Discrimination of sea-bird sounds vs. garden-bird songs: Do Scottish and German-Saxon infants show the same preferential looking behaviour as adults?

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Birdsong and human speech share some genetic origins (Haesler, Rochefort, Georgi, Licznarski, Osten, & Scharff, 2007; Vargha-Khadem, Gadian, Copp, & Mishkin, 2005). In two studies ($N=67$ infants and $N=28$ adults) in Scotland (UK) and Saxony (Germany), perceptual discrimination of innate, repetitive, lower frequency sea-bird sounds vs. learned, melodic, higher frequency garden-bird songs was tested in infants in their first year as well as in adults, using the conditioned head-turn procedure (CHTP; e.g., Jusczyk, Friederici, Wessels, Svernerud, & Jusczyk, 1993). Infants and adults reliably distinguished between the two types of sounds. Independently of environment, infants paid more attention to sea-bird sounds than to garden-bird songs, while adults showed the reverse preference. Further analysis revealed additional insights into the underlying processes.

Keywords: Bird sound preference; Categorical bird sound perception; Infants and evolution; Faculty of language in broad and narrow sense (FLB FLN).

INTRODUCTION

Birds are more intelligent species than the size of their “birdbrain” suggests. Birdsong and human speech share some genetic origins, i.e., mutation of the

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FoxP2 gene is responsible for articulation disorders in children (MacDermot et al., 2005; Marcus & Fisher, 2003; Vargha-Khadem et al., 2005), and disruption of this gene caused song disorders in the zebra finch (Haesler et al., 2007). Songbird and human vocal learning share 100% identity within the DNA-binding domain (Haesler et al., 2004). Furthermore, both humans and songbirds show an early perceptual phase of vocal learning, which later serves to guide vocal production (Doupe & Kuhl, 1999; Eilers, 1996; Jusczyk, 1997). These findings were crucial for developing a more comprehensive, cross-species and evolution-informed framework for sounds and language (Hauser, Chomsky, & Fitch, 2002; see Pinker & Jackendoff, 2005, for criticism). In this framework, the evolution and adaptability of human language is explained with our ability to conceptualize, externalize and interpret potentially infinite vocal expressions given limited resources. In most cases, research within this framework involved efforts to teach animals human language processing abilities in order to investigate commonalities and differences in learning capacity. However, during evolution, often human competence was achieved by modelling those animal features that we found attractive but did not possess, such as flying, wearing colourful feathers, or opera sopranos producing melodies at a pitch more similar to birdsong than to the everyday human voice (Joliveau, Smith, & Wolfe, 2004; Wolfe, 2004). Furthermore, auditory perception of language-less sounds such as crying can trigger strong emotional reactions in adults (Sander & Scheich, 2001). In particular human infants' capacity for vocal distress articulation via crying may necessitate coping strategies in adults to modulate infant arousal; this can involve infant-directed speech (Papousek & Von Hofacker, 1995) or infant-directed singing (Shenfield, Trehub, & Nakata, 2003). However, almost 60% of parental utterances consisted of non-lexical utterances such as interjections, imitative sounds and calls with a high repetition rate and a high degree of similarity across repetitions (Green, Gustafson, Irwin, Kalinowski, & Wood, 1995). Infants and elderly people process basic environmental sounds faster than complex verbal stimuli (Saygin, Dick, & Bates, 2002), but adults are more efficient at processing language than non-speech sounds (Jaramillo et al., 2001). Hence, the ability and willingness of human adults to emulate auditory features of human infants and of other species such as songbirds indicate that humans have a potentially unlimited repertoire in the faculty of language in a broad sense (FLB), not just in recursive language, i.e., their faculty of language in a narrow sense (FLN; Hauser et al., 2002). The current study investigated whether already human infants would be able to distinguish between two kinds of bird sounds, i.e., more repetitive, lower frequency sea-bird sounds in comparison to more melodious, higher frequency garden-bird songs.

Auditory sounds emitted and perceived by animals vary from simple signals, which trigger behaviour, to sophisticated calls, which serve

communicative purposes. Specific parameters of bird sounds serve circumscribed social purposes (Catchpole & Slater, 1995; Kroodsma & Miller, 1996), e.g., calls to find and rescue an offspring in an emergency situation, to attract and negotiate with a mate, or to alert the community when defending a territory. In birds, calls and songs are distinguished, only songs being complex, learned sound structures (Catchpole & Slater, 1995). Critical parameters are duration (Snowdon, 1987), a precisely constrained frequency band range of KHz (Ehret, 1987) as well as repetition rate (Gottlieb, 1982). Furthermore, birdsongs can vary in complexity, variation and number of notes.

The complexity of garden-bird songs has attracted many studies on their repertoire, improvisation, and song learning (e.g., Beecher, 1996; Horn & Falls, 1996; Payne, 1996). Songbirds are able to learn precisely varied and complex songs from laboratory simulations, and they learn from their own as well as from different species (Catchpole & Slater, 1995). Disruption of the *FoxP2* gene caused less precise copying of the bird tutor's model song on parameters such as one-to-one mapping of syllables two weeks after hatching, and differences to control birds deepened thereafter (Haesler et al., 2007). In comparison, correct and precise perceptually based language sound production of human infants is relatively delayed in time. Word production appears to be initially only an "echo" (Greer & Ross, 2004), with production of some syllables in babbling (De Boysson-Bardies, 1996/1999) in the first year, and word approximations (Dromi, 1987) in the second year. However, also word fragments can be efficient for communication (Fernald, Swingley, & Pinto, 2001). It is only from age two onwards that a vocabulary explosion occurs due to "fast mapping" (Carey & Bartlett, 1978). Yet correct pronunciation of words still increases for some further time, most likely due to the articulatory difficulty of some particular consonants (Prather, Hedrick, & Kern, 1975).

While garden birds learn complex melodies, sea birds do *not* learn songs, and their sounds do not vary in different ecologies (Bretagnolle, 1996; Miller, 1996). Sea-bird calls are very efficient low-frequency signals that can travel long distances (Catchpole & Slater, 1995). Garden birds would not be able to emit lower frequency calls as they lack the body volume (Lambrechts, 1996). In summary, sea-bird sounds are innate, relatively lower frequency, rhythmic and repetitive, while garden-bird songs are learned, comparably higher in frequency, and more melodious. Would human infants and adults be able to discriminate between examples of these naturally occurring auditory stimuli of two distinct classes of birds?

A study with human adults and monkeys (Snowdon, 1987) found that monkeys could not use critical parameters when processing human speech sounds, but human adults could discriminate monkey calls based on the rate of frequency modulation. However, in more recent research, monkeys

appeared to monitor communicative signals in the same way as humans (Ghazanfar, Nielsen, & Logothetis, 2006), and both monkeys and infants could distinguish between languages as long as the contrast of language *rhythm* was large enough (Nazzi, Bertoncini, & Mehler, 1998; Ramus, Hauser, Miller, Morris, & Mehler, 2000; Ramus et al., 2001), suggesting a common origin of auditory sound-perception processing (see also White, Fisher, Geschwind, Scharff, & Holy, 2006).

Already at about four months, infants noticed meaningful pauses between sentences in language (Jusczyk, 1989; Polka, Jusczyk, & Rvachew, 1995) and in musical phrases (Jusczyk & Krumhansl, 1993; Krumhansl & Jusczyk, 1990), indicating parallel development of rhythmic abilities in speech and non-speech sounds. Six-month-old infants could detect small auditory time differences of 30 to 40 ms (Ashmead, Davis, Whalen, & Odom, 1991; Smith, Trainor, & Shore, 2006). The ability to discriminate sounds already develops in the womb, whether stimuli were pure tones generated on a computer or human voices (e.g., Abrams, Gerhardt, Huang, Peters, & Langford, 2000; Groome et al., 2000; Lecanuet et al., 1995; Lecanuet, Granier-Deferre, Jacquet, & Busnel, 1992; Lecanuet, Granier-Deferre, Jacquet, Capponi, & Ledru, 1993; Pujol & Lavigne-Rebillard, 1992). Infants also hear sounds generated from the physiological system of the maternal body itself. Saling (1985; Saling & Arabin, 1987) demonstrated by inserting a surgical microphone into the womb, that the foetus hears the loud, constant, rhythmic sound of the heartbeat of the mother, as well as sounds from her digestive system.

Trainor and Zacharias (1998) concluded that the intrauterine experience of infants would make infants more sensitive towards lower pitched voices. While newborns recognized low-pass filtered speech from their mothers (Spence & DeCasper, 1987), they did not recognize whispered speech of their mothers when the low-frequency energy was removed (Spence & Freeman, 1996). However, infants also preferred higher pitched singing that has been raised by approximately 100 Hz to about 350 Hz, probably because of the contrast to normal everyday speech (Trainor & Zacharias, 1998). Hence young infants seem dependent on low frequency, but given that their daily caregivers have familiar and stable voices (Bergeson & Trehub, 2002), it may need slightly elevated pitch to attract infants' attention towards language (Trainor & Zacharias, 1998). Thus, the lower frequency, rhythmic and repetitive sea-bird sounds, which are in fact in about the same frequency range as the human voice, may be more in tune with young infants' auditory perceptual ability than the very high-pitched garden-bird songs. Infants retain information about frequency range readily (Trehub, Endman, & Thorpe, 1990), but their sensitivity to very high frequencies is less developed (Mehler & Dupoux, 1994, p. 163). Folsom and Wynne (1987) as well as Spetner and Olsho (1990) found that infants could identify tones at lower

frequencies of 500 and 1000 Hz (normal human voices are usually below 500 Hz). They could also identify some tones of 4000 and 8000 Hz, which are more similar in frequency to professional soprano singers (Joliveau et al., 2004; Wolfe, 2004). High-frequency tones at 100,000 Hz (equivalent to 10 KHz; Trehub, Schneider, Morrongiello, & Thorpe, 1989) needed increased intensity (loudness) to be perceptible in the first six years of life.

THE PRESENT STUDY

There are no previous studies on infants' perceptual discrimination of bird sounds, and this is the first study of this kind. It was expected that infants would be more likely to listen to the lower frequency sea-bird sounds rather than to the melodically more varied, higher frequency garden-bird songs. The frequency range of the sea-bird sounds ranged up to 1500 Hz, while the garden-bird sounds ranged from 2000 to 8000 Hz. All stimuli were audible for infants and when the word "sensitivity" is used here, it is not in the psychophysical sense that physiological hearing is sensitive enough to detect a stimulus at a particular psychophysical frequency threshold. Instead, "sensitivity" is used in a wider sense, denoting that infants' would react selectively towards audible auditory stimuli.

The conditioned **head-turn procedure (CHTP)** was used with bird-sound stimuli as in infant speech perception research (e.g., Jusczyk, 1997; Jusczyk et al., 1993; Kemler Nelson et al., 1995). Observers usually cannot see whether and to what sound participants are listening. Thus, in the CHTP, infants' auditory attention is conditioned using visual stimuli: Infants are conditioned initially with a blinking green light to look straight ahead towards a fixation point. Thereafter, a blinking red light would be presented randomly on either the left or right hand side. Once the participant has turned the head to the red light, a sound would emerge from the same location. Then only the light is switched off, while the sound stays on until the participant looks away. In this way, while the beginning of listening is visually conditioned, the end of listening is indicated by a voluntarily controlled head turn.

Although infants in general use similar mechanisms as adults when processing music (Trehub, Zatorre, & Peretz, 2001), infants and young children may classify auditory stimuli in a different way to older children or adults. For example, classification of visual animal stimuli such as cats, dogs and birds is often based on perceptual similarity of exemplars to a prototype (e.g., Farah & Kosslyn, 1982; Hayes & Taplin, 1993; Quinn & Johnson, 1997; Sloutsky, 2003; Sloutsky & Fisher, 2004; Sloutsky, Lo, & Fisher, 2001; Smith, 1979). For the auditory domain, Kuhl (1993) explained that attention would be attracted towards a prototype like a "perceptual magnet". For example, 2-week-old infants preferred a female over a male voice

(Lecanuet & Granier-Deferre, 1987) and could distinguish their mother's voice over other exemplars of female voices (Aldrige, Braga, Walton, & Bower, 1999; Bergeson & Trehub, 2007; DeCasper & Fifer, 1980), even when still in the womb (Smith, Dmochowski, Muir, & Kisilevsky, 2007). Thus, unique individual sounds may play an important role in early auditory perception. Hence, while a first analysis tested the hypothesized infant preference of sea-bird sounds with looking/listening times per bird category averaged across exemplars, thereafter item-based analyses followed. It was hypothesized that in infants some individual exemplars would have more power to determine looking/listening behaviour than others, while adults would pay more equal amounts of attention towards each exemplar, as each sound would just represent an instantiation of a category. Hence, it was expected that within-category correlations in infants would be less numerous than in adults (Lotto, Kluender, & Holt, 1998).

EXPERIMENT 1

Method

Participants. A sample of $N=35$ participants took part. Infants were recruited in the harbour town of Aberdeen in Scotland where sea birds belong to the natural habitat. Data sets of six infants were excluded from analyses because of fussiness. Age groups were eleven 5- to 7-month-old and eight 10- to 12-month-old infants. Mean ages (months;days) were $M=6;4$ (range 4;28 to 7;18) and $M=11;27$ (range 10;25 to 12;24). Adults were ten Scottish undergraduate students.

Apparatus and material. The lab was a completely empty room except for apparatus. The task was carried out in a three-sided, open booth, constructed according to Jusczyk et al. (1993), see Figure 1. The three panels of the booth were 4×6 ft (approx. 1.20 m wide $\times$ 1.80 m high) each. The infant was seated on the caretaker's lap between two loudspeakers on the left and right. These two loudspeakers had a red light above, which would blink before the onset of a sound to attract infants' attention. The central panel facing the participant had an observation window with a metal lattice sheet, painted in the same colour as the booth, so that it could be used like a one-way mirror. A green light below this observation window functioned as a centre fixation point, which blinked at the onset of each trial. Lab and booth were painted light grey.

Bird sounds were from the audiotapes No. 1 "Garden Birds" and No. 7 "Sea Cliffs and Islands" (Waxwing, Birdwatching, used with permission by John Wyatt, Tring, Hertfordshire, UK). All sea birds were breeding in

Figure 1. The upper part of the figure shows an infant in the booth turning its attention towards the light on its right. The light was switched off once the infant had turned the head and the sound was released (drawing from a video capture). The lower part of the figure shows the booth layout. The three possible directions in the booth that the infant could be conditioned to look with flashing lights are indicated by arrows.

Aberdeen, with the exception of the Storm petrel and the Leach petrel, which had their breeding grounds some hundred miles further north in Scotland, but could be expected to be vagrant in the area (Peterson,

Mountfort, & Hollom, 1993). The songs were digitized with a Soundblaster card into a .wav format, and then converted into .voc format, so that they could be played back controlled for loudness from the hard disk using the experimental software ERTS (Beringer, 1993; see *ERTS Reference Manual*, p. 56). Using the sound editing software Powertracks Pro Audio, long silences in the garden-bird songs were cut in order to avoid infants looking away during pauses in the stimulus presentation. No other changes were made. To bird watchers and ornithologists, the garden-bird songs would have appeared a bit less contemplative than normal, but none of the lay adult participants noticed this.

The durations of the five sea-bird sounds were as follows: Fulmar 10.37 s; Leach petrel 13.36 s; Storm petrel 19.50 s (the call of the Storm petrel consisted of one long phrase, which could not be clipped, a sonogram similar to an infant cry, see Figure 2); Black-headed gull 10.51 s; and Herring gull 10.24 s; i.e., the total theoretically possible exposure time to sea-bird sounds was on average 12.80 s. Because the presentation was aborted as soon as an infant did not pay attention, average looking time was much shorter than absolute sound duration.

For the five garden-bird songs, durations were as follows: Song thrush 11.43 s; Mistle thrush 11.39 s; Wren 11.02 s; Blackbird 11.50 s; and Robin 11.78 s; i.e., on average 11.44 s. Sounds were presented twice on either side of the booth, randomized for both bird sound and booth side. Data of five participants who had experienced each sound only once on either side, as in Experiment 2, were included in the analysis.

Figure 2. The “solid” one-phrase sonogram of the Storm petrel (left) in comparison to the Leach petrel (right), which shows shorter, editable phrases. The one-phrase structure of an infant cry is included as comparison.

Spectrograms of the sound files are listed in the appendix. They show that there were plenty of varied notes constituting a melody in the garden-birds' songs, but more repetitive ones in a more monotonous rhythmical sound pattern in sea-birds' sounds. The average frequency of each waveform was analysed using Adobe Audition, Blackmann–Harris, Area Frequency Analysis, fast Fourier transformation (FFT) size 1024, see Figure 3. There are different FFT methods of selecting and weighing the components of a sound, which can yield somewhat different results, but despite this weakness the FFT method is still more preferable than others, e.g., linear predictive coding (LPC) (Green et al., 1995, p. 163). Indeed, in the current study, the average frequency had also been calculated by Powertracks Pro Audio and other FFT methods within Adobe Audition, with slightly different results for bird sounds of similar frequency, but this did not affect the frequency boundary between sea and garden birds. Average frequency of sea-bird sounds at 839.5 Hz was lower than of garden-bird songs 4062.4 Hz, $t = -3.25$, $p < .05$.

Presentation of sounds and lights was programmed with the software Experimental Run Time System (ERTS; Beringer, 1993). An ERTS EXKEY-logic device enhanced recording precision. A specially built relay station was necessary to control lights and sound simultaneously. Looking data were stored as individual result files on the computer by ERTS.

Figure 3. Frequencies (in Hz) of sea- and garden-bird sounds. The frequencies of the waveforms were computed using Adobe Audition (Blackmann–Harris).

Procedure. Each participant completed four practice trials with auditory stimuli, two on either side, which were not bird sounds, to familiarize infants with the laboratory environment and to confirm that the CHTP worked. The CHTP followed Jusczyk et al. (1993): The green light in the centre panel was flashed to attract the infant's attention. Once this was ascertained, the experimenter behind the lattice window would press a key to onset a red light at one side of the booth. The experimenter was blind as to which side and sound was selected by the experimental programme on each trial. Once the infant was looking towards the side where the red light was on, the experimenter again pressed a key to elicit the actual bird sound, which extinguished the flashing light. When the participant turned away at an angle of more than 30 degrees for more than 2 s, the experimenter pressed the key again and the experimental programme recorded the looking time. A second observer, who was blind as to the purpose of the experiment, recorded looking times with a stop watch. Inter-rater reliability for five infant sessions was .96. CHTP was used with infants and adults, but as adults could not be conditioned with a flickering light, the head-turn procedure was explained. In particular, they were asked to turn away their entire head from the sound rather than just their eyes when no longer interested in listening.

Results

Preference as per looking times were averaged per bird category and analysed with analysis of variance (ANOVA). Cluster analysis was used to test whether some bird sounds had more impact than others to determine looking behaviour. Finally, correlational analysis was used for within- and between-category correlations (Pearson correlations $p \leq .05$, two-tailed tests).

A 3 (Age) $\times$ 2 (Side) $\times$ 2 (Bird Type) ANOVA with repeated measures on the last two factors showed a significant two-way interaction of Age by Bird Type, $F(2, 29) = 17.75$, $p < .001$, $\eta^2 = .58$ (see Figure 4). Post hoc tests showed that both infant groups tended to pay more attention to sea-bird than to garden-bird sounds, while adults showed the reverse preference.

A marginally significant main effect of Side showed that right-side sounds were more attended than left-side ones, $F(1, 29) = 5.37$, $p = .057$, $\eta^2 = .13$. The effect of side did not interact either with age or the type of birdsong, and no other effects were significant, $ps > .16$.

K-means cluster analyses showed that the sounds of the Black-headed gull, the Leach petrel and the Storm petrel contributed significantly to

Figure 4. Study 1. Preferential looking times towards sea-bird sounds and garden-bird songs in Aberdeen infants and adults.

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responses of 5- to 7-month-old infants, see Table 1 (on next page). The long-phrase sound of the Storm petrel had the highest impact. But also the Robin and the Song thrush contributed significantly in this age group.

In contrast, the highest contribution to responses of 10- to 12-month-old infants was made by garden-bird songs only, i.e., Blackbird and Song thrush. In Scottish adult participants, exemplars of both birds types contributed significantly.

TABLE 1
Results of the cluster analyses, Study 1: Contributions of individual bird sounds
(significance of *F*-values)

<i>Bird type</i>	<i>5–7 months</i>	<i>10–12 months</i>	<i>Adults</i>
<i>Garden birds</i>			
Blackbird	0.83	42.32***	21.9**
Mistle thrush	0.03	0.03	8.49*
Robin	5.79*	2.28	53.6***
Song thrush	11.07**	49.46***	23.9***
Wren	1.14	7.12*	4.32
<i>Sea birds</i>			
Black-headed gull	9.97*	5.81	3.75
Fulmar	2.25	4.85	11.64**
Herring gull	0.36	0.30	14.74**
Leach petrel	6.47*	0.01	3.70
Storm petrel	72.7***	0.15	4.68

Notes: * $p < .05$; ** $p < .01$; *** $p < .001$.

The plotted significant correlations in Figure 5 (on next page) show that in 5- to 7-month-old infants within-category correlations occurred mainly for sea-bird sounds, while in 10- to 12-month-old infants within-category correlations occurred more often for garden-bird songs. In general, there were about the same amount of within- as between-category correlations in infants. Adults showed more within- than between-category correlations for both sea- and garden-bird sounds.

Discussion

Results were straightforward. Both children and adults reliably distinguished between the two types of bird sounds. Infants showed a reversed preference compared to adults: Infants listened longer to sea-bird sounds, while adults concentrated more on garden-bird songs. The 10- to 12-month-old infants already showed some systematic attention to garden-bird songs, with sea-bird sounds having dropped out as a source of their perceptual discrimination. Although their preference of sea-bird sounds was not yet changed, their looking towards garden-bird songs had somewhat increased so that the difference was diminished to a trend.

Garden-bird songs might have attracted less looking time because their more varied songs may have been too high in frequency and too complex in melody to attract infants' attention, while the rhythmic lower frequency sounds of sea birds might have appealed to infants because of their similarity with intra-uterine auditory experiences of the mother's physiological sounds, because of their own cry production and/or infants' and caregivers' non-lexical, vocal exchanges at a similar frequency. However, it

Figure 5. Study 1. Significant correlations between examples of sea- and garden-bird sounds in two groups of Scottish infants and in adults.

could be that this Scottish sample of infants was so familiar with the nearly ubiquitous, raucous, emphatic, harsh, noisy, predatory sea-bird calls (all descriptions from Peterson et al., 1993) in their seaside town that a familiarity effect occurred. That is, infants just liked to listen to what they

were familiar with. Thus, it could not be decided from the current data set whether the infant preference for sea-bird sounds was solely based on a specific Scottish seaside environmental experience, or because of an early and possibly innate disposition, which would be universal to all infants. For this reason, a follow-up infant experiment was conducted in Central Europe, at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, where sea birds do not belong to the natural habitat.

EXPERIMENT 2

Method

Participants. Seventy-five participants took part in the experiment. Data sets of 9 infants were excluded from analyses because of fussiness. As research conditions were more favourable, participants for three infant groups could be recruited. There were sixteen 4- to 5-month-old, fifteen 6- to 8-month-old, and seventeen 10- to 12-month-old infants. Mean ages (months;days) were $M=4;16$ (range 3;28 to 4;28), $M=6;26$ (range 6;7 to 7;21), and $M=11;7$ (range 9;4 to 12;8). Adults were 18 multi-ethnic students in London.

Apparatus and material. The task was carried out with infants at the Max Planck Institute of Evolutionary Anthropology in a same-sized three-sided open booth as in Experiment 1, except the booth was black, not light grey. Instead of the one-way observation window, sessions were filmed. A hole for the camera lens was made in the panel beneath the central green light. The task with adults was carried out at the London Metropolitan Psychology Department. Steel frames of the same measurements covered with black linen were used instead of the wooden panel setup, and again a hole was cut into the cloth beneath the green light for the camera. Using a camera, the experimenter could directly observe participants on a monitor on her desk when they were turning away from the sound, i.e., without peeping through the lattice as in Experiment 1. The same bird sounds were used, except that this time they were about doubled in length to 20 ms in order to match the length of the Storm petrel sound, and played once on each side of the booth.

Procedure. The same procedure was followed as in Experiment 1. Inter-rater reliability was assessed by a rater blind to the research question using the videos with video analysis software (Interact). Agreement for 12 infant sessions (4 from each age group) was 89.6%. With the longer duration of the stimuli, it was noted that ERTS did not record looking times longer than

18 s (47 out of 1320 data points = 3.6%). These missing data were coded directly from the session video tapes by two raters simultaneously, using the video-editing software Adobe Premiere.

Results and discussion

Statistical analyses were carried out as before. A 4 (Age) $\times$ 2 (Side) $\times$ 2 (Bird Type) ANOVA with repeated measures on the last two factors showed a main effect of Bird Type, $F(2, 66) = 9.40$, $p < .01$, $\eta^2 = .13$, with sea-bird sounds gaining more attention than garden-bird songs. As in Experiment 1, a significant two-way interaction of Age by Bird Type, $F(3, 66) = 10.98$, $p < .001$, $\eta^2 = .35$, was found, see Figure 6 (on next page). Post hoc tests showed that all three infant groups paid more attention to sea-bird sounds than to garden-bird songs, while adults showed the reverse preference. No other effects were significant, $ps > .21$.

K-means cluster analyses (see Table 2) showed that both sea and garden birds contributed to the looking behaviour of all three infant age groups. In 4- to 5-month-old infants, the highest contribution was produced by the Black-headed gull, a sea bird, while in both 6- to 8-month-old and 10- to 12-month-old infants two garden birds, i.e., the Blackbird and the Robin, respectively, were contributing most. While this change from sea-bird sounds to garden-bird songs was also the case in Experiment 1, in the continental infants sea-bird sounds did not completely “drop out” at the end of the first year. The Storm petrel when embedded in sounds of similar

TABLE 2
Results of the cluster analyses, Study 2: Contributions of individual bird sounds
(significance of F -values)

<i>Bird type</i>	<i>4–5 months</i>	<i>6–8 months</i>	<i>10–12 months</i>	<i>Adults</i>
<i>Garden birds</i>				
Blackbird	10.47**	20.90***	6.16*	27.01***
Mistle thrush	2.72	7.48*	10.56**	25.40***
Robin	4.56	0.40	16.10***	30.95***
Song thrush	4.90*	3.39	1.41	13.39**
Wren	0.30	0.00	0.07	11.66**
<i>Sea birds</i>				
Black-headed gull	18.82***	2.23	0.54	6.77*
Fulmar	4.51	0.59	9.85**	11.13**
Herring gull	0.00	2.23	0.87	8.11*
Leach petrel	5.42*	10.04**	0.37	9.41**
Storm petrel	0.13	3.30	6.87*	13.33**

Notes: * $p < .05$; ** $p < .01$; *** $p < .001$.

Figure 6. Study 2. Preferential looking times towards sea-bird sounds and garden-bird songs in Leipzig infants and adults.

length had lost its impact. In adults again most exemplars had a significant impact on looking behaviour.

Correlational analyses showed that different to Scottish infants, all three age groups of German-Saxon infants showed very few within-category correlations for sea-bird sounds and garden-bird songs, see Figure 7 (on next page). Instead, between-category correlations occurred more often. Again, in adults in general more correlations were found than in infants. The multinational students showed both within- and between-category correlations.

Figure 7. Study 2. Significant correlations between examples of sea- and garden-bird sounds in three groups of Leipzig infants and in adults.

GENERAL DISCUSSION

In Experiment 2, as in Experiment 1, infants and adults reliably distinguished between the two types of sounds. In both experiments, infants

preferred sea-bird sounds to garden-bird songs, while adults preferred garden-bird songs over sea-bird sounds. The replication with infants living in Central Europe thus indicated that infants' preference of sea-bird sounds was not a local preference of seaside-raised babies, but more likely a universal disposition.

In both studies, more exemplars of each category contributed to looking behaviour of adults than in infants in the cluster and the correlational analysis, suggesting that adults were scrutinizing the stimuli more systematically than infants, especially the London-based students. Infants' attention appeared to be captured by few sounds. This result would support a view that the early categorization of infants is not yet a cognitively based thorough inspection, which exhaustively sorts all exemplars into two relatively neat categories. Adults knew that looking away would terminate the auditory stimulus, and hence their attention towards the stimulus was much more consciously directed than that of infants. The reduced conscious stimulus control of infants does not lessen the reliability of the result that sea-bird sounds attracted comparably more of their auditory attention, it just shows that the underlying attention system of infants and adults for successful sound discrimination is different.

Furthermore, in both studies, younger infants' looking behaviour was more determined by sea-bird sounds, while in older infants, garden-bird songs had gained in influence. This indicated increased auditory sensitivity of older infants towards more melodious, higher frequency songs, but it had not changed the preference yet. Further research with children should be able to demonstrate when the preference changes towards garden-bird songs. In particular, it would be theoretically interesting to investigate whether the onset of infants' own word production and syntax would change their preference from sea-bird sounds towards garden-bird songs, i.e., whether this cross-species preference is coupled with productivity rather than sensitivity.

After the commonalities between the two experiments, differences also need to be mentioned. Both Scottish infants and adults showed comparably more within-category correlations between exemplars than the German-Saxon infants and the multi-ethnic students. It may be that this revealed some local Scottish environmental influence insofar as the above-average exposure to sea-bird sounds may have enabled direct perceptual redescription into categories from early on (Mandler, 1988, 1992).

Hence, the study yielded considerable first results on infant discrimination of wildlife bird sounds, with important clues for further research about the faculty of language in a broad sense. It might not be the case that the genetic code "generated a vast number of mutually incomprehensible

communication systems across species while maintaining clarity of comprehension only within a given species” (Hauser et al., 2002, p. 1569). The message of an angry or soothing bird sound might be just as comprehensible as that of an angry or soothing parent.

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APPENDIX

Bird-sound spectrograms

Sea birds

Fulmar

Leach petrel

Storm petrel

Black-headed gull

Herring gull

Garden birds

Song thrush

Mistle thrush

Wren

Blackbird

Robin