Differentiating Normal Variability From Inconsistency In Children'S Speech: normative Data

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Research Report

Differentiating normal variability from inconsistency in children's speech: normative data

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Abstract

Background: In young, typically developing children, some word production variability is expected, but highly inconsistent speech is considered a clinical marker for disorder. Speech–language pathologists need to identify variability versus inconsistency, yet these terms are not clearly differentiated. Not only is it important to identify inconsistency, but also it needs to be defined and measured so that clinical decisions are evidence based. In order to understand inconsistent speech production, typical variability must be described.

Aims: This paper differentiates between variability and inconsistent productions. Variability is defined as productions that differ, but can be attributed to factors described in normal acquisition and use of speech. Inconsistency is speech characterized by a high proportion of differing repeated productions with multiple error types, both segmental (phoneme) and structural errors (consonant–vowel sequence within a syllable). The study describes and quantifies the consistency of word production in typically developing children aged between 3;0 and 6;11 years.

Methods and Procedures: This paper reports a large cross-sectional study (n=409) of the consistency of children's production of words within the same linguistic context.

Outcomes and Results: The study found that the speech of typically developing children is highly consistent. Children in the youngest age group demonstrated the highest levels of variability, but it remained below 13% with 10% reflecting maturational influences.

Conclusions: Inconsistent production cannot be considered a typical feature of speech development. The results inform differential diagnosis of speech disorder.

Keywords: variability, inconsistency, whole word production, speech development.

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Introduction

It is often assumed that children referred for assessment of a speech disorder pronounce words in the same way every time they say them. For example, children name pictures only once on most assessments of articulation and phonology. Previous research, however, indicates that some children make inconsistent errors (Dodd *et al.* 1989, Ozanne 1995, Forrest 2003). Despite these findings, little is known about the extent to which typically developing children's productions of the same word differ when they are produced more than once. Although variability in young children's speech has often been reported, particularly during the early stages of speech development (Ingram 1989, Vihman 1996, Stackhouse and Wells 1997), most studies investigating the development of speech in typically developing children do not measure speech production consistency. Studies that have measured consistency of production indicated that typically developing children's pronunciation is highly consistent (Burt *et al.* 1999, Williams and Stackhouse 2000). Given that inconsistent speech is a feature used to diagnose differentially pervasive speech disorder it is important to determine the consistency of word production in children with typically developing speech. The aim of the research reported here was to establish normative data for consistency of word production in 3;0–6;11-year-old children.

Operational definitions for variability versus inconsistency

The terms 'variability' and 'inconsistency' are often used interchangeably. Marquardt *et al.* (2004) highlighted the 'lack of operational definitions for inconsistency and variability' (p. 128). It is important to define normal variability and also to differentiate this from atypical inconsistency. Variability can be defined as repeated productions that differ, with the variability attributed to factors described in normal acquisition and use of speech (e.g. phonetic context, pragmatic influences, maturation or cognitive–linguistic influences). It is the purpose of this paper to describe this variability. In contrast, inconsistency is speech characterized by a high proportion of differing repeated productions with multiple error types (unpredictable variation between a relatively large number of phones and/or structural changes, e.g. [drʌkm kinʌ, fokum timʌ, bwokjum kinʌ] for vacuum cleaner; Bradford and Dodd 1996) that cannot be attributed to factors responsible for normal variability. Inconsistency is qualitatively and quantitatively different to developmental variability. It is characteristic of a pervasive speech disorder categorized by Dodd (1995) as inconsistent speech disorder.

Variation across children

A number of studies have shown that variation across children occurs in early phonological development. For example, Ferguson and Farwell (1975) presented longitudinal data on three children acquiring their first 50 words. They suggested that individual differences across children learning the same language partly reflected the different strategies adopted by the children. Individual strategies reflected preferences for sounds, sound classes, features, markers for classes of words, preferences for lexical expansion or phonological differentiation and avoidance of particular sounds. Similarly, Vihman and Greenlee (1987) examined the

spontaneous speech of ten typically developing 3-year-old children. They also reported differences across children, in particular the use of prosodic processes and consistency in the use of cluster reduction and segment substitution (reporting a range of 0–89%). Vihman (1993) concluded that the findings of previous studies on variability across children indicated the operation of internal factors such as differences in anatomical structure, rate of physiological maturation, attention, memory and learning, or the integration of input (McLeod 2003). These factors, however, cannot explain why children might pronounce the same words differently on repeated productions. A range of factors has been suggested as being associated with within-child variability in word production.

Factors associated with normal within-child variability

All children exhibit some variability in their production of a particular word or particular context-specific phonological features (Grunwell 1981, Dodd 1995). The variability may take several forms. It may also be due to different factors. For example, phonetic context (e.g. position of the sound in the word) may affect the phonetic accuracy of phonemes. In a study of typically developing children, Kenney and Prather (1986) found that the phoneme /ʃ/ was produced more accurately in word initial than in word final position. Similarly, the surrounding consonants have been shown to affect accuracy of production (Haynes *et al.* 1982).

Some phonetic variability may be attributed to the motor variability inherent in developing speech motor systems of young children. Kinematic studies have found that jaw movement stabilizes earlier than upper and lower lip movement. Green *et al.* (2002) investigated the sequential development of the articulators by examining the upper lip, lower lip and jaw movements of 1-, 2-, 6-year-olds and adults during speech. Within-subject comparisons revealed mature movement patterns for speech emerging earlier in the mandible than the upper and lower lips. The 1-year-old jaw movements were consistent and similar to that of the adults. The investigation revealed age-based differences in lip movement patterns.

In other cases, the production of a word may be variable (in comparison with the production of phonemically similar words) because of an isolated misperception and/or misrepresentation of that word in the child's lexicon (Dodd 1995, Stackhouse and Wells 1997). Alternatively, variability may signal a transitional period as more mature realizations of words develop (Grunwell 1981, Ferguson and Farwell 1975, Dodd and Bradford 2000, Forrest *et al.* 2000).

Pragmatic context may also trigger production variability in children. For example, Weiner and Ostrowski (1979) reported that listener uncertainty prompted children to change their productions of words. Lack of opportunities for feedback during conversation has also been reported as a cause of variability in speech production (Stampe 1969).

Cognitive–linguistic influences can affect consistency of speech production. For example, changing the linguistic context of the word from single word imitation to spontaneous speech may alter its production realization (Kenney *et al.* 1984, Healey and Madison 1987, Dodd *et al.* 1989). A large normative study of 684 British English-speaking children aged 3;0–6;11 years sampled two contextual tokens of a set of 14 target words (Dodd *et al.* 2003). Children produced the target words in single-word and spontaneous sentence contexts. Children's realizations of the target words in the

two contexts were compared. A developmental progression was evident with single word versus connected speech agreement increasing with age. This type of variability is not well understood. Two hypotheses emerge: that the number of phonological features children can include in any one phonological plan is limited resulting in speech–language trade-offs; or that variability may reflect the use of rules that regulate whole utterances rather than single words (Dodd and McCormack 1995).

Trade-offs also occur outside of context variables. Leonard *et al.* (1981) studied new word acquisition. They reported that the child making a trade-off between production of the appropriate consonants and maintenance of the word shape could exhibit variability in successive attempts at new vocabulary items. Crystal (1987) presented a 'bucket theory' to account for variability which has some similarities with the concept of trade-offs. His theory was that children's variability is the result of an interaction between the many components of language: An increase in demand in one component of language (i.e. phonetics, phonology, morphology, syntax, semantics or pragmatics) results in 'spillage' of skills from another component. The results of these experiments, designed to account for variable production of words, do not provide data about the extent of variability in children's single-word production during the period of phonological acquisition.

Effect of age on variability

Younger children are reported to be more variable in their production of words than older children (Grunwell 1987, Menn and Stoel-Gammon 1995, Teitzel and Ozanne 1999). However, Hewett (2002) noted that few studies on variability in the speech of typically developing children had investigated beyond the first 50-word stage, and claimed that:

> the few studies that are available suggest that variability within individuals continues to feature prominently in development beyond the acquisition of the first fifty words.
>
> (Hewett 2002: 151)

This assertion is not supported by the available evidence.

Diadochokinetic tasks

Williams and Stackhouse (2000) described 30 typically developing 3–5-year-old children. They found a developmental progression with age: 5-year-olds were the most consistent (91.6%), followed by 4-year-olds (89.7%) and then 3-year-olds (84.5%). They reported that the children's consistency of response improved significantly between 3 and 4 years of age, although significant difference between 4 and 5 year olds was reported. However, the children's variable productions remained minimal in the overall responses and decreased with age. Further, the majority of the children's responses were consistent, even when inaccurate. These findings are not surprising given the important speech development that occurs at this age (Grunwell 1987, Ingram 1989).

Speech sounds

Kenney and Prather (1986) studied the consistency of production of children aged from 2.5 to 5 years on nine frequently misarticulated phonemes. They found that the

number of errors of production on these phonemes significantly decreased with increased age.

Lexical items

Burt *et al.* (1999) described the phonological variability (a comparison of imitation, naming and connected speech contexts) and word consistency (comparison of three productions in the same single-word naming linguistic context) of 57 typically developing children aged 46–58 months. They found that age negatively correlated with phonological variability. The older children in their study had the same production across all speech contexts, reflecting the increase in accuracy and stability of the phonological system of children in this age range. Although there was no statistically significant difference between the word inconsistency scores of younger (5.7%) and older (3.6%) children, this is not surprising because the age range investigated spanned only 12 months, both groups showing ceiling performance at this age.

These studies provide some preliminary evidence for the effect of age on the consistency of speech production of children. Rice (1996) hypothesized that variable production was evident in unstructured systems and that variability gradually decreased as knowledge of contrasts emerged. Although the reviewed studies found that minimal variability existed, more data are required to clarify the degree of normal variability across the age range typical of children referred for assessment of speech disorders. This information would allow the extent of inconsistency indicative of disordered speech development to be determined.

Effect of gender on variability

Girls are generally thought to perform better than boys in verbal and linguistic functions (Winitz 1969, Maccoby and Jacklin 1974, Halpern 1986). McCormack and Knighton (1996) reported that 2.5-year-old girls had more accurate phonological output than boys. Hyde and Linn (1988) conducted a meta-analysis of over 170 studies and found that gender accounted for approximately only 1% of the variance in speech and language acquisition. The only exception was in the area of speech production, where girls performed better than boys. Moore (1967) studied the speech and language development of children during their first eight 8 years. Measures of intelligence and linguistic development were taken longitudinally. Similar to the findings of Hyde and Linn, the only significant gender difference lay in the higher speech quotient of the girls at the age of 18 months. The findings indicate that typically developing girls do better than boys in terms of phonological accuracy and consistency reflecting data from research on children with atypical speech and language acquisition.

Weindrich *et al.* (1998) found that more boys than girls had speech and language disorders. They found statistically significant gender differences for expressive disorder at 2 years of age and speech disorder at the age of 4.5. Kenney and Prather (1986) investigated gender differences in the speech production variability of children aged 3–5 years, reporting that boys were significantly more variable than girls. However, a study of the speech skills of 4-year-old children revealed no gender effect in terms of consistency of production (Burt *et al.* 1999). The difference

between the findings of these two studies, probably due to differences in the ages of the populations studied and the tasks administered, needs to be resolved through further research.

Previous research indicates that boys' speech acquisition is slower than that of girls and is more likely to be disordered. Differences in both biological maturation (Templin 1957, Darley and Winitz 1961, Hyde and Linn 1988) and social environment (Moore 1967) have been suggested as explanations for gender differences in speech development. Lewis (1990) proposed a 'sex-specific threshold' that interacts with social and environmental factors to make boys more vulnerable to speech disorders. Nevertheless, available data concerning gender differences for variability in speech production are limited and require more detailed investigation.

Variability of speech production in children with speech difficulties

Research on the variability of speech production in children with speech difficulties tends to discuss variability associated with mode of elicitation or process application. Weston (1997) investigated the influence of elicitation variables on the speech production of 15 children with speech delays of unknown origin. The investigation compared children's productions of target words in self-generated sentences and adult-modelled sentences. Elicitation affected production with adult-modelled sentences resulting in more accurate productions. This finding, however, does not explain why some children with speech disorder pronounce words differently in repeated productions of the same words in confrontation naming tasks.

Another clinical perspective is that variability is a positive sign of change. For example, Grunwell (1992) described categories of variability that can be used to indicate whether the child's speech system is undergoing change. She argued that variability can only be considered positive when there is evidence that the change results in a production closer to the target. These findings illustrate the need for further investigation to determine the degree and type of variability that is typical of phonological acquisition.

Inconsistency indicative of disorder

The inconsistent speech errors of some children do not seem to fit any of the possible causes of normal variability. Inconsistency characterized by multiple error types (unpredictable variation between a relatively large number of phones and phonotactic errors) suggests a lack of systemic stability. This type of inconsistency indicates more pervasive speech processing difficulties (Grunwell 1981, Williams and Stackhouse 2000). Forrest *et al.* (1997) considered variability of errors as having a negative impact on speech sound learning. High variability is thought to limit the acquisition of new phonemes as inconsistency hinders the development of phonemic categories (Forrest *et al.* 2000). Grunwell (1981) also claimed that the degree of variability should be taken to be a potential indicator of deviant or disordered speech. Forrest *et al.* (2000: 530) stated that:

> "variation must remain within certain limits" and that "variability will have a negative impact on phonological acquisition and may contribute to a profile that characterizes children with persistent phonological disorders" (p. 530).

Crosbie *et al.* (2005) identified two groups of children with phonological disorder: children who consistently make developmentally atypical errors (e.g. bilabial fricatives marking all clusters, affrication, velar replacement of alveolars) and those who inconsistently produce the same words or phonological features not only from context to context, but also within the same context (McCormack and Dodd 1996, Holm and Dodd 1999, Dodd and Bradford 2000). In other words, they are likely to pronounce the same word differently each time they say it.

Children with inconsistent speech disorder (Dodd *et al.* 2005) differ from children with childhood apraxia of speech (CAS) in surface speech error characteristics and underlying deficit. Unlike children diagnosed with CAS, children with inconsistent speech disorder have age appropriate oro-motor ability, normal prosodic patterns and their speech accuracy (PCC) increases on imitation tasks.

Describing and analysing the inconsistent child's surface error pattern in terms of phonological rules is not possible and deciding the focus of therapy is difficult (Dodd and Bradford 2000). Forrest *et al.* (2000) agreed that it is difficult to choose phonemes to contrast in therapy for children who make inconsistent errors. Clinical efficacy studies (Dodd and Bradford 2000, Crosbie *et al.* 2005) indicate that children who make inconsistent speech errors are less likely to respond positively to therapy that is based on phonological contrasts. These findings suggest that the deficit underlying inconsistent speech disorder differs from that of children who respond well to phonological contrast therapy.

A deficit in phonological planning is thought to underlie inconsistent speech disorder (i.e. generating a plan for word production that specifies the sequences of consonants and vowels to be produced) (Chiat 1983, Bradford and Dodd 1994, 1996, Bradford-Heit and Dodd 1998). Dodd and McCormack (1995) argued that children with speech characterized by inconsistency generate under-specified or degraded phonological plans for word production. Such an impairment in phonological assembly might be due to children having established inaccurate mental phonological representations of words (Griffiths and Snowling 2002), problems accessing accurate phonological representations or difficulty 'setting-up' the phonological plan. An incomplete phonological plan leads to inadequate phonetic programmes (Ozanne 1995) with articulatory parameters that are too broad (i.e. neural messages that sequence speech movement provide imprecise instructions).

Alternatively, it could be argued that variability and inconsistency in children's speech are on a continuum. Quantifying consistency on a percentage scale implies a continuum, but does not discriminate between different underlying sources of inconsistent production. If typically developing children's inconsistency scores are low, while a small group of children with speech disorder score is more than 2 standard deviations higher, then the two groups' sources of inconsistent production are likely to differ. Additional evidence can be derived from the type of changes made to repeated pronunciations. To examine this argument the extent of consistency in typically developing children's multiple productions of words needs to be examined both quantitatively and qualitatively. The results will provide normative data that will allow clinicians to discriminate between typical variability and inconsistent speech disorder.

Aims and hypotheses

The purpose of the present study was to describe and quantify the degree and nature of consistency of word production in children's speech. The paper reports data on the consistency of children's speech from 3;0 to 6;11 years. It also investigates the effect of age and gender on the consistency of production. The following are hypothesized:

- Inconsistency will not be a prominent feature of the speech of any age group. However, age will have an effect on the variability of word productions: older children will be less variable in their productions than younger children.
- Most children's productions will be consistently correct, however, they will also have some consistent incorrect productions.
- Proportion of consistent incorrect productions will decrease with age (as accuracy increases).
- Variable productions are likely to be variations between incorrect and correct forms (due to a transitional period as more mature realizations of words develop).
- Consistency of word production will reveal gender differences: girls will be more consistent than boys.

Methods

Participants

A total of 409 British children aged 3;0–6;11 years participated in the study. This age range was chosen because it reflects the age of referral of most children with speech disorders. The sample contained 191 boys (46.7% of the sample) and 218 girls (53.3% of the sample). Table 1 summarizes the sample by age group. The assessment data reported in this paper were collected at the same time as data for the Preschool and Primary Inventory of Phonological Awareness (Dodd *et al.* 2000) normative study in the UK in 1999. A letter explaining the purpose of the study and inviting participation was sent to schools and nurseries. All children in participating schools and nurseries were given an information letter and a consent form to take home to be signed by parents. Only monolingual English speaking children not currently attending speech therapy were included in the sample. Parents were invited to attend

Table 1. UK sample by age

Age group (year; month)	*n*	Mean age	Standard deviation (months)	Percentage of sample
3;0–3;5	20	3;3	1.46	4.89
3;6–3;11	48	3;9	1.62	11.74
4;0–4;5	44	4;2	1.86	10.76
4;6–4;11	92	4;9	1.57	22.49
5;0–5;5	85	5;2	1.61	20.78
5;6–5;11	75	5;9	1.68	18.34
6;0–6;5	38	6;2	1.69	9.29
6;6–6;11	7	6;6	0.00	1.71
Total	409			100

the assessment. To reach quotas in terms of age and gender in particular geographic areas, assessors randomly selected children who had documented consent for participation in the study.

Description of stimulus materials

The task that was used in this study was the Inconsistency Assessment (Dodd 1995), which measures how consistently children produce words in the same linguistic context (i.e. same word in confrontation naming task). Each child was asked to name 25 easily recognizable coloured pictures on three separate occasions within the session. The 25 words consist of one to four syllables, and sample most of the consonant and vowel sounds in English (see appendix A for a list of the 25 words and table 2 for a description of the words' characteristics).

Procedure

Data collection

Undergraduate and postgraduate speech–language pathology students carried out testing. All of the assessors were trained in administration, transcription and analysis of the Inconsistency Assessment. Each child was assessed individually in a quiet room in their nursery or primary school. The three trials of the 25 words were separated by an unrelated activity (a phonological awareness task). A broad phonetic

Table 2. Characteristics of items from the inconsistency assessment

Consonant (n=24)	Frequency		Syllable shape	Frequency
	Syllable: initial	Syllable: final		
m	1	2	V	3
b	5	1	CV	13
t	3	3	VC	3
d	3	2	CVC	19
k	4	4	CCV	2
g	2		CVCC	4
m		2	CCVC	4
n	2	1		
ŋ		2		
f	3			
v		1		
θ	1	2		
ð			Length of syllables	Number of items
s	4	1	1	12
z	2	1	2	4
ʃ	1	1	3	6
tʃ	1	1	4	3
dʒ	1	1		
l	1	4	Length of phonemes	Number of items
r	5		3	9
w	1		4–6	8
j	1		7–11	8
h	1			

transcription was made after each production of the 25 words. When the transcriber did not hear the child's production clearly the child was asked to repeat the word. The assessor provided cues or a model for imitation if the child was unable to name a picture. If the child imitated the target word in the first trial then it was also elicited via imitation in the second and third trials. This process ensured the target word was produced in the same linguistic context on all three trials. These productions were included in the analysis. Imitated responses were included in the sample to maximize the amount of data collected and to ensure that as many words of different phonotactic structures were included in the sample. This was done to minimize the possibility that younger children might have produced fewer multisyllabic words and this might have skewed the results.

When a child failed to provide a response for any target word in any of the three trials this item was excluded from the analysis. Therefore, the percentage inconsistency score is a percentage that reflects the number of items completed by an individual child (i.e. usually but not always 25 items).

Tape recordings were also made to allow the revision of transcription difficulties and transcription reliability measurement. The transcribers reviewed each transcription with reference to the audiotapes to ensure the accuracy of their online transcriptions. Once completed, the three transcribed productions of each of the 25 words were compared.

Scoring and analysis

Inconsistency score

The assessment was administered and scored in accordance with the test's instructions (Dodd 1995). This process involved each child's production being transcribed phonemically and compared across the three trials. When all three productions of a word were the same, the word was considered consistent, irrespective of whether the word was produced accurately. A word was considered variable when any differences in production occurred across the three trials. An inconsistency percentage score was determined by dividing the number of variable words by 25 (or number of completed items) and multiplying by 100. Broad phonemic transcriptions were used to establish variation in children's productions for two reasons. The first reason was to reflect typical practice in clinical settings. The main aim of this research was to provide clinically useful normative data. Although phonetic transcription might have allowed more theoretical insights, clinical applicability was considered more important. It is unlikely that the majority of clinicians would have confidence in their narrow phonetic transcription skills or have access to tools for spectrographic analysis. Secondly, previous research using acoustic (Nittrouer 1993) or kinematic tools (Smith and Goffman 1998) has already examined stability of gestural patterning at the segmental level. The consistency of whole word production in typically developing children has not been previously described or quantified.

For statistical analysis, responses were categorized in one of four ways:

- Consistent correct: all three responses were the same and produced accurately.
- Consistent incorrect: all three responses were the same but contained at least one error.

- Variable — no hits: the three responses differed and all contained phonological errors.
- Variable — with hits: the three responses differed but at least one production was accurate.

Reliability

Inter-rater reliability measures were taken for the phonemic transcriptions and the inconsistency score.

Phonology samples

Broad transcriptions (phonemic) were made online during administration of the Inconsistency Assessment. To determine inter-judge reliability an independent experienced trained transcriber (a speech and language clinician) re-transcribed 30 children's data: 7.3% of the transcriptions (2250 words). Point-to-point reliability was calculated based on each judge's transcription of each phoneme. Identical segmental transcriptions (excluding diacritics) were coded as agreements. The overall mean for speech transcription agreement was 99.01% across the 30 samples, with a range from 95.45 to 100%. It is important to note that these transcriptions were of typically developing children's speech. They contained few errors, resulting in high reliability of the transcriptions. A Pearson correlation coefficient was also calculated to determine further the level of inter-rater reliability of the transcriptions. The per cent phonemes correct (PPC) values of each of the transcribers for the 30 samples were compared, and the result $r=0.96$ and $p<0.01$, confirms the high inter-rater agreement between the two assessors.

Inconsistency score

Each assessor determined an inconsistency score for each child's transcription. The 30 samples that were re-transcribed to examine transcription reliability were also used to examine the reliability of the Inconsistency Scores. The reliability transcriber also determined which items were produced differently by each child and calculated an Inconsistency Score for each of the transcribed samples. Point-to-point reliability was calculated based on both judge's score for each of the 25 items (variable versus consistent production). Identical scores were coded as agreements. The overall mean for inconsistency score agreement was 95.2% with a range from 88 to 100%. A Pearson correlation coefficient was also calculated to determine the level of inter-rater reliability of the total Inconsistency Scores allocated to each child. The Inconsistency Score of both the original assessor and the reliability transcriber were compared, and the result $r=0.98$ and $p<0.01$, confirms the high inter-rater agreement between the two assessors.

Results

The mean percentage consistency scores (SD) for girls and boys at each age group are provided in table 3. It shows that the majority of children's responses were

Table 3. Mean percentage (standard deviation) of responses of girls and boys at each age group

		Consistent		Variable	
Age (years; months)		Correct	Incorrect	No hits	With hits
3;0–3;5	Whole	76.48 (21.64)	10.56 (11.32)	3.41 (9.99)	9.55 (9.74)
	Male	73.41 (25.60)	13.09 (12.78)	5.83 (13.19)	7.67 (10.80)
	Female	80.25 (16.24)	7.46 (8.95)	0.44 (1.33)	11.85 (8.29)
3;6–3;11	Whole	78.92 (20.55)	9.07 (11.26)	3.77 (7.57)	8.23(8.86)
	Male	70.23 (23.41)	13.72 (13.57)	5.82 (10.54)	10.22 (7.94)
	Female	84.13 (16.96)	6.29 (8.72)	2.53 (4.87)	7.04 (9.29)
4;0–4;5	Whole	86.91 (14.39)	6.18 (7.87)	1.08 (4.25)	5.83 (8.21)
	Male	82.03 (18.78)	7.29 (9.49)	2.55 (6.61)	8.13 (11.08)
	Female	89.99 (10.00)	5.48 (6.76)	0.15 (0.77)	4.38 (5.51)
4;6–4;11	Whole	90.29 (9.82)	4.39 (6.97)	0.61 (1.96)	4.70 (4.84)
	Male	89.15 (8.89)	5.43 (5.86)	0.89 (2.40)	4.53 (5.22)
	Female	91.40 (10.61)	3.40 (7.82)	0.34 (1.40)	4.86 (4.49)
5;0–5;5	Whole	93.46 (7.87)	2.35 (4.67)	0.38 (1.91)	3.81 (4.89)
	Male	92.70 (8.19)	2.60 (4.11)	0.60 (2.65)	4.10 (5.30)
	Female	94.13 (7.61)	2.13 (5.16)	0.18 (0.83)	3.56 (4.53)
5;6–5;11	Whole	94.03 (9.49)	3.09 (6.22)	0.59 (2.61)	2.29 (3.73)
	Male	92.35 (12.89)	4.00 (8.53)	0.94 (3.56)	2.71 (4.03)
	Female	95.41 (5.02)	2.34 (3.22)	0.29 (1.38)	1.95 (3.48)
6;0–6;11	Whole	95.82 (5.84)	1.6 (3.56)	0.18 (0.84)	2.4 (3.56)
	Male	95.53 (6.43)	2.15 (4.26)	0.15 (0.78)	2.15 (3.79)
	Female	96.21 (5.07)	0.84 (2.14)	0.21 (0.92)	2.74 (3.28)

correct and consistent (e.g. 76.5% of the 3;0–3;5-year-old's responses). For statistical analysis the children in the last two 6-month age bands were collapsed into one group because of the small number of children in the 6;6–6;11 age group ($n=7$). An analysis of variance with repeated measures (between-subjects factors of age and gender, within-subjects factor of response: number of responses consistent correct, consistent incorrect, variable — with hits, variable — no hits) examined the consistency data.

The results showed a significant effect of age ($F=7.35$, d.f.$=6$, $p<0.001$). The estimated effect size (η^2) was 0.10 with an observed power of 1.00, indicating the strength of the effect size. Bonferroni post-hoc comparisons of the group differences are shown in table 4. The 3-year-old children were less consistent than the older children. By 3.5 years of age the children's productions were highly consistent and no significant differences in consistency scores were observed.

Table 4. Post-hoc comparisons of mean differences in type of responses between age groups

Age (years; months)	3;0–3;5	3;6–3;11	4;0–4;5	4;6–4;11	5;0–5;5	5;6–5;11	6;0–6;11
3;0–3;5	–						
3;6–3;11	*	–					
4;0–4;5	*	n.s.	–				
4;6–4;11	*	n.s.	n.s.	–			
5;0–5;5	*	n.s.	n.s.	n.s.	–		
5;6–5;11	*	n.s.	n.s.	n.s.	n.s.	–	
6;0–6;11	*	n.s.	n.s.	n.s.	n.s.	n.s.	–

*$p<0.05$; n.s., non-significant.

Table 5. Breakdown of the mean percentage (standard deviation) of responses by gender

		Male (n=191)	Female (n=218)
Consistent	correct	88.01 (15.53)	91.50 (11.04)
	incorrect	5.52 (8.53)	3.54 (6.54)
Variable	no hits	1.64 (5.60)	0.57 (2.22)
	with hits	4.83 (6.71)	4.39 (5.84)

The effect of gender was significant (F=4.92, d.f.=1, p<0.05). The estimated effect size (η^2) was 0.01 with an observed power of 0.60. Inspection of the mean percentages of consistent responses by gender (table 5) indicated that girls produced more consistent correct responses and less variable incorrect responses than boys. The interaction between age and gender was significant (F=6.99, d.f.=6, p<0.001). The estimated effect size (η^2) was 0.10 with an observed power of 1.00. Table 6 shows post-hoc Bonferroni comparisons of gender by age group.

The effect of response type was significant (F=6582.74, d.f.=3, p<0.001). The estimated effect size (η^2) was 0.94 with an observed power of 1.00. Table 7 shows post-hoc Bonferroni comparisons. All children produced significantly more consistent correct responses than any other response type. When children produced variable responses the responses were usually a variation between a correct and incorrect production (variable — with hits). It should be noted that variable responses were not a frequent occurrence in children at any age. That is, variable — no hits responses were rare. Children produced a similar number of incorrect but consistent responses and responses that were variable with hits.

The results also showed a significant interaction between the type of response and age (F=15.62, d.f.=18, p<0.001). The estimated effect size (η^2) was 0.19 with an observed power of 1.00. Children in the youngest age group had fewer consistent correct productions and more consistent incorrect productions than children in the older age groups. As children got older they produced more consistent correct responses than consistent error responses, and fewer variable error responses than variations that reflected maturation.

Table 6. Gender post-hoc comparisons of differences in type of responses by age

Type of response	3;0–3;5	3;6–3;11	4;0–4;5	4;6–4;11	5;0–5;5	5;6–5;11	6;0–6;11
Consistent correct	n.s.	*	*	*	*	*	n.s.
Consistent incorrect	*	*	n.s.	*	n.s.	n.s.	n.s.
Variable: no hits	*	*	n.s.	n.s.	n.s.	n.s.	n.s.
Variable: with hits	n.s.	*	*	n.s.	n.s.	n.s.	n.s.

*p<0.001; n.s., non-significant.

Table 7. Post-hoc comparisons of differences in type of responses (p-values)

Response	Consist correct	Consist incorrect	Variable: with hits	Variable: no hits
Consistent correct				
Consistent incorrect	0.00			
Variable: with hits	0.00	1.00		
Variable: no hits	0.00	0.00	0.00	

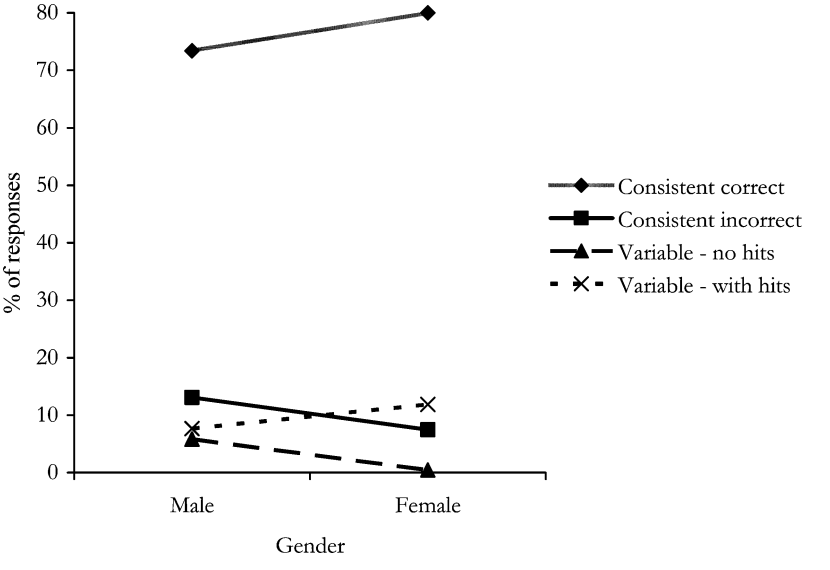

Figure 1. Interaction between gender and type of response in children aged 3;0–3;5.

The interaction between response and gender was also significant (F=11.20, d.f.=3, p<0.001). The estimated effect size (η^2) was 0.03 with an observed power of 0.99. Inspection of the mean percentage of responses for boys and girls (table 5) revealed that boys produced more consistent incorrect productions than girls. Boys also produced more responses that contained three error productions than girls.

The interaction between age, gender and the type of response was significant (F=1.80, d.f.=18, p<0.05). The estimated effect size (η^2) was 0.03 with an observed power of 0.97. Inspection of the data (table 3) revealed the interaction was due to the different profiles of performance by boys and girls in the youngest age group. The majority of responses made by all children were correct and consistent. However the boys in the youngest age group made more consistent incorrect responses than the girls. The girls made more responses that contained a correct and incorrect production of the target (variable — with hits) than the boys. Figure 1 plots the interaction.

Discussion

This study examined the consistency of word production in 409 British English-speaking children aged between 3;0 and 6;11 years. Children's responses (three productions of a word in the same linguistic context) were classified as consistent correct, consistent incorrect, variable — no hits, or variable — with hits. It was hypothesized that variability would be found at relatively low levels in the youngest children and that these levels would decrease with age. The results supported this hypothesis: consistency of phonological production developed with age. Gender was hypothesized to influence consistency. Girls were predicted to be more phonologically consistent than boys. In general, the results confirmed that girls

had higher levels of correct consistent productions. However, while boys were not necessarily more variable, they were less accurate (i.e. produced more consistent incorrect productions). The effect of age and gender on consistency, are discussed separately.

Effect of age on consistency of word production

Few studies have measured consistency of word production in typically developing children beyond the age of 3.5 years despite inconsistency being considered a marker for pervasive speech disorder (Grunwell 1981, Dodd 1995, Forrest *et al.* 2000). It is clinically important to distinguish between normal variation and inconsistency as a feature of impairment. The results of this large study provide evidence that children's word productions elicited in the same linguistic context are highly consistent. While there was evidence of limited variability in the youngest age group in this study this variability decreased with age.

It was hypothesized that age would have an effect on the consistency of production and that older children would be more consistent than the younger ones. The results confirmed this hypothesis: 3-year-old children were significantly more variable than the older children in the sample. Although there was a significant difference between the children in the youngest age band and the rest of the group, it is important to examine the degree of variability and the pattern of response. In the 3;0–3;05 age group the mean percentage variability was only 13%. Two response patterns were classified as variable: variable — no hits (i.e. those containing three error productions) and variable — with hits (i.e. those containing a variation between an immature and mature realization). The second pattern is considered to reflect maturation or phonological change. Examination of the mean percentages of variable responses in the youngest age group revealed that the majority of variable responses (approximately 10/13%) were variable — with hits. Only 3% of young typically developing children's variable productions reflected the production of more than one error form. By the time children were 4.5 years of age their word productions were highly consistent (>95%).

The findings of this study are comparable with previous research that found consistency of production increased with age (Kenney and Prather 1986, Burt *et al.* 1999, Teitzel and Ozanne 1999, Williams and Stackhouse 2000). Williams and Stackhouse reported a significant improvement in the consistency of diadochokinetic performance in typically developing children's productions between the ages of 3 and 4 years. The results of this study confirm that children's word production is highly consistent. When there are variable productions it predominantly reflects phonological maturation.

Phonological maturation could be accounted for by lexical learning, better specification of phonological representations, and changes in peripheral auditory or motor abilities. The current data describes changes in consistency of speech production in typically developing children but does not explain it. Now that normative data has been established future research will be able to explore the processes that underlie the change. Words produced with repeated productions characterized by multiple error types (unpredictable variation between a relatively large number of phones, and/or structural changes) are not a feature of normal phonological development.

Effect of gender on consistency of word production

This study found that gender exerted an influence on consistency of word production until 6 years of age. It was hypothesized that gender would have an effect on consistency of word production and that girls would be more consistent than boys. The results confirm this hypothesis but the pattern of gender-related differences across age is complex. An interaction between gender and age in phonological development has been reported in the literature, although the studies disagree about when gender-differences occur. Smit *et al.* (1990) studied phonological acquisition and found statistical differences in gender only in the 4;0-, 4;6- and 6;0-year age groups. Kenney and Prather (1986) found that the boys in their study made more errors and were more variable than girls between the ages of 2;6 and 5;0 years. In contrast, Burt *et al.* (1999) found no effect of gender on consistency of production. The findings of this study indicate that there was an interaction between age, gender and accuracy of response. Girls produced more consistent correct responses than boys between the ages of 3;6 and 5;11 years. The results probably reflect the trend for girls to master phonology earlier than boys.

A large body of research reports gender bias in speech disability (Chazan *et al.* 1980, Shriberg *et al.* 1999, Cheung and Abberton 2000). More boys than girls have speech development delays and disorders. Inconsistency is not a feature of normal development, however it is a significant feature of disorder. It is possible that the gender difference evident in the consistency of production within the normal population will be even more evident in a disordered population.

Clinical implications

Results of this investigation have significant implications for the assessment of developmental speech disorders. Approximately 6% of the pre-school/school population are referred to speech and language therapy because of concerns about their speech skills (Enderby and Phillipp 1986, Broomfield and Dodd 2004). Speech and language therapists are required to assess and decide whether a child's speech skills are developing normally. It is essential that reliable and representative data about various aspects of speech production (e.g. phonetic, phonological, consistency) are available to make clinical decisions.

The data reported in this paper were based on a large representative sample and provide important information regarding the consistency of typically developing children's speech. Specifically, the findings of the current study revealed that age and gender have an effect on consistency of productions.

It is difficult to pinpoint when behaviour evident to a limited extent in normal development becomes a characteristic of impairment. Clinicians need to differentiate between sources of variability and inconsistency. When a child is producing a significant percentage of words in error within identical linguistic contexts, that inconsistency is characteristic of impairment.

Dodd (1995) set a criterion of 40% variable production as indicative of an inconsistent speech disorder. The most variable age group (3;00–3;05 years) within the normative study had a mean inconsistency score of 12.96%. Therefore, Dodd's 40% cut-off is almost 2.5 standard deviations (SD) above this mean. The group of children with inconsistent speech disorder described in the literature is significantly different to typically developing children in terms of their degree of inconsistency

(McCormack and Dodd 1996, Holm and Dodd 1999, Dodd and Bradford 2000). Inconsistency of production is not a feature of normal development at any age.

In the introduction the possibility of a continuum from variability to inconsistency was raised. The results of the current study show that there is minimal variability in the speech of young children. In contrast, a recent study (Holm *et al.* 2005) showed that children with inconsistent speech disorder had a mean inconsistency score of 51% (i.e. half of the words they produced were different across three productions). In addition to this quantitative difference there are also qualitative differences between variability and inconsistency. Children with inconsistent speech disorder make a large number of 'variable, no hits' errors (Holm *et al.* 2005).

Further, there is evidence that children with inconsistent speech disorder differ from not only typically developing children but also children with other phonological disorders. A series of experiments have shown differences and similarities between children with consistent and inconsistent speech disorders and typically developing controls on a range of other measures (e.g. literacy, phonological awareness, phonological planning) (Dodd *et al.* 2005).

Conclusion

The primary aim of this study was to document the consistency of speech production in children aged 3;0–6;11 years. The results showed that typically developing children's speech is highly consistent. The youngest children in the sample were more variable than the older children but variable productions remained below 13%, with 10% containing a variation between a correct and immature realization of the target word. Age and gender affected the pattern of response. Inconsistency cannot be described as a prominent feature of speech development, even in 3-year-old children's speech, it should be considered a marker of speech disorder.

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Appendix A: Stimuli in the inconsistency assessment

Stimuli	IPA
Shark	ʃak
Elephant	ɛləfənt
Boat	boʊt
Rain	ɹeɪn
Helicopter	hɛlikoptə
Birthday cake	bɜθdeɪkeɪk
Parrot	parət
Thank you	θænkju
Jump	dʒʌmp
Vacuum cleaner	vækjumklinə
Bridge	bɹɪdʒ
Slippery slide	slɪpɹislaɪd
Umbrella	ʌmbɹɛlə
Scissors	sɪzəz
Tongue	tʌŋ
Kangaroo	kæŋgəɹu
Five	faɪv
Chips	tʃɪps
Zebra	zɛbɹə
Fish	fɪʃ
Witch	wɪtʃ
Girl	gɜl
Dinosaur	daɪnəsɔ
Teeth	tiθ
Ladybird	leɪdibɜd