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Use of phonetic specificity during the acquisition of new words: differences between consonants and vowels

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Abstract

The present study explores the issue of the use of phonetic specificity in the process of learning new words at 20 months of age. The procedure used follows Nazzi and Gopnik [Nazzi, T., & Gopnik, A. (2001). Linguistic and cognitive abilities in infancy: When does language become a tool for categorization? *Cognition*, *80*, B11–B20]. Infants were first presented with triads of perceptually dissimilar objects, which were given made-up names, two of the objects receiving the same name. Then, word learning was evaluated through object selection/categorization. Tests involved phonetically different words (e.g. [pize] vs. [moʀa], Experiment 1), words differing minimally on their onset consonant (e.g. [pize] vs. [tize], Experiment 2a), and conditions which had never been tested before: non-initial consonantal contrasts (e.g. [pide] vs. [pige], Experiment 2b), and vocalic contrasts (e.g. [pize] vs. [pyze]; [pize] vs. [paze]; [pize] vs. [pizu], Experiments 3a–c). Results differed across conditions: words could be easily learnt in the phonetically different condition, and were learnt, though to a lesser degree, in both the initial and non-initial minimal consonant contrast; however, infants' global performance on all three vocalic contrasts was at chance level. The present results shed new light regarding the specificity of early words, and raise the possibility of different contributions for vowels and consonants in early word learning.

Keywords: Language acquisition; Word learning; Object categorization; Phonetic specificity; Consonants/vowels

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1. Introduction

In the past 20 years, many studies have provided evidence that infants are born with sophisticated speech perception abilities that allow them to process various dimensions of speech inputs, including the ability to discriminate from birth many consonantal and vocalic contrasts (Jusczyk (1997) for a review). Moreover, these abilities develop during the first year of life (and beyond), becoming more and more attuned to the processing of the specific properties of the infants' native language. More specifically, several studies have provided evidence that infants start acquiring the phonetic inventory of their native language during the second half of the first year of life: as early as 6 months for vowels (Kuhl, 1991; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Polka & Werker, 1994), and around 10–12 months for consonants (Best, 1994; Best, McRoberts, & Sithole, 1988; Werker & Tees, 1984). Therefore, it was hypothesized that when infants start acquiring words around their first birthday (Benedict, 1979; Clark, 1993; Hallé & de Boysson-Bardies, 1994), they should be able to build phonetically specific representations of words; this hypothesis seemed supported by evidence showing that when 7.5-month-olds are segmenting stressed monosyllabic word forms (e.g. *feet*), they do not confuse them with phonetic neighbors such as *zeet* (Jusczyk & Aslin, 1995) or *feek* (Tincoff & Jusczyk, 1996). However, because further studies reopened the issue of the phonetic specificity of early word forms, the present study was conducted to explore 20-month-olds' use of phonetic information while learning new words.

Two distinct lines of research have addressed the issue of the phonetic specificity of early words. The first one explored whether the lexical representations of the words *already known* by young infants are specific by evaluating the impact of mispronunciations on the recognition of these words. This approach therefore evaluates the product of lexical acquisition, the lexical trace of the word in memory. Complementing these studies, other researchers have adopted a more dynamic approach, focusing on *the process of lexical acquisition itself*. In these studies, researchers explore whether infants' ability to simultaneously learn two words is rendered more difficult if those two words are phonetically similar.

Regarding the research on the specificity of early lexical representations, two studies have evaluated 11-month-olds' reaction, in the absence of any visual referent, to lists of words that they know, lists of words that they do not know, and lists of phonetic neighbors of known words (for French: Hallé & de Boysson-Bardies, 1996; for English: Vihman, Nakai, DePaolis, & Hallé, 2004). Their results suggest that these infants have representations in which the consonants are phonetically specified (vowels were not investigated), but only if they are in a word-initial position *and* belong to a stressed/accented syllable. Other studies have investigated the phonetic specificity of lexical representations in infants aged 14–24 months, using procedures in which they have to match a known word form (or a mispronunciation of that word) to its referent presented together with a distracter (Bailey & Plunkett, 2002; Fennell & Werker, 2003; Swingley, 2003; Swingley & Aslin, 2000, 2002). Their results first support the hypothesis of phonetically specific representations, at least when it comes to consonants (again, vowels were not tested, except in a non-systematic way in Swingley and Aslin (2000)) embedded in stressed word-initial positions (though see Swingley (2003), for a first exploration of non-initial positions). These studies also show that infants listen longer to the "matching" image than to the distracter even when hearing the mispronounced label, suggesting that mispronunciation affects but does not block comprehension entirely. Therefore, a cautious interpretation of this body of research would be that infants' early representations of known words are at least partly phonetically specified, and that there is some degree of tolerance to phonetic variation when hearing mispronunciations. But does this mean that when learning new words, which is a computationally very demanding task, infants would be able to process such specific phonetic information?

In order to address this issue, recent studies have looked at whether infants are affected in their ability to simultaneously learn two words when these words are phonetically similar. In a seminal study, Stager and Werker (1997) found that 14-month-olds can simultaneously learn two words when they are phonetically very distinct (*nim* and *leef*), but not when they are phonetically similar (*bih* and *dih*), even though they are capable of discriminating such similar word forms in a similar task that, crucially, does not involve word learning. This failure to simultaneously learn phonetically similar words at 14 months was later extended to other contrasts (place of articulation, voicing, place + voicing, see Pater, Stager, and Werker (2004)). Werker and colleagues have proposed that, initially, the process of word learning is too demanding for infants' limited computational resources, and that in this process, some phonetic information is disregarded or impossible to access. Therefore, it seems that even though infants' early representations of familiar words may already be specific by 14 months of age (with the proviso already signaled above), 14-month-olds' use of specific phonetic information in the process of acquiring new words is limited. Later studies showed that infants start being able to acquire these two phonetically similar words around 17- to 20-months of age, a result interpreted as the end of infants' computational limitations (Werker, Fennell, Corcoran, & Stager, 2002).

The above studies are compatible with the proposal that there is a window of phonetic "unspecificity" for early word learning that lasts up until about 17–20 months of age. This conclusion raises several issues that need to be explored. First, one needs to address the question of whether the emergence of infants' ability to use phonetic information around 17–20 months reflects a genuine improvement in their lexical acquisition skills, or whether the effect is due to the task used. In other words, is the improvement due to the emergence of infants' ability to use phonetic information or their better grasp of the task used to assess them. Therefore, the first aim of the present study was to try and replicate the finding that 20-month-olds can process phonetic details while learning new words (Werker et al., 2002) by testing them with a different task, with different cognitive/computational requirements. Second, Werker et al. (2002) proposal that the window of phonetic unspecificity ends around 17–20 months needs to be evaluated using more than one pair of words, as different types of phonetic contrasts might be relevant for word learning in different ways. In particular, given findings that both onset position and stress assignment affect 11-month-olds' recognition of mispronounced familiar words (Hallé & de Boysson-Bardies, 1996; Vihman et al., 2004), would Werker et al. (2002) results (obtained for a consonant in initial stressed position) generalize to consonants in less prominent positions, and especially in non-initial positions? Would this finding also generalize to contrasts other than consonantal contrasts?

This last point is important to evaluate given that, based on the literature, two opposite hypotheses could be envisaged with respect to infants' comparative performance with consonantal and vocalic contrasts. On the one hand, vowels are more salient than consonants in the speech signal (Mehler, Dupoux, Nazzi, & Dehaene-Lambertz, 1996), and are the main carriers of prosodic information (pitch, stress, rhythm), dimensions to which infants are very sensitive during the first months of life (Jusczyk, 1997; Morgan & Demuth, 1996; Nazzi, Bertoncini, & Mehler, 1998; Nazzi & Ramus, 2003). Moreover, as mentioned earlier, there is evidence that infants start learning the inventory of the vowels of their native language around 6 months (Kuhl, 1991; Kuhl et al., 1992; Polka & Werker, 1994), earlier than when they start learning the inventory of the consonants of their native language around 10–12 months (Best, 1994; Best et al., 1988; Werker & Tees, 1984). Given these facts, one might expect that it would be easier for infants to learn pairs of words contrasting on one of their vowels than on one of their consonants.

However, on the other hand, it has recently been proposed that vowels and consonants play different roles in language, consonants being more important at the lexical level, and vowels being more important at the prosodic and morphosyntactic levels (Nespor, Peña, & Mehler, 2003). The claim that consonants are more important at the level of the lexicon is based on considerations gathered across the domains of linguistics, adult psycholinguistics and language acquisition. The analysis of many languages first suggests that consonants tend to outnumber vowels, making them more informative at the lexical level, especially given that vowels also tend to loose quality distinctiveness (in unstressed positions, and through the phenomenon of harmony). Further evidence for this proposal comes from "word reconstruction" studies showing that English, Dutch and Spanish adults are better at changing a non-word into a word when it involves changing one of its vowels, suggesting that vowels are not constraining lexical access as tightly as consonants (Cutler, Sebastian-Galles, Soler-Vilageliu, & van Ooijen, 2000; Van Ooijen, 1996). The fact that these results have been obtained in three languages that differ in their consonant/vowel ratios (24/17, 19/16, and 20/5, respectively) further suggests that this greater reliance on consonants might be general across languages (consonant/vowel ratio for French: 18/16). Finally, a recent word segmentation/learning experiment showed that French adults can track lexical transitional probabilities in a context of fixed consonants and variable vowels, but cannot do so when the consonants are changing while the vowels are constant, again suggesting that consonants matter more at the lexical level (Bonatti, Peña, Nespor, & Mehler, 2005). Note that although this last study bears on acquisition, it involves adults learning an "artificial" language, not infants acquiring a natural language. No developmental evidence exists to date regarding the different involvement of consonants and vowels in the early lexicon. One way to address this issue is to evaluate how infants learning pairs of new words would comparatively fare according to whether the words contrast on one of their vowels or on one of their consonants. Nespor et al. (2003) proposal predicts, contrary to what could have been inferred from infants' early sensitivity to and acquisition of vowels, greater difficulties with the vocalic contrasts in this lexical acquisition task.

In order to address these issues, we used the name-based categorization task developed by Nazzi and Gopnik (2001). In that study, infants were given several trials in which three dissimilar-looking objects were introduced and named, two of these objects receiving the same name. Name-based categorization was then tested by taking one of the two objects of the named pair, and asking the infant to give “the one that goes with this one”. Success in this task was found for typically developing 20-month-olds, though not 16-month-olds. In the present study, we take advantage of this new procedure to further evaluate the interface of phonetic specificity and lexical acquisition in 20-month-olds. Experiment 1 replicates Nazzi and Gopnik (2001) study with a population of 20-month-olds growing up in a French-speaking environment, using pairs of very different pseudowords (e.g. [pize]/[moʀa]). Experiment 2 evaluates whether these infants can simultaneous learn two pseudowords when they differ minimally either on their initial consonant (e.g. [pize]/[tize], Exp. 2a), or on a non-initial consonant (e.g. [pige]/[pide], Exp. 2b). Experiment 3 explores whether 20-month-olds also use vocalic contrasts when learning new pseudo-words. Three different vocalic contrasts were tested: a minimal contrast on the vowel of the first syllable (e.g. [pize]/[pyze], Exp. 3a), a more pronounced contrast on the vowel of the first syllable (e.g. [pize]/[paze], Exp. 3b), and a more pronounced contrast in word-final position (e.g. [pize]/[pizu], Exp. 3c).

2. Experiment 1

2.1. Method

2.1.1. Participants

Twenty-four 20-month-old infants ($M = 20$ months, 5 days; *range* = 19 months, 9 days–20 months, 27 days) from monolingual French-speaking families participated in this experiment. There was an equal number of boys and girls. Most infants came from white, middle-class backgrounds, although infants from other ethnic backgrounds were also represented. Four additional infants were tested, but failed to complete the session.

2.1.2. Stimuli

Six triads of small objects were used during the testing session (an additional triad being used during a pretest). All objects were selected so that the infants would be unfamiliar with them and would not already have a name for them. All sets were made up of three very distinct objects, that all differed in shape, color, and texture in an effort to equalize their perceptual distance (see example in Fig. 1). The rationale for using triads of very different objects, rather than very similar objects, was to help infants learn and remember the different object–label pairings (see also Nazzi and Gopnik (2001)).

One pair of non-words was used for the training trial ([laf] and [nim]). Three other pairs of non-words were used for the six test trials, [duk]/[zap], [pize]/[moʀa], and [kepɔd]/[nylis]. All three pairs of non-words were used once, in counterbalanced order, for the first three test trials, and then reused in the same order for the last three test trials (the word of the pair being used as target being switched between the two occurrences).

2.1.3. Procedure

The procedure was identical to that used in Nazzi and Gopnik (2001), with the exception that this time only naming trials were presented (as also done in Nazzi, Gopnik,

Fig. 1. One of the 6 sets of objects used in the present study. Which two objects were given the same name was counterbalanced across participants.

and Karmiloff-Smith (2005)). Infants were tested individually for about 10 min in a quiet room, in the presence of a caregiver.

After an informal warm-up period (playing with spinning plastic rings), the infant was seated on a chair across a table from the experimenter, and the testing session started. It comprised a training trial and 6 test trials. All trials were "naming" trials that tested for categorization based on naming.

The training trial was identical to the test trials (see below) except that the presentation of the objects and the categorization question were repeated if the infant's initial response was incorrect (although the infant was not told the answer was incorrect). The testing phase started independently of the response provided the second time.

Each of the six test trials was composed of a presentation phase, followed by a categorization question. Each trial started with the presentation of the 3 objects, one at a time. The infant was encouraged to manipulate each object for a few seconds, before placing it on the table. Within each trial, the objects were arranged on the table on a left-to-right sequence (child's perspective) in order to minimize memory load. The experimenter spoke while presenting each object, saying (for example): "Look! A [zap]. This is a [zap]. Do you want to play with the [zap]? Yes, play with the [zap]. See this [zap]? All right, let's put the [zap] on the table. Here." Each object was named exactly 6 times.

After the presentation phase, the experimenter tested categorization by putting one object of the named pair in his own hand, placed at equal distance from the remaining two objects, and asking the infant to give him "celui qui va avec" (the one that goes with (this one). While waiting for the response, the experimenter looked at either the infant's face or the object in his hand in order to avoid influencing the infant's response. After the infant's response, positive feedback was provided regardless of the choice made. Successful performance corresponded to the selection of the similarly labeled object. The order of presentation of the trials (for the first 3 trials, that order being then repeated for the last 3 trials), the position of the paired objects on the table, the side of the object picked up by the experimenter, and the pairs defined by the names were counterbalanced across participants.

Finally, before the testing session, the parent filled out the vocabulary part of the French equivalent (Kern, 2003) of the MacArthur Communicative Development Inventory: Toddlers (CDI; Fenson et al., 1993) in order to determine the size of the infants' productive vocabulary.

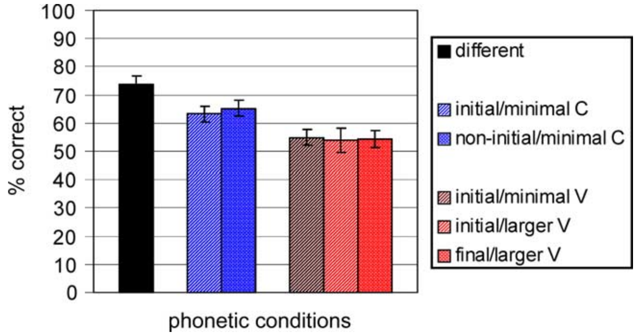

Fig. 2. Infants' mean performance (and Standard Error) for each experimental condition (Experiments 1, 2a–b, 3a–c). Chance level is 50%.

2.2. Results and discussion

For each trial, infants were given a score of 1 when the chosen object was the second of the named pair, and a score of 0 otherwise. Total scores could range from 0 to 6. The infants chose the second object with the same name 73.6% of the time (see Fig. 2), which is significantly more than chance ($t(23)=7.88$, $P<0.0001$). Moreover, as can be seen from Fig. 3, almost all the infants chose the correct object on more than half of the test trials.

The infants had a mean of 80 words (SD=82; range 8–375); the median was of 55 words. There was no correlation between vocabulary size and categorization performance ($r=0.16$, $P=0.47$).

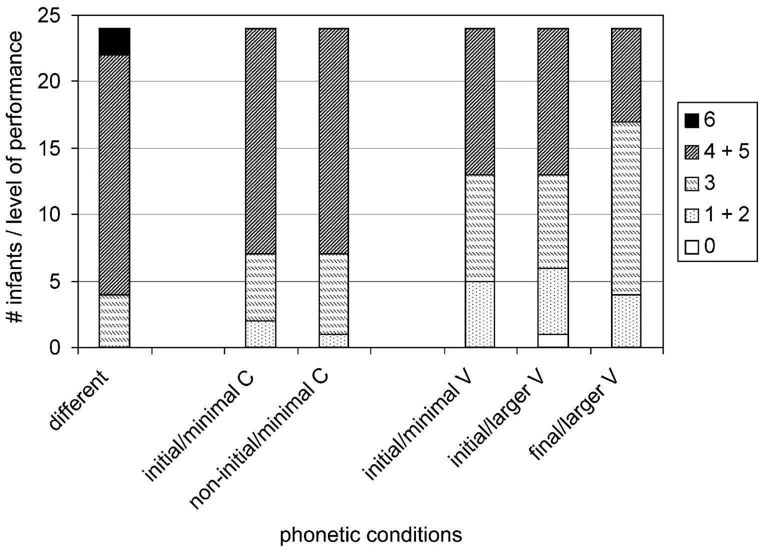

Fig. 3. Number of infants at each level of performance for each experimental condition (Experiments 1, 2a–b, 3a–c).

The present results confirm the finding by Nazzi and Gopnik (2001) that 20-month-old infants can rapidly learn new words, and use the fact that two objects received the same name to group them together. In the following, this name-based categorization task is used to evaluate whether 20-month-old infants can learn new words that differ minimally. These infants were first tested on a minimal consonantal contrast bearing on the first consonant of the target words and involving a place of articulation change, such as [pize]/[tize]. This is the same kind of contrast that has been used in previous studies looking at the use of phonetic specificity during word learning (Stager & Werker, 1997; Werker et al., 2002). Another group of infants was also tested on a minimal consonantal contrast bearing on a non-initial consonant of the target words that also involved a place of articulation change, such as [pide]/[pige]. This contrast was tested in order to determine whether or not positions other than the word-initial one are phonetically specified (see also discussion on the results with vowels).

3. Experiment 2a–b

3.1. Method

3.1.1. Participants

Forty-eight 20-month-old infants ($M = 20$ months, 13 days; $range = 19$ months, 26 days–21 months, 17 days) from monolingual French-speaking families participated in this experiment. There was an equal number of boys and girls. Most infants came from white, middle-class backgrounds, although infants from other ethnic backgrounds were also represented. Four additional infants were tested, but failed to complete the session.

3.1.2. Stimuli and procedure

The procedure was identical to that used in Experiment 1, and the object triads were the same. The single but crucial difference was the names used to label the objects. Experiment 2a tested a minimal consonantal contrast on the word-initial consonant; the pair for the training trial was [dim]/[bim], and the three pairs for the test trials were [duk]/[guk], [pize]/[tize], and [kepɔd]/[tepɔd]. Experiment 2b tested a minimal consonantal contrast on a non-initial consonant; the pair for the training trial was [dib]/[dig], and the three pairs for the test trials were [duk]/[dut], [pide]/[pige], and [kepɔd]/[ketɔd]. Note that all paired words are contrasted on their first consonant in Experiment 2a, and on one of their non-initial consonant in Experiment 2b. Moreover, for the bisyllables, the contrast is embedded in the non-accented syllable in Experiment 2a, while it is embedded in the accented syllable in Experiment 2b.

3.2. Results and discussion

In order to maintain a parallel with the way Experiment 1 was analyzed, the two conditions of Experiment 2 were analyzed separately (they were actually run as independent experiments). In both conditions, infants were given, for each trial, a score of

1 when the chosen object was the second of the named pair, and a score of 0 otherwise. Total scores could range from 0 to 6.

3.2.1. Experiment 2a: minimal consonantal contrast, word-initial position

The infants chose the second object with the same name 63.2% of the time (see Fig. 2), which is significantly more than chance ($t(23)=4.66$, $P=0.0001$). Moreover, as can be seen from Fig. 3, almost all the infants chose the correct object on more than half of the test trials.

The infants had a mean of 129 words (SD = 82; range 10–368); the median was of 79 words. There was no correlation between vocabulary size and categorization performance ($r=0.36$, $P=0.088$).

3.2.2. Experiment 2b: minimal consonantal contrast, non-initial position

The infants chose the second object with the same name 65.3% of the time (see Fig. 2), which is significantly more than chance ($t(23)=5.41$, $P<0.0001$). Moreover, as can be seen from Fig. 3, most of the infants chose the correct object on more than half of the test trials.

The infants had a mean of 77 words (SD = 117; range 7–486); the median was of 26 words. There was no correlation between vocabulary size and categorization performance ($r=0.16$, $P=0.45$).

The present results show that 20-month-old infants are able to simultaneously learn two phonetically similar words that contrast only by the place of articulation of one of their consonant, be it the word-initial or a non-initial consonant. These results confirm similar findings by Werker et al. (2002), and extend them in different directions. First, the new results bear on a new population of infants, of similar ages but acquiring a different language, French, thus suggesting that the pattern obtained for English extends beyond that language.

Second, the confirmation was obtained using a different method, which has different cognitive demands, and thus provides converging evidence: the current task is more naturalistic (infants playing with objects), a feature that could facilitate learning, though on the other hand it is more demanding as infants have to learn three new object/label pairings (rather than two) and then perform an overt categorization based on their memory of these three pairings. Therefore, it is more likely that the developmental pattern observed by Werker et al. (2002) reflects an improvement of infants' ability to learn new words, rather than enhanced ability at "solving" a specific experimental task.

Third, infants were tested on three different contrasts, embedded in different words of varied structural complexity (monosyllabic CVC, and bisyllabic CVCV and CVCVC), thus showing the robustness of their ability to use specific consonant-related phonetic information when learning new words.

Lastly, results on lexical recognition at 11 months had suggested that consonants were more likely to be fully specified if they were *both* in a word-initial position and embedded in a stressed or accented syllable (Hallé & de Boysson-Bardies, 1996; Vihman et al., 2004). This was the case for the *bih/dih* pair tested by Werker et al. (2002). Given the structure of the present experiment (contrast either in initial or non-initial word position; contrast embedded in a monosyllabic, a simple bisyllabic or a complex bisyllabic) and given that accent is word-final in French, the fact that similar performance levels were obtained for both conditions suggest that 20-month-old infants can take into account such minimal phonetic contrasts if they are *either* word-initial *or* embedded in accented syllables. In a way, these results suggest that whether or not a consonant is fully specified at 20 months is less dependent on its acoustic salience (at the onset of a word; in an accented syllable) than it seemed to be around 11 months. Importantly, it appears that the word-initial position is not the only position of the word to be fully specified at the phonetic level.

In the following experiment, we extend the present research on phonetic specificity to contrasts that have never been studied so far in the context of the acquisition of new words: we explore whether 20-month-old infants can simultaneously learn two words that differ solely on one of their vowels. Three types of contrasts were tested: a minimal contrast on the vowel of the first syllable (e.g. [pize]/[pyze], Exp. 3a), a more pronounced contrast on the vowel of the first syllable (e.g. [pize]/[paze], Exp. 3b), and a more pronounced contrast in word-final position (e.g. [pize]/[pizu], Exp. 3c). As discussed earlier, there are two opposite predictions regarding infants' comparative performance with consonantal and vocalic contrasts. Based on evidence of the importance of vowel processing in infancy, vocalic contrasts are expected to be easier; but based on Nespor et al. (2003) proposal of a greater involvement of consonants at the lexical level, vocalic contrasts should be more difficult.

4. Experiment 3a–c

4.1. Method

4.1.1. Participants

Seventy-two 20-month-old infants ($M=20$ months, 12 days; $range=19$ months, 20 days–21 months, 05 days) from monolingual French-speaking families participated in this experiment. There was an equal number of boys and girls. Most infants came from white, middle-class backgrounds, although infants from other ethnic backgrounds were also represented. Nine additional infants were tested, but failed to complete the session.

4.1.2. Stimuli and procedure

The procedure was identical to that used in the previous experiments, and the object triads were the same. The single but crucial difference was the names used to label the objects. Experiment 3a tested a *minimal vocalic contrast* (one phonetic feature) *on the first vowel of the words*; the pair for the training trial was [dim]/[dɛm], and the three pairs for the test trials were [duk]/[dɔk], [pize]/[pyze], and [kepɔd]/[køpɔd]. Experiment 3b tested a *more pronounced vocalic contrast* (more than one phonetic feature) *on the first vowel of the words*; the pair for the training trial was [dim]/[dɔm], and the three pairs for the test trials were [duk]/[dœk], [pize]/[paze], and [kepɔd]/[kupɔd]. Finally, Experiment 3c tested an even bigger contrast: the same kind of *more pronounced vocalic contrasts* used in Experiment 3b was used this time in *word-final position*, a position which might be more perceptually prominent given word-final accentuation in French (and even more so here as the vowel was also the last phoneme of the words presented). The pair for the training trial was [dRO]/[dRy], and the three pairs for the test trials were [da]/[di], [pize]/[pizu], and [kepRO]/[kepRi].

Note that, for the bisyllables, all paired words are contrasted on the vowel of their first/accented syllable in Experiments 3a–b, and on the vowel of their last/accented syllable in Experiment 3c. For the monosyllables, the vocalic contrasts are embedded in the first/non-accented syllable in all three conditions; however, the contrasting vowel was word-final only in Experiment 3c, while it was followed by a coda consonant in Experiments 3a–b.

4.2. Results and discussion

In order to maintain a parallel with the way Experiments 1 and 2 were analyzed, the three conditions of Experiment 3(a–c) were analyzed separately (they were actually run as independent experiments). In all three conditions, infants were given, for each trial, a score of 1 when the chosen object was the second of the named pair, and a score of 0 otherwise. Total scores could range from 0 to 6.

4.2.1. Experiment 3a: minimal vocalic contrast, first syllable

The infants chose the second object with the same name 54.9% of the time (see Fig. 2), which is not significantly different from chance ($t(23)=1.67$, $P=0.11$). Moreover, as can be seen from Fig. 3, less than half of the infants chose the correct object on more than half of the test trials.

The infants had a mean of 114 words (SD = 114; range 12–387); the median was of 62 words. There was no correlation between vocabulary size and categorization performance ($r=0.05$, $P=0.81$).

4.2.2. Experiment 3b: more pronounced vocalic contrast, first syllable

The infants chose the second object with the same name 53.8% of the time (see Fig. 2), which is not significantly different from chance ($t(23)=0.89$, $P=0.38$). Moreover, as can be seen from Fig. 3, less than half of the infants chose the correct object on more than half of the test trials.

The infants had a mean of 68 words (SD = 62; range 8–230); the median was of 54 words. There was no correlation between vocabulary size and categorization performance ($r=0.13$, $P=0.56$).

4.2.3. Experiment 3c: more pronounced vocalic contrast, word-final position

The infants chose the second object with the same name 54.2% of the time (see Fig. 2), which is not significantly different from chance ($t(23)=1.37$, $P=0.19$). Moreover, as can be seen from Fig. 3, less than half of the infants chose the correct object on more than half of the test trials.

The infants had a mean of 95 words (SD = 101; range 7–358); the median was of 49 words. There was no correlation between vocabulary size and categorization performance ($r=0.05$, $P=0.81$).

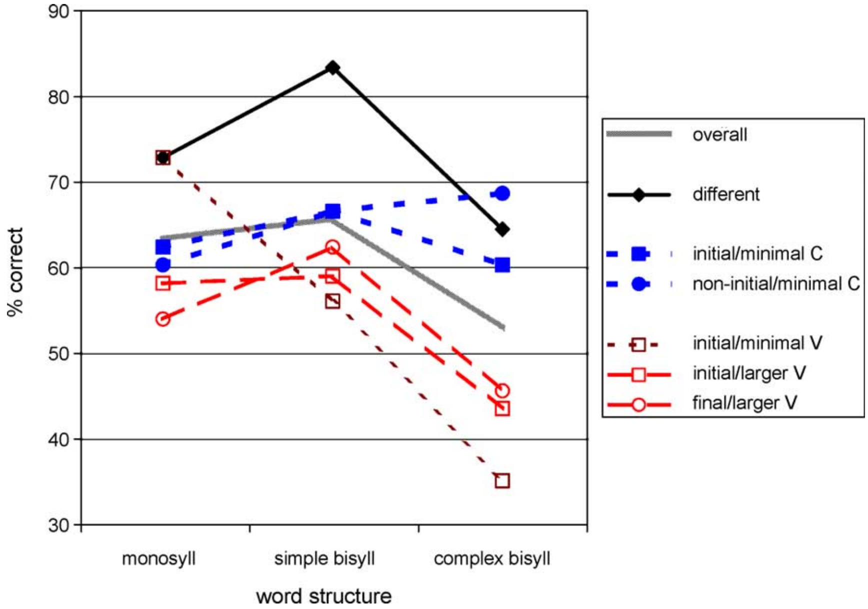

Fig. 4. Infants' mean performance for each experimental condition, broken down by lexical structure conditions (Experiments 1, 2a–b, 3a–c).

Overall, the results with the vocalic contrasts suggest that 20-month-old infants have difficulties learning simultaneously two words that differ only by one of their vowels. These difficulties seem not to be modulated by the phonetic distance between the contrasting vowels (Exp. 3a&b), nor by the position of the contrasting vowels within the word (initial/unaccented—Exp. 3a&b—or final/accented syllable—Exp. 3c). On these vocalic contrasts, infants were performing at chance level, contrary to what had been observed for words contrasting on minimal consonantal contrasts (Exp. 2). This suggests that at 20 months, infants do not use all phonetic contrasts while learning new words.

In order to directly compare infants' performance across the various experiments, we conducted an ANOVA on categorization scores with the main between-subject factor of Condition (Exp. 1, 2a, 2b, 3a, 3b, 3c) and the main within-subject factor of Structure (monosyllable, simple bisyllable, complex bisyllable). The results broken down by condition and structure are presented in Fig. 4.[1]

First, there was a main effect of Condition, $F(5,138)=6.32$, $P<0.0001$, confirming that infants' performance differed according to the way the simultaneously learnt words

[1] Above 50% chance performance (2-tailed *t*-tests) was found for the following contrasts: Exp. 1: monosyllables [duk]/[zap] ($P<0.001$), simple bisyllables [pize]/[moʀa] ($P<0.001$), complex bisyllables [kepɔd]/[nylis] (marginal effect, $P=0.07$); Exp. 2a: simple bisyllables [pize]/[tize] ($P=0.03$); Exp. 2b: simple bisyllables [pide]/[pige] ($P=0.03$), complex bisyllables [kepɔd]/[ketɔd] ($P=0.03$); Exp. 3a: monosyllables [duk]/[dɔk] ($P<0.001$). The only other significant effect was for the complex bisyllables [kepɔd]/[køpɔd] in Exp. 3a, where performance was significantly below chance level ($P=0.03$).

Table 1
Comparison of infants' performance across the different experimental conditions (*P* values, LSD Tests)

	different	ini mini C	nonini mini C	ini mini V	ini maxi V	fin maxi V
different (Exp. 1)		**0.022**	*0.066*	**<0.0001**	**<0.0001**	**<0.0001**
ini mini C (Exp. 2a)			0.641	*0.066*	**0.037**	**0.046**
non-ini mini C (Exp. 2b)				**0.022**	**0.011**	**0.015**
ini mini V (Exp. 3a)					0.805	0.877
ini maxi V (Exp. 3b)						0.926
fin maxi V (Exp. 3c)						

Ini = initial; non-ini = non-initial; fin = final; mini = minimal contrast; maxi = more pronounced contrast; C = consonant; V = vowel.

contrasted (see Fig. 2). Post-hoc tests (see details in Table 1) revealed three clusters of performance. Performance was highest in the phonetically different condition (Exp. 1), intermediate for the two consonantal contrasts (Exp. 2a&2b), and lowest for the three vocalic contrasts (Exp. 3a, 3b&3c).[2] These analyses thus confirm that infants' performance on the vocalic contrasts is lower than their performance on the consonantal contrasts. These results do not fit with what we know of the importance of vowels in early speech perception and acquisition (Kuhl et al., 1992; Werker & Tees, 1984), although they are compatible with the proposal that consonants and vowels play different roles, with consonants being more important for the specification of the lexical level (Nespor et al., 2003).

Second, there was a main effect of Structure, $F(2, 276) = 4.23$, $P = 0.016$, indicating that performance with the monosyllables (63.5%) and the simple bisyllables (65.8%) was higher than with the complex bisyllables (53.1%, see Fig. 4 and Table 2).[3] Note that this effect might signal that structural complexity impacts on ease of lexical acquisition; however, caution is needed in interpreting this effect given that, for each phonetic condition, the exact contrast tested differed between structures (e.g. in Experiment 2: [duk]/[guk], [pize]/[tize], and [kepɔd]/[tepɔd]). Therefore, the effect observed could also signal that the contrasts we used for the complex bisyllables might have been more difficult. Moreover, in spite of an absence of interaction between Condition and Structure, $F(10, 276) = 1.06$, $P = 0.395$, the effect of structure reaches significance in only one condition (Exp. 3a). Further investigations specifically designed at testing the impact of lexical structure when phonetic contrasts are controlled for will be needed to definitively answer this question.

Finally, four additional correlation analyses were conducted by pulling together data from the different experiments (Exp. 1–3, Exp. 2–3, both conditions of Exp. 2, all three conditions of Exp. 3). None of these analyses yielded significant correlations (all $Ps > 0.10$).

[2] The results of Scheffé tests on the same data were consistent with the LSD Test results, although unsurprisingly given the stringency of such tests and the noise characteristically present in infant data, the only differences that remained significant involved the phonetically different contrast and the three vocalic contrasts (all $Ps < 0.01$), the intermediate consonantal contrasts being not significantly different from these two endpoints.

[3] For the Scheffé tests, the performance for the complex bisyllables was significantly different from that for the simple bisyllables ($P = 0.026$), and marginally different from the performance for the monosyllables ($P = 0.082$).

Table 2
Comparison of infants' performance across the different lexical structures (*P* values, LSD Tests)

	monosyllables	simple bisyllables	complex bisyllables
monosyllables		0.632	**0.026**
simple bisyllables			**0.007**
complex bisyllables			

5. General discussion

The goal of the present study was to explore 20-month-old infants' use of phonetic specificity in the process of acquiring new words, following up on the finding that 17- to 20-month-olds (Werker et al., 2002), though not 14-month-olds (Pater et al., 2004; Stager & Werker, 1997; Werker et al., 2002), can learn simultaneously two phonetically similar words, a developmental change they have explained in terms of computational limitations in the younger infants.

In order to explore this issue, we used the name-based categorization task originally used by Nazzi and Gopnik (2001) to show that, when taught names for three new objects, and when two of the objects receive the same name (e.g. *tib*) and the third one receives a different name (e.g. *dap*), 20-month-old American infants growing up in an English-speaking environment categorize together the two objects that are given the same name. In Experiment 1, we replicated this result with a new population of 20-month-olds growing up in a French-speaking environment. Infants' performance was very high, as they chose the second object with the same name about 3 times out of 4. This finding thus extends the original English finding of early name-based categorization to a new language: French.

Given the preceding results, we proceeded to explore how infants perform in this task when the two words contrasted are phonetically similar, which should inform us on how infants cope with phonetic specificity in the process of word learning. Experiment 2 was intended to test the same kind of minimal contrast (place of articulation) as the one used by Werker et al. (2002), although looking at a consonant contrast in either initial (Exp. 2a) or non-initial (Exp. 2b) position, and using three different word pairs for each position (varying both in syllabic structure and identity of the consonants contrasted). Infants' performance was above chance level in both conditions, with a similar performance of about 2 correct responses out of 3. This result is compatible with Werker et al. (2002) original finding that 20-month-olds can use some phonetic specificity (*bih* and *dih* contrast) in a word-learning task. This replication extends the original finding at several levels. First, it is found using a different task with different cognitive and memory demands, thus suggesting that the pattern of emergence of the use of phonetic specificity observed by Werker et al. (2002) between 14 and 20 months is probably not limited to the specific task they have used.[4]

[4] Unfortunately, our task could not be used to test this issue in younger infants as it has been shown that 16-month-olds fail at this task even with phonetically different words (for English: Nazzi & Gopnik, 2001; for French: Nazzi & Pilardeau, in preparation, 2003).

Furthermore, the use of phonetic specificity during word learning was extended to new word pairs, presented to a population of infants acquiring another language: French. The interest of the replication with more and different word pairs is that the words we used were more complex than those used in Werker et al. (2002) and varied in their syllabic structures (monosyllables, simple and complex bisyllables), thus indicating that 20-month-olds' ability to cope with specific phonetic identity while learning new words extends beyond very simple word forms.

Moreover, the interest of using French was that it allowed us to explore the effect of two factors (word-onset position, and syllabic accentuation/stress) that have been shown to affect word recognition at around 11 months (Hallé & de Boysson-Bardies, 1996; Vihman et al., 2004). The fact that performance was equivalently correct in both conditions of Experiment 2, conditions that differed according to whether the contrasted phonemes were initial or not, suggests that in the process of acquiring new words, 20-month-olds can process and represent with precision consonantal identity in several lexical positions, not just the word-onset position. Moreover, given that the pairs of bisyllabic words in both conditions differed in whether the contrast was embedded in the non-accented (i.e. initial, Exp. 2a) or accented (i.e. final, Exp. 2b) syllable, and that performance did not differ significantly, it appears that full consonant identity is preserved through word learning at 20 months, even if the consonant is not in an accented syllable. These results contrast with results for younger, 11-month-old, infants, for whom phonetic specificity of known words was found for consonant in positions that were both stressed and word-initial (Hallé & de Boysson-Bardies, 1996; Vihman et al., 2004). Note however that the present study leaves open to future investigation the question of whether, at 20 months, the full identity of a consonant in a non-initial non-accented position is preserved through word learning. This could be tested by using pairs of trisyllabic words contrasting on their middle syllable, such as [kepɔdõ]/[ketɔdõ].

Finally, in Experiment 3, we explored how infants cope when they are taught pairs of new words that differ on one of their vowels. Three conditions were run, in which dissimilarity was progressively increased: first minimal contrasts in the initial (non-accented for the bisyllables) syllable (e.g. [pize]/[pyze]), then more pronounced contrasts in the same syllable (e.g. [pize]/[paze]), finally equivalently pronounced contrasts in word-final/accented position (e.g. [pize]/[pizu]). For all three vocalic conditions, not only was performance lower than for the consonantal contrasts, but it was overall at chance level. This was the case even when a pronounced contrast was presented in an accented position and was the last phoneme of the word (Exp. 3c), and even when the contrast presented was as salient and embedded in such a simple context as for [da]/[di] (for which performance level was 54.2%). Finally, there was no effect of position within the word, accentuation, or size of phonetic contrast between the two words contrasted.

In testing the vocalic contrasts, we wanted to determine whether the results obtained for the consonantal contrasts generalize to other kinds of contrasts, but we also wanted to evaluate two opposite predictions regarding how infants would fare on vowels compared to consonants in this word-learning task. As previously stated, one hypothesis, based on the literature on early speech perception and acquisition showing infants' great reliance on vowels during the first year of life, predicted that performance with vocalic contrasts would be higher than performance with consonantal contrasts. On the other hand, Nespor et al. (2003) have proposed that vowels and consonants play different roles in speech processing and language acquisition, with consonants being more important at the lexical level, and vowels being more important at the prosodic and morphosyntactic levels.

Our results with 20-month-old infants are contrary to the predictions of the first hypothesis, while they are compatible with the second proposal. Within Nespor et al. (2003) framework, our results might thus be interpreted as the first piece of evidence for a greater reliance on consonants at the lexical level in infancy, adding to previous evidence found for adults (Bonatti et al., 2005; Cutler et al., 2000; Van Ooijen, 1996). More evidence will nevertheless be needed to strengthen this interpretation, by exploring how this pattern replicates when using other tasks,[5] and how it extends both developmentally (by testing adults and infants of various ages) and cross-linguistically. Such extensions of the present study will allow to evaluate whether the processing differences observed here are general or whether they are determined by the phonological properties of the language in acquisition, for example, by its consonant/vowel ratio (even though that factor does not seem to have an influence in adulthood) or the ratio of consonantal and vocalic minimal pairs present in that language (for which, to the best of our knowledge, there is no available data at present). We will also have to specify the factors that lead to the processing differences between consonants and vowels (is vocalic information discarded? Is there more tolerance to vocalic variability? And what happens with consonants other than plosives?). But, as a final note, we would like to underline that the present results also call for more systematic research to be conducted on the vocalic specificity of infants' representations of words they already know.

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[5] As pointed out by one reviewer, while the naturalistic nature of our word-learning procedure is a strength, its live, interactive procedure prevents a precise acoustic control of the occurrences of the words used to label the objects. Therefore, we cannot completely rule out the possibility that there was more variability in the acoustic realization of the vowels used to contrast words in Exp. 3a–c, than in the acoustic realization of the consonants used to contrast words in Exp. 2a–b, and that this might have made the word-learning task more difficult for the vowel conditions. However, note that if this were true, it might signal, given our use of 9 vocalic contrasts and 6 consonantal contrasts, that vowel realization is in general more variable than consonant realization, which would make vowels less informative at the lexical level than consonants, a finding that would fit into the framework proposed by Nespor et al. (2003).

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