Research Article

Hemispheric Differences in the Recognition of Environmental Sounds

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ABSTRACT—*Recent work has found support for two dissociable and parallel neural subsystems underlying object and shape recognition in the visual domain: an abstract-category subsystem that operates more effectively in the left cerebral hemisphere than in the right, and a specific-exemplar subsystem that operates more effectively in the right hemisphere than in the left. Evidence of this asymmetry has been observed for linguistic stimuli (words, pseudoword forms) and nonlinguistic stimuli (objects). In the auditory domain, we previously found hemispheric asymmetries in priming effects using linguistic stimuli (spoken words). In the present study, we conducted four long-term repetition-priming experiments to investigate whether such hemispheric asymmetries would be observed for nonlinguistic auditory stimuli (environmental sounds) as well. The results support the dissociable-subsystems theory. Specificity effects were obtained when sounds were presented to the left ear (right hemisphere), but not when sounds were presented to the right ear (left hemisphere). Theoretical implications are discussed.*

There is an ongoing debate concerning the nature of the representations involved in object recognition in the visual domain. Marsolek and his colleagues hypothesize the existence of two dissociable and parallel neural subsystems: The *abstract-category subsystem* operates more effectively in the left than in the right hemisphere and is less sensitive to specific surface characteristics of stimuli, and the *specific-exemplar subsystem* operates more effectively in the right than in the left hemisphere and

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is more sensitive to specific stimulus characteristics (Marsolek, 1999; Marsolek & Burgund, 2008). This theory would explain the apparent dilemma of why two objects (e.g., two different exemplars of pianos) are recognized as belonging to the same abstract category, but also to different specific categories.

The dissociable-subsystems framework challenges other contemporary object-recognition theories proposing a single and undifferentiated object-recognition system. These theories differ in whether this single system relies on relatively abstract representations (Biederman, 1987; Hayworth & Biederman, 2006; Wagemans, Van Gool, & Lamote, 1996), relatively specific representations (Bülthoff & Edelman, 1992; Tarr, Williams, Hayward, & Gauthier, 1998), or both abstract and specific representations on a continuum (Farah, 1992; Hayward & Williams, 2000).

Behavioral evidence for two dissociable subsystems has been found in the recognition of objects, words, pseudoword forms, and letterlike forms (but see Koivisto, 1995; for a review, see Marsolek, 2003). Other data from neuropsychology (Beeri, Vakil, Adonsky, & Levenkron, 2004; Farah, 1991), electrophysiology (Pickering & Schweinberger, 2003), and functional magnetic resonance imaging (Koutstaal et al., 2001) are consistent with the dissociable-subsystems account. Neurocomputational simulations show that abstract and specific categorizations are performed more effectively by a dual-subsystems model than by a single-system model, particularly when abstract categories include both similar and dissimilar exemplars (see Marsolek, 2003).

The strongest support for the dissociable-subsystems theory comes from studies using the *long-term repetition-priming* paradigm. In this paradigm, *priming* (enhancement of performance) due to repetition of a stimulus may be attenuated if the first and second presentations of the stimulus mismatch on some dimension (e.g., different letter case for words or different exemplars for objects). This attenuation of priming is referred to as *specificity*. In a study of object recognition, Marsolek (1999)

reported distinct patterns of specificity in the two hemispheres. Participants named objects (e.g., a piano) presented in either the left visual field (right hemisphere) or the right visual field (left hemisphere) after having viewed a series of centrally presented objects during an initial encoding phase. Some of the test objects were repetitions of the same exemplars seen during encoding, and others had been preceded by different exemplars from the same category (e.g., one exemplar of a piano during encoding and a different exemplar of a piano during test). Equivalent priming was obtained in the same- and different-exemplar conditions when test objects were presented to the left hemisphere, but priming was reduced in the different-exemplar condition (a demonstration of specificity) when test objects were presented to the right hemisphere. A similar pattern of right-hemisphere specificity was obtained when objects did or did not vary in depth orientation (Burgund & Marsolek, 2000) and when the objects used were unfamiliar or novel (Marsolek & Burgund, 2008).

There are reasons to believe that two dissociable neural subsystems may underlie abstract and specific perception beyond the visual domain. We recently obtained hemispheric differences in talker specificity effects in spoken word recognition (González & McLennan, 2007), a finding analogous to Marsolek and his colleagues' findings of hemispheric differences in letter-case specificity effects in visual word recognition (Burgund & Marsolek, 1997; Marsolek, 2004). Specifically, we observed that the right hemisphere was more sensitive than the left hemisphere to surface information associated with talker identity. The question of interest in the study we report here is whether this hemispheric asymmetry in auditory priming is unique to linguistic stimuli, or whether it extends to nonlinguistic stimuli. If the asymmetry does extend to nonlinguistic stimuli, then it can be considered a general property of the auditory perceptual system, and we should obtain the same pattern of results in the auditory recognition of environmental sounds as in the auditory recognition of linguistic sounds.

Dichotic-listening, neuropsychological, electrophysiological, and neuroimaging studies have provided a great deal of evidence for auditory processing asymmetries (see Tervaniemi & Hugdahl, 2003), and demonstrate that such asymmetries are not limited to a single domain (e.g., language, music, environmental sounds). However, no hemispheric distinction can account for all the data (Sanders & Poeppel, 2007). In particular, classical dichotic-listening studies revealed an overall right-ear advantage for processing some types of verbal stimuli and a left-ear advantage for processing prosody, some aspects of music, and environmental sounds (Hugdahl, 1999); however, no study to date has investigated the lateralization of specificity effects.

In the present study, we tested hemispheric asymmetries in specificity by performing four long-term repetition-priming experiments in which the task was to identify environmental sounds. An obvious prerequisite was demonstration that such stimuli are subject to long-term priming and specificity effects in

the first place. Some studies have reported priming for environmental sounds (Chiu, 2000; Chiu & Schacter, 1995; Stuart & Jones, 1996), and one study obtained specificity effects (Chiu, 2000). In particular, Chiu observed exemplar specificity effects in four repetition-priming experiments in which participants attempted to identify environmental sounds from their initial sound stems or to identify environmental sounds embedded in white noise. He found that priming was more robust when a sound was repeated than when it was preceded by a different exemplar from the same category. Our aim was to investigate potential hemispheric differences in exemplar specificity effects during the recognition of environmental sounds. We expected to find a pattern similar to that reported by Marsolek (1999) in his work on visual object recognition. In particular, we predicted significantly better performance in sound recognition after same-exemplar priming than after different-exemplar priming when stimuli were presented to the right hemisphere, but not when they were presented to the left hemisphere.

In each experiment, 24 (Experiments 1 and 2) or 30 (Experiments 3 and 4) participants of both sexes, recruited from the University Jaume I, volunteered in return for course credit. All participants were right-handed (Edinburgh Handedness Inventory; Oldfield, 1971) native speakers of Spanish with no reported history of speech or hearing disorders. No one participated in more than one experiment.

EXPERIMENT 1

Method

Materials

The experimental stimuli consisted of 24 digitized target sounds (see Table 1) that were selected from Marcell, Borella, Greene, Kerr, and Rogers's (2000) database as representing a variety of everyday nonverbal acoustic events, such as sounds produced by animals, people, musical instruments, tools, and other objects. According to the normative data reported by Marcell et al., the mean naming accuracy for these sounds was 78%. Following Shafiro and Gygi's (2004) guidelines, we selected an additional

TABLE 1
Target Stimuli Used in the Experiments

Experiments 1–2: bagpipes, boat horn, chewing, child coughing, church bells, coin dropping, cutting paper, drill, elephant, frying food, gong, harmonica, helicopter, jackhammer, monkey, ocean, owl, pouring water, thunder, toilet flushing, turning pages, violin, wind, yawning

Experiments 3–4: accordion, airplane, brushing teeth, cash register, clapping, crumpling paper, donkey, dropping ice in a glass, flute, gargling, guitar, harp, horse galloping, lion, organ, ping-pong, police siren, rattlesnake, snoring, train, typewriter, whistling, wolf, zipper

Note. These stimuli were obtained from Marcell, Borella, Greene, Kerr, and Rogers (2000).

set of 24 digitized sounds from a variety of sound databases. These sounds represented the same acoustic events as the target set. Thus, we had two exemplars for each event. Both sets of sounds were 16-bit WAV files saved at a sampling rate of 22,050 Hz. Durations of the sound files ranged from 1.1 to 5.9 s. A different set of environmental sounds was used as filler stimuli. All audio files were equated in root-mean-square (RMS) amplitude. Auditory stems were created by digitally truncating each target sound so that only the initial 750 ms were preserved (Chiu, 2000, and Chiu & Schacter, 1995, used the first 1,000 ms).

Design and Procedure

The design was similar to that of other long-term repetition-priming experiments (González & McLennan, 2007; McLennan & Luce, 2005; McLennan, Luce, & Charles-Luce, 2003). Participants were seated in front of a computer and listened to stimuli presented in two blocks. In the first block (the study phase), 24 stimuli were presented binaurally in random order (8 same-exemplar primes, 8 different-exemplar primes, and 8 fillers). These stimuli were preceded and followed by 2 additional fillers to minimize primacy and recency effects (Chiu, 2000). Participants were instructed to type the name of the acoustic event represented by the sound in each trial. After a short distractor task (performing arithmetic operations for 4–5 min), participants received the second block (the test phase). During this block, they were instructed to identify target sounds from their 750-ms sound stems. Stems were presented monaurally in random order. Half the stems were presented to the left ear, and half were presented to the right ear. Note that because the majority of neural projections are contralateral, a stimulus presented to the right ear should be processed more efficiently in the left than in the right hemisphere, and a stimulus presented to the left ear should be processed more efficiently in the right than in the left hemisphere. Of the 24 sound stems presented in the test phase, 8 were primed by a same-exemplar sound in the study phase, 8 were primed by a different-exemplar sound in the study phase, and 8 were unprimed (the control condition).

The experiment was conducted on a Pentium PC computer, using Inquisit 1.33 software, and stimuli were presented over calibrated headphones (AKG-K55; Vienna, Austria) at 70 dB in a quiet room. Examples of possible correct responses were given during three preliminary practice trials, but not during the study or test phases.

The experimental design was an orthogonal combination of three levels of prime type (same-exemplar, different-exemplar, and control) and two levels of ear of target-stem presentation (left and right). Table 2 summarizes the six within-participants conditions. Six stimulus lists were created to ensure that each target stem was assigned to every possible condition across participants. No participant heard more than one version of a given sound within a block.

TABLE 2

Experimental Conditions in the Four Experiments

Condition	Block 1: prime	Block 2: target
Same-exemplar	bagpipe$_A$	bagpipe$_A$
Different-exemplar	bagpipe$_B$	bagpipe$_A$
Control	duck	bagpipe$_A$

Note. The conditions are illustrated by examples of stimuli used in Experiments 1 and 2. Subscripts identify different exemplars of the same sound event. Complete sound files were presented binaurally during Block 1, and truncated versions (target stems) were presented monaurally in Block 2. The target stems were presented to the right ear on half the trials and to the left ear on the other half.

Results

Responses in the test phase were scored according to the guidelines for scoring naming responses outlined by Marcell et al. (2000, pp. 836–842). Figure 1 displays the mean proportion of naming accuracy as a function of prime type and ear of target-stem presentation. Separate analyses were carried out with participants (F_1, t_1) and items (F_2, t_2) as the random variable.

Accuracy was analyzed in a two-way repeated measures analysis of variance (ANOVA) with prime type (same-exemplar, different-exemplar, or unprimed control) and ear of target-stem presentation (left or right) as within-participants factors. Planned comparisons were performed to examine any possible difference between the same-exemplar and different-exemplar conditions for each ear (hemisphere). We observed a significant main effect of prime type, $F_1(2, 46) = 10.20$, $MSE = 0.038$,
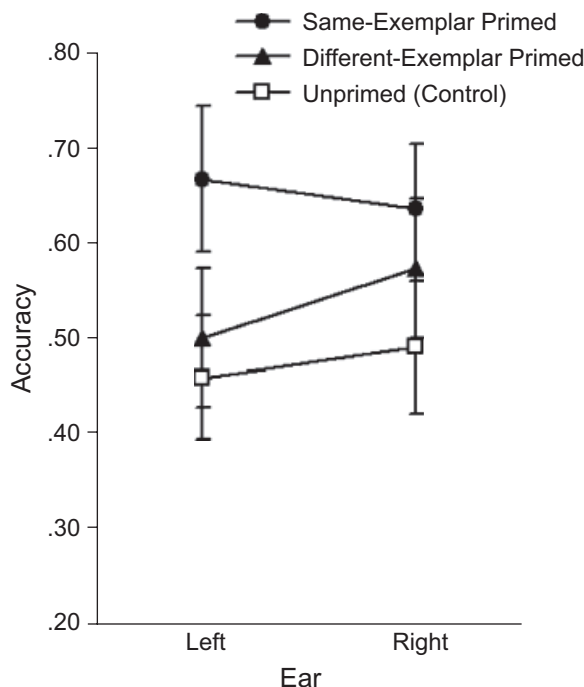

Fig. 1. Mean proportion of naming accuracy in Experiment 1 as a function of prime type and ear of target-stem presentation. Error bars indicate standard errors of the means.

$\eta_p^2 = .31$; $F_2(2, 46) = 10.20$, $MSE = 0.038$, $\eta_p^2 = .31$. No other significant effect was obtained. Post hoc analyses revealed significant differences between the same-exemplar and control conditions, and between the same-exemplar and different-exemplar conditions.

Crucially, planned comparisons demonstrated that the difference between the same-exemplar and different-exemplar conditions (Ms = .64 and .57, respectively) was not significant when the target stems were presented to the right ear (both $ts < 1$), but was significant (Ms = .67 and .50) when the target stems were presented to the left ear, $t_1(23) = 3.56, p < .003, p_{rep} = .99$, $d = 0.73$; $t_2(23) = 3.56, p < .003, p_{rep} = .99, d = 0.73$.

Discussion

These results are consistent with our predictions based on Marsolek's (1999, 2003) results in the visual domain. In particular, exemplar specificity effects emerged when the target stimuli were presented to the left ear (right hemisphere), but not when the target stimuli were presented to the right ear (left hemisphere).

EXPERIMENT 2

In an attempt to minimize the involvement of the hemisphere on the same side as the ear receiving the target stimuli (via ipsilateral projections), in Experiment 2 we presented noise to the ear not receiving each auditory target stem. Presenting information to the two hemispheres simultaneously would be expected to increase competition between the hemispheres and to increase the likelihood of observing hemispheric asymmetries (Fecteau, Enns, & Kingstone, 2000; González & McLennan, 2007; Kimura, 1961).

Method

The materials, design, and procedure were all identical to those of Experiment 1, with the following exceptions: A 750-ms audio file containing white noise was created; the noise was low-pass-filtered at 11,025 Hz and digitized at a sampling rate of 22,050 Hz, and the RMS amplitude was set to 5 dB below the level of the sound files. During each trial in the test phase, a sound stem was presented in one ear, and the noise was presented simultaneously in the opposite ear.

Results

Figure 2 displays the mean proportion of naming accuracy as a function of prime type and ear of target-stem presentation. As expected, overall performance was lower than in Experiment 1 because of the noise's masking effect. We observed a significant main effect of prime type, $F_1(2, 46) = 25.87$, $MSE = 0.052$, $\eta_p^2 = .53$; $F_2(2, 46) = 19.67$, $MSE = 0.068$, $\eta_p^2 = .46$. Post hoc analyses revealed significant differences among the three priming conditions.
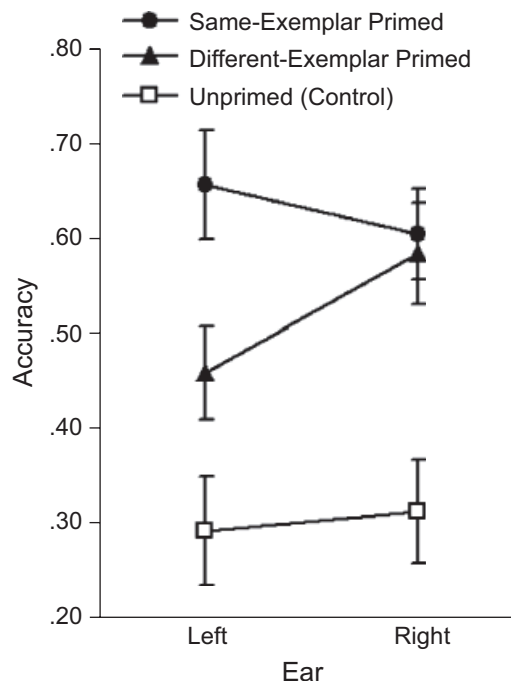

Fig. 2. Mean proportion of naming accuracy in Experiment 2 as a function of prime type and ear of target-stem presentation. Error bars indicate standard errors of the means.

Crucially, planned comparisons demonstrated that the difference between the same-exemplar and different-exemplar conditions (Ms = .60 and .58, respectively) was not significant when the target stems were presented to the right ear (both $ts < 1$), but was significant (Ms = .66 and .46) when the target stems were presented to the left ear, $t_1(23) = 2.74, p < .02, p_{rep} = .91$, $d = 0.56$; $t_2(23) = 2.74, p < .02, p_{rep} = .91, d = 0.56$.

Discussion

Once again, the results are consistent with our predictions based on Marsolek's (1999, 2003) results in the visual domain. In particular, exemplar specificity effects emerged when the target stimuli were presented to the left ear (right hemisphere), but not when the target stimuli were presented to the right ear (left hemisphere).

In order to test the generalizability of the pattern of results, we planned two additional experiments that used a new set of stimuli and a new task during the study phase (i.e., different study and test tasks). An advantage of using different tasks during the two phases was that this minimized the likelihood that simple, rapid stimulus-response learning was responsible for any priming effects observed (Dobbins, Schnyer, Verfaellie, & Schacter, 2004).

EXPERIMENT 3

Method

The method in Experiment 3 was identical to that in Experiment 1, with two exceptions. First, from the Marcell et al. (2000)

database, we selected a new set of 24 digitized target sounds representing a new set of acoustic events (see Table 1). According to the normative data reported by Marcell et al., the mean naming accuracy for these sounds was 80%. Following Shafiro and Gygi's (2004) guidelines, we selected from a variety of sound databases an additional set of 24 digitized sounds representing the same acoustic events as the target set. Durations of the sound files ranged from 1.2 to 5.9 s. Second, during the study block, a pleasantness-rating task was used. Participants were instructed to rate each sound for "pleasantness" on a scale from 1 (*unpleasant*) to 4 (*pleasant*). This task has been used in other long-term priming experiments during the study phase (González & McLennan, 2007; Schacter & Church, 1992).

Results

Figure 3 displays the mean proportion of naming accuracy as a function of prime type and ear of target-stem presentation. We observed a significant main effect of prime type, $F_1(2, 58) = 6.20, MSE = 0.041, \eta_p^2 = .18; F_2(2, 46) = 4.63, MSE = 0.043, \eta_p^2 = .17$. No other significant effect was obtained. Post hoc analyses revealed significant differences between the same-exemplar and control conditions, and between the same-exemplar and different-exemplar conditions.

Crucially, planned comparisons demonstrated that the difference between the same-exemplar and different-exemplar conditions ($Ms = .56$ and $.52$, respectively) was not significant when the target stems were presented to the right ear (both $ts < 1$), but was significant ($Ms = .62$ and $.48$) when the target stems were presented to the left ear, $t_1(29) = 2.29, p < .04, p_{rep} = .88, d = 0.42; t_2(29) = 2.43, p < .03, p_{rep} = .96, d = 0.50$.

Discussion

Our data showed the same pattern as in the previous experiments: Exemplar specificity emerged when the target stimuli were presented to the left ear (right hemisphere), but not when the target stimuli were presented to the right ear (left hemisphere).

EXPERIMENT 4

In Experiment 4, we attempted to replicate the results of Experiment 3, this time presenting noise to the ear not receiving the auditory target stem.

Method

The method in Experiment 4 was identical to that in Experiment 3, except that during each trial in the test phase, a sound stem was presented in one ear, and noise (the same audio file created in Experiment 2) was presented in the opposite ear.
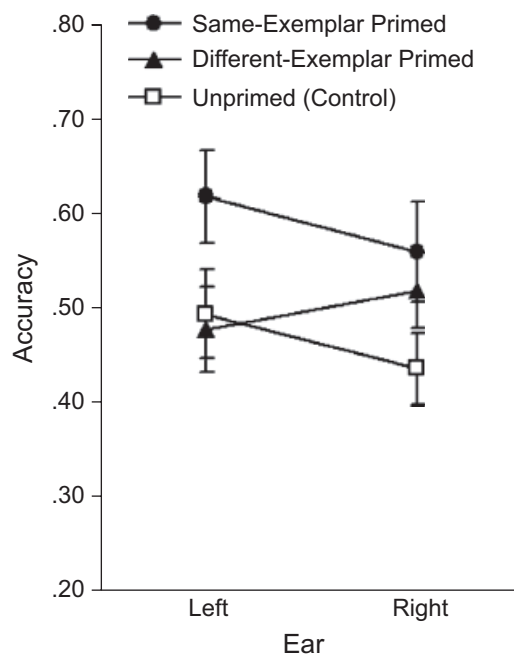

Fig. 3. Mean proportion of naming accuracy in Experiment 3 as a function of prime type and ear of target-stem presentation. Error bars indicate standard errors of the means.

Results and Discussion

Figure 4 displays the mean proportion of naming accuracy as a function of prime type and ear of target-stem presentation. As expected, overall performance was lower than in Experiment 3 because of the noise's masking effect. Again, we obtained a significant main effect of prime type, $F_1(2, 58) = 5.63, MSE = 0.067, \eta_p^2 = .16; F_2(2, 46) = 9.62, MSE = 0.031, \eta_p^2 = .30$. Post hoc analyses revealed significant differences between the same-exemplar and control conditions, and between the different-exemplar and control conditions. Unlike in the previous experiments, we also observed a significant main effect of ear of target-stem presentation; the sound stems administered to the left ear (right hemisphere) were recognized better than the sound stems administered to the right ear (left hemisphere; $Ms = .45$ and $.35$, respectively), $F_1(1, 29) = 5.97, MSE = 0.084, \eta_p^2 = .17; F_2(1, 23) = 15.07, MSE = 0.027, \eta_p^2 = .40$.

Planned comparisons demonstrated that the difference between the same-exemplar and different-exemplar conditions ($Ms = .41$ and $.39$, respectively) was not significant when the target stems were presented to the right ear (both $ts < 1$). The difference between these conditions was larger ($Ms = .53$ and $.45$) when the target stems were presented to the left ear, although it was not significant across participants, $t_1(29) = 1.27, p = .213, p_{rep} = .75, d = 0.23$, and reached only marginal significance across items, $t_2(29) = 1.81, p = .083, p_{rep} = .97, d = 0.37$.

It is important to note that overall performance was significantly lower in this experiment ($M = .40$) than in Experiments 1
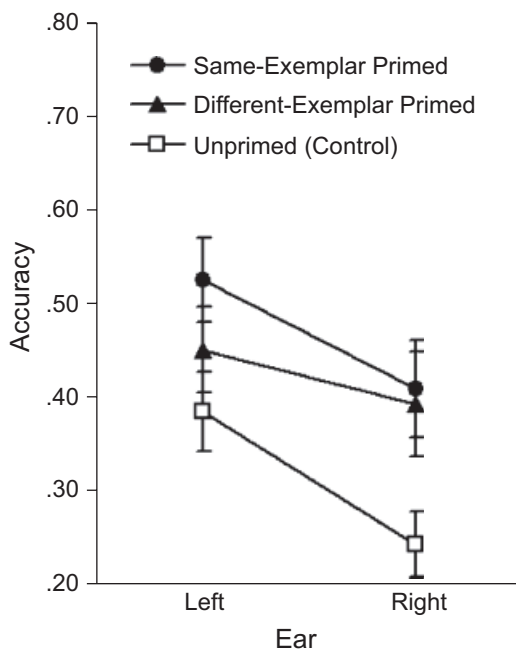
Fig. 4. Mean proportion of naming accuracy in Experiment 4 as a function of prime type and ear of target-stem presentation. Error bars indicate standard errors of the means.

through 3 (Ms = .55, .48, and .51, respectively; all ps < .01). It is possible that the reduction in overall performance decreased the opportunity to observe specificity and, consequently, effects of hemispheric asymmetry. Nevertheless, although specificity in the right hemisphere was only marginally significant, the pattern of results was consistent with the pattern observed in the previous experiments (i.e., greater specificity in the right than in the left hemisphere).

Low overall performance due to demanding conditions (different study and test tasks, masking noise) may have favored the emergence of the general left-ear advantage observed in earlier studies on the identification of environmental sounds. Those studies used dichotic-listening tasks, which are presumably more demanding than monaural tasks (Curry, 1967; Knox & Kimura, 1970).

GENERAL DISCUSSION

We tested whether specificity effects would be obtained when environmental sounds were presented to the left ear (right hemisphere), but not when they were presented to the right ear (left hemisphere). In four long-term priming experiments, we observed specificity effects (an advantage for same-exemplar priming relative to different-exemplar priming) when target stems were presented to the left ear (right hemisphere), but not when they were presented to the right ear (left hemisphere). This pattern was consistent, emerging when the study and test tasks were the same (Experiments 1 and 2) and when they were

different (Experiments 3 and 4), when noise was presented to the opposite ear (Experiments 2 and 4) and when it was not (Experiments 1 and 3), and when either of two sets of stimuli was used (Experiments 1 and 2 vs. 3 and 4).

The pattern of our data is analogous to the pattern observed in visual object recognition. Given the similarity of our current results on the recognition of acoustic events, our previous results on spoken word recognition (González & McLennan, 2007), and Marsolek and his colleagues' results (Burgund & Marsolek, 1997, 2000; Marsolek, 1999, 2004) on visual object and visual word recognition, we suggest that the pattern is not specific to any particular sensory modality, but rather reflects a more general property of the human perceptual-processing system. According to the dissociable-subsystems theory, an abstract-category subsystem operates more effectively in the left than in the right hemisphere and is less sensitive to the specific surface characteristics of stimuli, whereas a specific-exemplar subsystem operates more effectively in the right than in the left hemisphere and is more sensitive to specific stimulus characteristics. That is, each subsystem is more efficient at a different type of processing: *Analytic* (features-based) processing that does not include specific stimulus characteristics may characterize the computations of the former subsystem, and *holistic* (whole-based) processing that includes specific stimulus characteristics may characterize the computations of the latter (Marsolek, 1999).

Some authors have suggested that the widespread existence of specificity effects in several domains implies that specificity has an adaptive value and might be associated with some type of cognitive-resource conservation (Schacter, Dobbins, & Schnyer, 2004). In a continuously changing environment, it is important to categorize the objects and events in one's surroundings in both abstract and specific terms, and this requirement is not exclusive to any one sensory modality. This dual categorization implies opposing capabilities. Computational reasoning and hemispheric asymmetries suggest that the human brain may perform dual categorization better by means of two dissociable subsystems than by means of a single, undifferentiated system (see Marsolek, 2003). Each of the two theorized parallel neural subsystems, or processing styles, operates more effectively— although not exclusively—in a different hemisphere and may obey a general processing principle that transcends particular modalities. Several neuroimaging studies of auditory and visual priming have shown reduction of activity in cortical areas involved in multimodal functions (Buckner, Koutstaal, Schacter, & Rosen, 2000; Carlesimo et al., 2004; for a review, see Schacter et al., 2004).

In recent years, research has suggested that certain characteristics of specific processing systems can be integrated into more general principles. For example, the distinction between local and global processing was initially confined to the visual domain. Data suggested a hemispheric specialization: Global (or low-spatial-frequency) information was preferentially processed

in the right hemisphere, and local (or high-spatial-frequency) information was preferentially processed in the left hemisphere (Sanders & Poeppel, 2007). New data from the auditory domain are consistent with the same general pattern: Relatively slow auditory changes (200–300 ms) are preferentially processed in the right hemisphere, whereas relatively fast changes (25–50 ms) are preferentially processed in the left hemisphere (see Boemio, Fromm, Braun, & Poeppel, 2005).[1] Given the convergence of data across modalities, the local-global distinction may define a general organizational principle that is compatible with the dissociable-subsystems (analytic, holistic) account of lateralization.

The asymmetrical pattern of auditory specificity for word and environmental-sound perception should be considered in the more general framework of lateralization of auditory-cortex functions. Evidence from behavioral dichotic-listening studies and more recent data from positron-emission tomography, magnetoencephalography, and functional magnetic resonance imaging research suggest that a parameter model (rapid vs. slow temporal or frequency changes) provides a better account of hemispheric differences than the classical domain (e.g., speech vs. music) model (Tervaniemi & Hugdahl, 2003). The existence of two subsystems with two different processing styles would fit well with this newer conceptualization of auditory lateralization.

Finally, the possibility that the dissociable-subsystems framework characterizes perceptual and memory processing in multiple modalities suggests directions for future work. For example, behavioral, electrophysiological, and neuroimaging studies could examine potential priming asymmetries in other auditory subdomains, including music perception, voice recognition, and pseudoword processing. Also, it would be of interest to examine asymmetries using synthetic and novel sound stimuli, given the recent hemispheric asymmetries Marsolek and Burgund (2008) observed using novel visual stimuli in a working memory task. Finally, research could extend to the three remaining sensory modalities (touch, taste, and smell). For example, it is an interesting question whether specificity in tactile recognition is greater when objects are handled with the left hand (right hemisphere) than when they are handled with the right hand (left hemisphere).

[1]Some authors suggest that lateralization of speech perception may arise as a result of different timescales: Fast auditory changes correspond to segmental- and syllabic-level timing (left hemisphere), and slow changes correspond to prosody- and melody-level timing (right hemisphere).

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