "bath" for word initial [b] and "body" and "teddy" for word medial [d]). The analysis incorporated all words produced including multiple productions of the same target. For example, if the child produced an allophonic variation, she was credited with the actual segment produced within the given word target (e.g. if the word 'chocolate' was produced as [t͡ʃokoˈlata], [sokoˈlata] and/or [ʃokoˈlata], credit was given for [t͡ʃ], [s] and [ʃ] respectively depending on the child's productive preference for that given target). In addition, instances in which the child substituted the target segments (e.g., [s] was substituted with [θ] and [ɾ] with [l]) the child was credited with the segment produced regardless of non-target realization (e.g., /s/ -> [θ] in [‘supa] “soup” produced as [‘θupa]). The number of established sounds was used to construct each child’s PIS index.

Number of different words (NDWS)

NDWS has been a widely-used measure of lexical diversity (Fenson et al. 1994) and has been one of the language parameters used to examine linguistic continuities and correlations in typically developing and language impaired children in (Conti-Ramsden and Jones 1997). In the current study, each child’s NDWS was constructed by following the recommended process presented by Olswang et al. (1987) in their assessment of early linguistic behaviors in toddlers. NDWS counts included function words, as well as content words (verbs, nouns, articles, adverbs and prepositions). Imitated utterances, rituals, songs, rote memorized and unintelligible non-glossable productions were excluded from the counting process. Each word was counted only once irrespective of the number of times it was produced.

Mean length of utterance in words (MLU)

MLU has been used to examine morpho-syntactic development. In the current data set, MLU was calculated by dividing the total number of words produced by the total number of all consecutive utterances. Since CG is a highly inflected linguistic variety, for the current investigation counting words rather than morphemes was considered to be the most appropriate method of data analysis. This regime has been used successfully by similar investigators with a focus on CG (Petinou and Spanoudis 2014; Voniati 2016). The counting of words as opposed to morphemes has been strongly recommended by Leonard (2014) in examining syntactic growth in children who speak a highly inflected language. The rationale for this methodological procedure stems from the fact that in languages with rich inflectional systems, including CG, grammatical morphemes such as suffixes and prefixes, cannot be produced in isolation since they are encapsulated in the whole word and are used to modulate gender, number, case and tense (Leonard 2014). Utterance boundaries were determined on the bases of factors including falling intonation contour and pauses of one second duration as suggested by Petinou et al. (1999). Furthermore, identification and segmentation of an utterance was performed in reference to communication units as suggested by Moyle et al. (2007) and Loban (1976) in which a unit consists of an independent intelligible sentence containing subject + predicate and all its subordinating clauses. (Partially intelligible productions, elliptical responses to questions, memorized rote speech productions, incomplete sentences and dysfluent unintelligible productions were excluded from the counting process) has already been mentioned

Reliability

Approximately 10% of recorded samples were randomly selected for the purpose of phonetic transcription reliability, NDWS and MLU counts. The samples were phonetically transcribed by the first author and were checked against comparable coding from an independent transcriber (a speech language-pathologist trained in phonetic transcription) who was unfamiliar with the purpose of the study. Reliability on the relevant linguistic categories was based on the number of agreements divided by the sum of agreements and disagreements after the two transcribers had jointly listened to the targets and had compared their transcriptions with regards to place and manner of articulation. Inter-rater transcription reliability for manner and place of articulation was approximately 90% and 84% respectively. For NDWS and MLU agreement percentages were 95% and 85% respectively.

Analysis

The relationship among the three language measures, Phonetic Inventory Size (PIS), Number of Different Words (NDWS) and Mean Length of Utterance in words (MLUW), and for the two age levels (intake—28 months and reassessment—36 months) was examined using the Pearson r-correlation coefficient and based on Cohen's (1992) guidelines. The analysis was conducted *synchronically* to investigate how these measures behave at the same time and *predictively* to investigate whether a language measure at intake level can predict other language measures at reassessment level. In addition, using a K-means cluster analysis, we grouped the participants in three different ways based on their performance (low/high) in each language measure at intake level separately (MacQueen 1967). This resulted in a total of six groupings: High/Low PIS28, High/Low NDWS28 and High/Low MLU28. The reason for the division of participants in these groups was to examine if the relationships found in the whole sample apply uniformly to the children at a certain age or whether low and high performers show different profiles. Descriptive statistics for all language measures are provided in Table 1.

Results

Relationship of language skills within ages (synchronic correlations)

Table 2 presents all correlations between the three measures at age of intake (28 months) and age of reassessment (36 months). Figure 1 presents only the significant correlations among language skills at intake and reassessment ages, as well as across ages for *all participants*. We observe that all three language skills examined for all participants at intake level are highly positively correlated with each other ($p < .01$). However, a different picture emerges from reassessment age level which reveal significant positive correlations between PIS36 and NDW36 [$r(31) = 0.44$, $p < 0.05$] and between PIS36 and MLU36 [$r(31) = 0.46$, $p < 0.05$], while the relationship between MLU36 and NDWS36 is not significant [$r(31) = 0.46$, $p < 0.05$].

Relationship of language skills across ages (predictive correlations)

A second aim of this study was to explore the relationship of the different language skills across ages (i.e. whether performance at 28 months can predict performance at 36 months). PIS28 months was strongly positive correlated with PIS36 [$r(31) = 0.68$, $p < 0.01$] and

Table 1 Descriptive statistics for each participant in the three language measures

ID	Gender	PIS28	NDWS28	MLU28	PIS36	NDWS36	MLU36
1	Girl	12	63	2.15	21	221	2.12
2	Boy	17	87	2.87	23	353	2.53
3	Girl	17	60	1.4	18	85	1.55
4	Girl	29	118	1.92	22	176	1.63
5	Girl	28	158	2.47	27	423	2.62
6	Girl	25	50	2.1	30	91	2.92
7	Boy	11	40	0.78	16	223	1.69
8	Girl	31	119	3.12	20	363	3.33
9	Girl	24	85	1.24	34	260	1.74
10	Girl	24	168	2.11	23	127	2.1
11	Girl	20	154	1.45	28	392	2.05
12	Boy	9	32	1.45	18	208	1.7
13	Girl	16	42	1.9	28	173	2.7
14	Girl	28	128	2.62	26	214	2.46
15	Girl	9	9	0.89	6	33	1.19
16	Boy	25	62	1.4	28	96	1.86
17	Girl	24	69	1.54	29	422	2.26
18	Boy	14	71	1.16	22	243	2.47
19	Boy	18	74	1.48	26	80	1.6
20	Boy	25	89	2.31	26	224	2.55
21	Girl	25	89	1.94	25	193	1.91
22	Girl	25	82	1.2	27	95	2.8
23	Girl	22	68	1.73	24	222	2.46
24	Boy	4	12	1	16	117	1.8
25	Boy	8	15	1	7	25	1.2
26	Boy	16	200	1.78	18	100	2
27	Girl	20	120	2.9	23	128	3.2
28	Girl	14	180	1.77	22	190	2.2
29	Boy	8	40	1	18	140	2.5
30	Girl	20	100	2.55	24	190	3.35
31	Girl	19	118	2	20	142	2.2
Mean (SD)		18.94 (7.14)	87.16 (49.73)	1.78 (.63)	22.42 (6.07)	191.90 (107.60)	2.21 (0.57)

Table 2 Correlations between the three measures at age of intake and age of reassessment for all participants

	PIS28	NDW28	MLU28	PIS36	NDW36	MLU36
PIS28	–	**0.51** (< .01)	**0.58** (< .01)	**0.67** (< .001)	**0.37** (< .05)	**0.43** (< .05)
NDW28		–	**0.52** (< .01)	0.34 (.06)	0.32 (.08)	0.31 (.10)
MLU28			–	0.34 (.06)	**0.38** (< .05)	**0.69** (< .001)
PIS36				–	**0.44** (< .05)	**0.45** (< .01)
NDW36					–	0.35 (.05)
MLU36						–

Significant correlations (*p*s < .05) are shown in bold

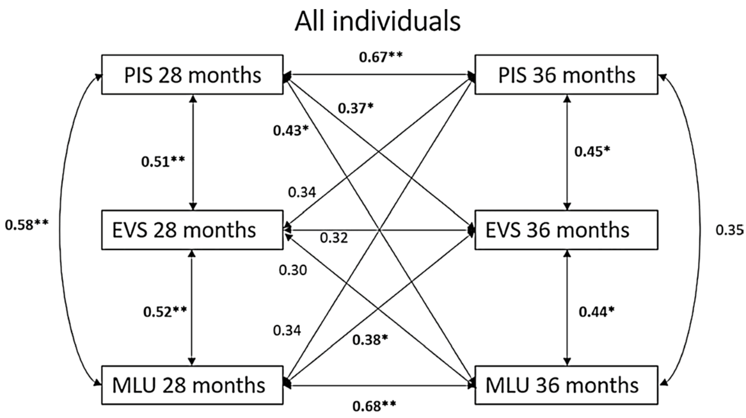

Fig. 1 Correlations between all language measures at age of intake and age of reassessment. The lines indicate significant correlations (one star: *p*s < .05; two stars: *p*s < .01). EVS stands for NDWs

Table 3 Division of participants into groups of High and Low performance for the three language measures

Language skill	Group	*N*	Intake (SD)	Sig.	Reassessment (SD)
PIS	Low	13	11.92 (1.14)	< .01	17.92 (1.67)
	High	18	24.01 (0.86)		25.67 (0.83)
NDWS	Low	21	59.05 (5.78)	< .01	225.50 (21.78)
	High	10	146.30 (9.46)		146.30 (38.21)
MLU	Low	17	1.31 (0.08)	< .01	1.94 (0.11)
	High	14	2.35 (0.11)		2.54 (0.14)

The number of participants in each group along with the means, and standard deviation, for each group at age of intake and age of reassessment are provided. The significance level of the comparison between the two groups for each measure at age of intake is also provided

moderately positive correlated with MLU36 [$r(31) = 0.43$, $p < 0.05$] and NDWS36 [$r(31) = 0.37$, $p < 0.05$]. Strong positive correlation exists for MLU28 and MLU36 [$r(31) = 0.69$, $p < 0.01$]. Finally, NDWS28 did not predict any of the skills at reassessment age.

Cluster analysis

A third aim of this study was to investigate whether children performed uniformly as a group or whether individual differences resulted in differences in the relationship between the three skills synchronically and predictively. Table 3 shows the two groups for each of the three language measures along with the number of children in each group, the means and standard deviations of each group and the ANOVA comparison between them. As is shown, all groupings based on performance differ significantly from each other.

As can be seen, the two groups for MLU28 and NDWS28 exhibit a similar increase from age of intake to age of reassessment, while the two groups based on PIS28 differ between them: the High PIS28 group shows minimal increase across ages, suggesting

Table 4 Correlations between the three measures at age of intake and age of reassessment for Low and High Performers separately

Cluster	PIS28	NDW28	MLU28	PIS36	NDW36	MLU36
PIS28						
Low	–	**0.60 (<.05)**	**0.66 (<.05)**	**0.60 (<.05)**	0.39 (.19)	0.44 (.13)
High	–	0.13 (.61)	0.31 (.21)	−0.03 (.91)	0.31 (.21)	0.11 (.66)
NDWS28						
Low	**0.77 (<.01)**	–	**0.62 (<.01)**	**0.73 (<.01)**	**0.49 (<0.05)**	**0.55 (<.01)**
High	0.31 (.21)	–	−0.55 (.0.09)	−0.09 (.81)	−0.12 (.75)	−0.38 (.28)
MLU28						
Low	**0.51 (<.05)**	**0.72 (<.01)**	–	0.48 (.05)	0.27 (.29)	0.31 (.22)
High	0.18 (.54)	0.28 (.33)	–	−0.25 (.39)	**0.54 (<.05)**	**0.69 (<.01)**

Significant correlations (*p*s < .05) are shown in bold

ceiling effects, while the Low PIS28 group exhibits an increase similar to the other two measures, that is MLU and NDWS.

Table 4 shows the Low and High performers for each of the language measures separately, along with the significant correlations for each measure. These correlations produced different profiles from the all participants analysis.

High performers

It appears that children in the High groups for all three skills exhibit very few relationships between variables: PIS28 and NDWS28 do not correlate with the other measures at age of intake or at age of reassessment ($p > .05$), while significant correlations are limited to MLU. Children with High MLU28 exhibit a high correlation between MLU28 and MLU36 [$r(14) = 0.69$, $p < 0.01$], as well as a significant correlation between MLU28 and NDWS36 $r(14) = 0.54$, $p < 0.05$.

Low performers

A more interesting pattern, however, is shown for children with Low PIS28, NDWS28 or MLU28. Children who had a Low PIS28 showed significant correlations between language skills synchronically and predictively. Significant correlations were shown for PIS28 and MLU28, $r(13) = 0.66$, $p < 0.02$, as well as for PIS28 and NDWS28, $r(13) = 0.60$, $p < 0.05$, and also PIS28 and PIS36, $r(13) = 0.60$, $p < 0.05$.

Children with a Low NDWS28 also showed significant correlations between language skills synchronically and predictively. Significant correlations were shown for NDWS28 and PIS28, $r(21) = 0.77$, $p < 0.01$, as well as for NDWS28 and MLU28, $r(21) = 0.62$, $p < 0.01$. Across ages, NDWS28 predicted all three language skills at reassessment, NDWS28-PIS36: $r(21) = 0.73$, $p < 0.01$; NDWS28-NDWS36: $r(21) = 0.49$, $p < 0.05$; NDWS28-MLU36: $r(21) = 0.55$, $p < 0.05$.

Finally children with Low MLU28 showed positive correlations between language skills only synchronically at age of intake; MLU28 correlated with both PIS28, $r(17) = 0.51$, $p < 0.05$, and NDWS28, $r(17) = 0.72$, $p < 0.01$.

Discussion

A first aim of this study was to investigate interdependencies between language subsystems, specifically phonetics, lexicon and grammar, in Greek-speaking toddlers in their third year of life. Interdependencies were studied both within ages, that is *synchronically*, as well as across ages, that is *predictively*. It was found that synchronically children at age of intake (28 m), as well as at age of reassessment (36 m) were shown to exhibit interdependencies between all three language skills: phonetic, lexical and grammatical.Additionally, such interdependencies were found predictively: phonetic skills at age of intake predicted all language skills at age of reassessment, while grammatical skills at age of intake predicted grammatical skills at age of reassessment. These results confirmed the existence of significant interdependencies within and across ages in the third year of life. In other words, at the age of 28 months, early in the third year of life, these interdependencies are shown to be quite robust with children who are more skilled at one aspect of language being skilled at other aspects as well. This is also the case late in the third year, but to a lesser degree. Furthermore, children who are advanced in their phonetic skills early in the third year have been shown to be more skilled in all other skills late in the third year. Such interdependencies are more evident early in the third year of life, while later on, when children become advanced language learners, ceiling effects make some relationships hard to trace using correlational analyses. All in all, as suggested by Dynamic Systems Theory approaches to language development, these linguistic interdependencies support a complex dynamic system, which is characterized by a high degree of *interconnectedness* between its subsystems. On par with Dynamic Systems Theory, the developing language system seems to be sensitive to *initial conditions* (De Bot et al. 2007), which seem to affect the functioning of certain parts of the system. This allows for interdependencies between subsystems to span the system horizontally, at the same time, but also vertically, from time point A to time point B. Specifically, the acquisition of the child's phonetic repertoire acts here as a strong predictor of later linguistic skills, which span from phonetics to the lexicon and grammar.

In the all participants analysis, the size of the phonetic inventory of children at age of intake was shown to predict phonetic ability later in the third year, but it also predicted lexical and grammatical ability. This supports the idea of some kind of early segmental/phonetic bootstrapping, suggesting that lexical and grammatical abilities are based on the child's acquired phonetic abilities. Once the child has acquired a robust phonetic system, then she/he can begin to learn words at a fast pace and combine those words to produce larger chunks of language (Sosa and Stoel-Gammon 2006; Vihman 2013). On the other hand, children's grammatical abilities at age of intake predicted their grammatical abilities at age of reassessment, but not other abilities. This is not surprising, since grammatical abilities constitute the more complex aspects of language and appear later on in development. Thus, phonetic and lexical abilities might be well advanced at 36 months, and grammatical abilities at 28 months do not have any predictive value regarding the former. However grammatical development has been shown to accelerate early in the third year (Taxitari et al. 2017), and thus grammatical abilities at age of intake act predictively.

Finally, children's lexical abilities in the form of semantic diversity through NDWs measures, did not predict any of the abilities at reassessment. This is a rather unexpected finding, since lexical abilities in young children have been shown to have predictive value for later skills, including academic performance (Duff et al. 2015). One possibility is that at the specific age the lexicon does not correlate with linguistic skills later on due to the variability in children's lexicons which does not allow for predictions to be made. In this case, the authors refer to variability in terms of the typological profiling contained in the child's cumulative expressive vocabulary output, in the sense that different parts of speech may have different predictive power on grammaticality (e.g. a verb vs. noun bias). Although the current investigation did not address lexical profiling, such a scenario could provide a plausible explanation for the absence of NDWS and MLU predictive correlations. In fact, the lack of detailed lexical profiling analysis might have masked any predictive power. Along this line, a number of studies conducted in English-speaking youngsters with typical language skills revealed the superiority of verb versus noun use in predicting morphological and grammatical skills (Conti-Ramsden and Jones 1997; Olswanget al. 1997). Specifically, research findings on the continuity between expressive vocabulary and MLU measured in morphemes, indicate that the grammatical load inherent in a verb along with its instrumental role in syntactic, morphological and morphosyntactic productions has greater impact on grammar as compared to nouns. Nevertheless, this overall linguistic profile suggests that linguistic subsystems are characterized by a high degree of interconnectedness, but also point to a possible developmental priority for sounds as opposed to grammar. Phonetic bootstrapping has been suggested in the past as mechanism by which other linguistic skills develop, thus setting sounds as the basis on which other skills later develop (Christophe et al. 1997; Stoel-Gammon and Sosa 2007). Overall, correlation analyses conducted in the current investigation revealed that PIS (segmental richness) correlated with most of the other language subtypes both within and across the age levels tested, supporting the existence of a "phonetic harness" to parallel phonological bootstrapping. A more detailed analysis of the particular segments established along with particular phonological, prosodic and syllable structure templates used, can provide further evidence regarding the crucial impact of phonological maturity and speech intelligibility on linguistic continuity, at least during the early stages of language development. With an increasing research and clinical emphasis in the field of cross-linguistic development, such detailed analyses wait further exploration.

A final aim of this study was to investigate whether these patterns are uniform for children of a certain age, or whether differences in performance skills affect children's linguistic behaviours. Dividing children in high and low performers on the basis of the three language skills tested resulted in the differentiation of language outcomes both within and across ages. The most notable finding was that the high performers at age of intake seized to exhibit the interactions found in the all participants analysis; they exhibited correlations only for grammatical skills between age of intake and age of reassessment as well as correlations between grammatical skills at age of intake and lexical skills at age of reassessment, suggesting across-domains and across age correlations between more complicated aspects of language (i.e., grammar in the form of MLU) and only predictively. On the other hand, children in the low performance groups showed a number of significant correlations, suggesting that it was this group of children possibly "driving" the effects as suggested by the overall performance regardless of group performance differentiation factor. Furthermore, for the group with a low phonetic inventory, phonetic skills early in the third year showed a positive relationship with both lexical and grammatical skills at the same age, but they also predicted phonetic skills at age 36 months. For the group with a low number of words, lexical skills early in the third year showed positive correlations with both phonetic and grammatical skills at the same age, but also predicted all language skills later in the third year. Finally, for the group with lower grammatical performance grammatical skills only correlated with phonetic and lexical skills synchronically, but showed no predictive value. Lexical skills here are those with a higher predictive value, as opposed to phonetic and grammatical; this could be due to the specific age level the children were assessed or to the fact that specific lexical types were not analysed. The third year sees an increase in lexical and then grammatical skills. When phonetic skills are still low, they do not predict any other skills, apart from a within-domain pattern, that is phonetic skills per se; this could be pointing to a system which struggles to develop its most basic abilities (segments) before moving on to more complicated and challenging linguistic landmarks. Conversely, when lower grammatical skills persist, they do not predict any other language domains, since these children could be working hard on other skills, before taking up the challenge of learning grammar. Children with low lexical abilities are the ones which might be going through the most pronounced advancement and this is evident in all other linguistic abilities as well. In contrast to the all participants analysis, children with less advanced skills have shown the size of the lexicon as a good indicator of simultaneous and subsequent language skills. The lexicon is shown here to have a strong predictive value for linguistic abilities at later times, following other studies which showed that the size of the lexicon can predict later performance in language or other skills (e.g. Fernald et al. 2006; Marchman and Fernald 2008).

As predicted by dynamic systems theory, variability is evident across participants, with children falling into different groups on the basis of their performance in all language skills under study, and these groups exhibit different linguistic profiles synchronically and predictively. Several real-time factors might be affecting the operation of each language subsystem at each point assessed resulting in different linguistic profiles between children both within and across ages. The groups with more advanced language skills show less correlations than the groups with less advanced skills, suggesting ceiling effects for advanced language learners which mask any effects in the correlational analyses. On the other hand, correlational analyses seem to capture more efficiently the development of less advanced learners, with relationships between language subsystems more evident both synchronically and predictively. Such correlations have been reported in the past; for example, Thordardottir (1998) studied Icelandic toddlers aged between 15 and 36 months of age, and showed correlations between the language measures used (e.g. MLU and sentence complexity), but not between language measures and age, suggesting the presence of such dynamic interconnections irrespective of the age of the child.

Looking beyond the theoretical implications of these findings, preschool language assessment on specific parameters including phonetic, lexical and grammatical skills would be useful in early language screening and identification of children "at risk" for linguistic and academic challenges (Aram and Nation 1980; Bishop and Edmundson 1987; Hulme and Snowling 2014; Curtin and Zamuner 2014). Such findings may have implications for the linguistic profiling of both typically developing (TD) and late talking (LT) children. The effects of early linguistic delay as a predictive factor of chronic language and academic challenges is well-documented (see Rescorla 2011 for a detailed review). Studies focusing the examination of semantic and phonetic skills offer robust evidence regarding "risk factor" predictability in 4-year-olds with early onset of expressive language delay (Paul and Alforde 1993; Mirak and Rescorla 1989). It has also been documented that children who present with diverse vocabularies have also more advanced phonological skills as compared to toddlers who exhibit restricted expressive vocabularies and consequently less advanced phonological forms (Paul and Jennings 1992; Rescorla and Ratner 1996). Furthermore, in a series of studies, Sosa et al. (2018) have provided evidence for early language delay normalization on the bases of combined articulatory and lexical discrepancies and dissociations. That is, intra-linguistic profiling gap (e.g., poor articulation but typical vocabulary skills) served as a strong predictor of communicative normalization without the need of early intervention. Notably, children with poor articulatory/phonological skills exhibited poor communicative outcomes suggesting that in examining articulatory delay vis-à-vis vocabulary skills, can provide valuable information regarding the need for early intervention and also where such intervention might focus (Sosa et al. 2018).

This is one of the first studies investigating linguistic interdependencies in Greek-Cypriot toddlers. Given the dynamic nature of language development trajectories, studies following children across larger time periods are necessary for accurately describing the trends and the times at which critical markers in language development appear, and the exact nature of such interdependencies between language subsystems. Additional measures of language development, as well as analyses of specific language patterns and subsystems (e.g., phonological intelligibility) need to be employed in order to describe the linguistic profiles of children more accurately. For example, although in highly inflected languages the MLU in words is a more appropriate measure of syntactic and grammatical growth (Leonard 2014; Petinou and Spanoudis 2014; Voniati 2016) it remains a restricted measure in the sense that it fails to capture morphosyntactic and morphophonological growth. Consequently, statements regarding the developmental relationship between grammatical, phonological and semantic interdependencies can be made on general levels and conclusions cannot be drawn regarding aspects of specific growth effects among language subsystems and vice versa. Finally, understanding the contributions of early language performance (e.g., cluster analysis) to later speech, remains a crucial challenge to the understanding of the nature of linguistic interactions and their clinical application in form of the “supply” (data driven analysis) and “apply” (evidence-based assessment) synergy facilitating assessment, prevention and application of effective early interventions regimes.

Future research should focus on discerning the true linguistic deficits in children with early speech delay and persisting linguistic deficits at later years on the bases of linguistic interactions. Therefore, assessment methods that focus on subtle and in-depth linguistic assessments, which are more closely linked to later outcomes, should be employed. Our future goal includes testing phonological awareness, and other factors related to phonology, semantic profiling, lexicon, syntax, and grammar, as these parameters are the basis for reading and academic performance (e.g. Muter et al. 2004; Schuelle 2004; Duff et al. 2015). Thus, the interaction between linguistic and academic skills and the negative impact of early language delay would be identified.

In conclusion, the study indicates that linguistic interdependencies seem to be evident at different points in development, especially during the critical years for language development, but still remain to be clearly delineated. Moreover, the characterization of the nature and of the operation of language interdependencies awaits further investigation, as a detailed examination of the interactions between language subsystems beyond the pre-linguistic and early linguistic stages remain understudied. Although developmental language data and theory-motivated research has provided us cross-linguistically with invaluable information regarding the child’s path towards reaching the adult language model, more research is needed, for shedding light onto the ways language systems interact, interphase and support each other during the dynamic process which underlies language acquisition.

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