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FEATURE ARTICLE

The effects of linguistic mediation on the identification of environmental sounds

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The effects of linguistic mediation on the identification of environmental sounds

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Abstract

Recent studies have suggested that environmental sound recognition shares many of the same processing demands - and possibly neural resources - as language comprehension. Some investigators have suggested that the tight correlations between linguistic and environmental sound deficits observed in aphasic patients - as well as the spatial overlap in functional activation patterns shown by fMRI - may be due to linguistic mediation of environmental sound processing. Here, we show that covert naming of environmental sound recognition exerts an additional processing load above and beyond that used for recognition alone. Furthermore, naming does not increase recognition accuracy above the levels for recognition alone. Thus, linguistic mediation of environmental sound recognition appears not to be an important or even natural component of most participants' processing strategies.

Introduction

An environmental sound can be defined as a sound that is produced by a real event, and has a meaning due to the causal relationship with that event (Ballas & Howard, 1987). Humans can easily comprehend both linguistic and environmental sounds and can usually identify the referents in either case. Similarities and differences between the processing of these two types of sounds however, is an area which calls for further attention.

Behavioral and neural imaging studies with neurologically normal subjects as well as brain-damaged patients suggest that environmental sounds may be processed similarly to linguistic stimuli. Like language processing, there are frequency and priming effects in processing environmental sounds: i.e., commonly encountered sounds are more easily identified, and hearing a sound can facilitate the identification of a subsequent sound that is related (Ballas, 1993; Gygi, 2001). Such results have been supported by neuroimaging studies as well. For instance, an event-related potential (ERP) study found that conceptual relationships between spoken words and environmental sounds influence the processing of both types of stimuli (Van Petten & Rheinfelder, 1995). In functional activation studies (as reported recently in Humphries, Buschbaum & Hickok., 2001; Janata & Adams, 2001; Lewis, Wightman, Junion-Dienger, & DeYoe, 2001;

Maeder, Meuli, Adriani, Bellmann, Fornari, Thiran, Pittet, & Clarke, 2001), environmental sounds were observed to activate some middle and superior temporal brain areas that have been associated with language-processing in earlier studies (e.g., Binder, 1997; Démonet, Chollet, Ramsay, Cardebat, Nespoulous, Wise, Rascol, & Frackowiak, 1992; Wise, Chollet, Hadar, Friston, Hoffner, & Frackowiak, 1991).

Faglioni, Spinnler, and Vignolo (1969) reported a group study on disturbances of environmental sound recognition due to unilateral brain damage. They observed that compared to normal controls, right hemisphere-damaged (RHD) patients performed significantly worse on perceptual tests involving environmental sounds while left hemisphere-damaged (LHD) patients performed significantly worse on associative/semantic tests. Varney (1980) used environmental sounds in examining verbal and nonverbal comprehension deficits in a group of aphasic patients (i.e., patients with diagnosed language deficits) and found that defects in environmental sound recognition were seen only in subjects with impaired verbal comprehension, and all the aphasics with intact verbal comprehension performed well on sound recognition. There were, however, aphasics who were impaired in verbal comprehension, but not in sound recognition. More recently, Schnider, Benson, Alexander, & Schnider-Klaus (1994) observed quite similar results and additionally saw that patients with impaired environmental sound recognition tended to have damage to the left posterior superior temporal gyrus and the inferior parietal lobe.

Unfortunately, these studies did not test language comprehension in relation to sound processing or if they did, they did not attempt to control for factors operating on the items (such as stimulus frequency, stimulus identifiability, and the relationship between the auditory and visual stimuli) across the two domains. Furthermore, none of the studies used online measures such as reaction time and therefore could not make use of information that the time course of processing may provide. In our laboratory, we recently conducted an experiment along these lines, contrasting linguistic and non-linguistic processing of auditory information in a group of neurological patients (Saygin, Dick, Dronkers, & Bates, 2002). We designed an online task with aphasic patients and age-matched controls, in which stimuli in both domains were matched for identifiability, frequency, and semantic relationship to the visual target. Here the data revealed no clear evidence of an advantage for nonverbal auditory processing in aphasic patients. Furthermore we found the severity of language comprehension deficit goes hand-in-hand with the severity of the deficit in environmental sound recognition, as evidenced by high correlations between accuracy and response latencies between the two domains. In sum, when the linguistic and environmental sound stimuli were carefully matched in an online experiment we found that processing of verbal and nonverbal auditory information is strongly associated in aphasic subjects. Thus we argued that language shares at least some of its neural resources with those used for processing information in other domains.

To summarize, there is evidence from both behavioral and neuroimaging studies with both normal and impaired populations that there are similarities and relationships between the processing of linguistic sounds and environmental sounds, consistent with the view that these two processes may have common neural substrates. However, the apparent association between processing in these two domains could have a different explanation, namely, subvocal naming of the environmental sounds. In other words, linguistic processing could be mediating the identification of environmental sounds, thereby causing the seemingly correlated processing patterns in experimental studies. While this hypothesis has occurred to researchers who have worked with environmental sounds (as evidenced by discussion and interpretation of data in many studies cited here, as well as the position argued by Bartlett, 1977, for instance), to our knowledge it has not been tested empirically.

We have put the subvocal mediation hypothesis to test in a new version of the environmental sound identification task used in Saygin et al., 2002. Here, we manipulated the experiment instructions in a very straightforward way to create two different conditions: a covert naming condition, where subjects were asked to silently name the environmental sounds in their heads while identifying them, and a non-naming condition, where subjects were instructed to refrain from covert naming during identification. If subvocal rehearsal is indeed a necessary and/or often-used strategy in environmental sound recognition, then we would expect to see not only less accurate performance in the non-naming condition, but equivalent reaction times between naming and non-naming conditions for items that are accurately identified. On the other hand, if environmental sound identification or recognition is not primarily mediated linguistically, then we may see similar accuracy scores across conditions, but increased reaction times in the naming condition compared to the non-naming condition because of the greater number or complexity of processes taking place.

Method

Participants. 18 students (8 females, 10 males, mean age 21.6 years) from the University of California, San Diego took part in the study. All received course credit for their participation, and were right handed with normal hearing and normal or adjusted-to-normal vision as assessed by a standard intake questionnaire. Participants were monolingual native English speakers, with no significant exposure to another language prior to the age of 12. All were treated in accordance with the Ethical Principles of Psychologists and Code of Conduct (American Psychological Association, 1992).

Materials and Design. Participants were asked to perform a picture and sound matching task. Visual stimuli were 10.6 cm x 10.6 cm digitized black-and-white line drawings of familiar objects and actions culled from several databases and normed as part of the International Picture Naming Project (see Bates et al, 2000). Auditory stimuli consisted of 45 environmental sounds derived from BBC, Digifex SoundEffects, and freeware sound libraries. Sounds were selected based on identifiability, inter-rater reliability for identifiability, imagability and reaction time in a previous study (Saygin, 2001). All sounds were converted to SoundEdit16 files, with a 44.125 kHz sampling rate and 16-bit quantization.

The experiment utilized two within-subjects factors: Task Instruction (Naming/Non-Naming) and Distracter Relatedness (Related Distracter/Unrelated Distracter). In the Naming condition, participants were asked to covertly name the sound that they heard as they performed the task, while in the Non-Naming condition they were specifically instructed not to covertly name the sound. In the Related Distracter condition, the picture target (the picture related to the sound, e.g., ‘cow’) was semantically related to the distracter picture (e.g., ‘sheep’), whereas in the Unrelated Distracter condition, target and distracter were semantically unrelated (e.g., ‘cow’ and ‘violin’ - see Figure 1 for example).

To assure that the semantically related and unrelated distracters were properly assigned, we made use of the measure Latent Semantic Analysis, or LSA (Landauer, Foltz, & Laham, 1998). Each sound/target pair appeared twice - once with the related distracter, and once with the unrelated distracter. 6 quasi-random orders of the list were rotated among the subjects.

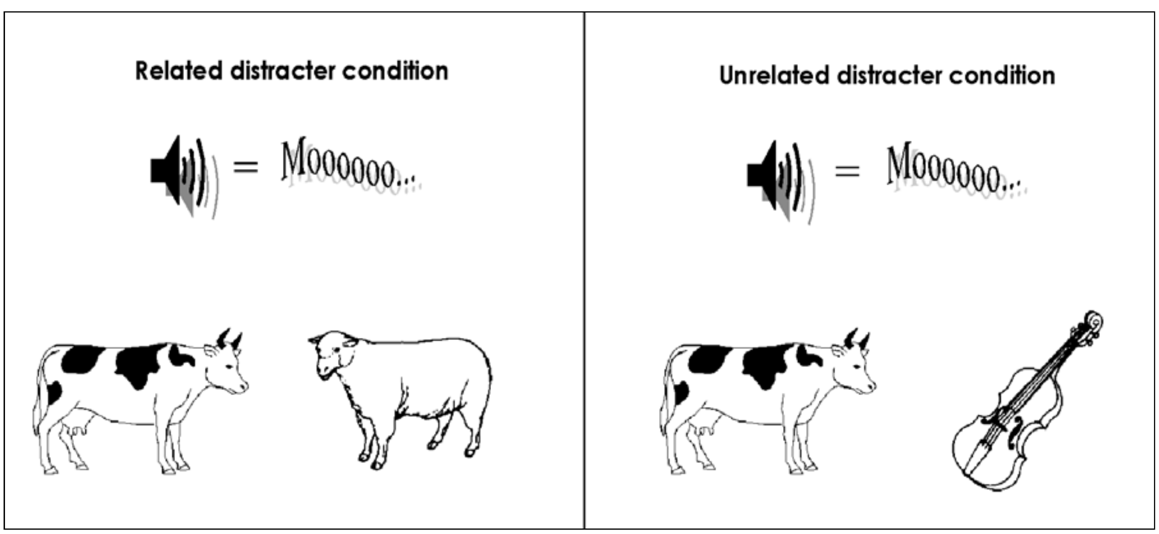

Figure 1. Example of sound with target and semantically related and unrelated distracter.

Equipment. PsyScope software was used to deliver stimuli and collect data (Cohen, MacWhinney, Flatt, & Provost, 1993). Software was run on a Macintosh Performa 6214 computer, connected to a VGA color monitor and Yamaha YST-M7 external speakers. A PsyScope button box was used for response and experimental timing.

Procedure. Participants sat in a small room in front of the color monitor, speakers, and PsyScope button box. The experiment was divided into two parts, where the only difference between the two was in the instructions given to the participant. The participant was told to either covertly name the sound they heard, (Naming condition) or specifically told not to covertly name the sounds (Non-naming condition). The order in which these instructions were given to the participants was randomized. Each part of the experiment consisted of 3 practice trials, followed by an experimental block of 45 trials. A trial consisted of the following: After initiation by the experimenter, two line drawings appeared side by side on the screen. After a delay of 1000ms, an auditory stimulus (an environmental sound) was presented. Participants responded by using their right index finger to press a button on the PsyScope button box corresponding to the picture that they thought matched the sound (the rightmost button for the picture that appeared in the right half of the screen, and the leftmost button for the picture that appeared in the left half of the screen). The picture chosen was briefly highlighted before the screen was reset for the next trial.

Reaction time and accuracy were recorded for each trial. Each experimental block was cued up by the experimenter, who observed the participants' performance and demeanor to assure that they were remaining attentive and alert. It was emphasized that participants should respond as quickly and as accurately as possible to the stimuli. At the end of the experimental session, the experimenter debriefed each participant. During the debriefing, subjects were asked whether they had experienced any difficulties either with naming the stimuli or in suppressing naming.

Results

Accuracy: All subjects performed at or above 97% accuracy on the task. There was a main effect of Distracter Relatedness ($F(1,17)=9.040$, $p=0.0079$), with lower accuracy on the related Distracters (98.7%) than the unrelated Distracters (100%). There was no significant main effect of Task Instruction on accuracy ($F(1, 17)=0.001$, $p=0.9754$).

Reaction Time, all responses: When including all trials in reaction time means, we found a main effect of Task Instruction ($F(1,17)=17.941$, $p=0.0006$), where mean reaction times for the Naming condition (1264 msec) were longer than that for the Non-Naming condition (1084 msec). The effect of Distracter Relatedness ($F(1,17)=26.393$, $p<0.0001$) was also significant, where subjects responded more slowly to items with a semantically related Distracter (1250 msec) than with a semantically unrelated Distracter (1097 msec). There was no significant interaction between Distracter and Naming conditions ($F(1, 17)=0.435$, $p=0.5185$).

Reaction Times, correct responses only: When including reaction times to correct responses only, we found that results remained essentially unchanged - there was a main effect of naming ($F(1,17)=16.207$, $p=0.0009$) and of relatedness ($F(1,17)=22.646$, $p=0.0002$), with no interaction between the two factors ($F(1,17)=0.835$, $p=0.3737$). Main effects means were virtually identical to those calculated over all responses: Naming (1257 msec) vs. Non-Naming (1084 msec), and Related Distracter (1243 msec) vs. Unrelated Distracter (1098 msec) - see Figure 2.

Discussion

We found that subjects were equally accurate in identifying environmental sounds regardless of whether they were instructed to name or not name the sounds as they performed the task. However, there was a significant difference in reaction time, with the performance on the Non-Naming condition being faster than on the Naming condition. As such, this supports the hypothesis that subvocal rehearsing is just an additional, and likely unnecessary process in the identification of environmental sounds, and that there is little, if any, linguistic mediation in most subjects' processing of this type of auditory stimuli. These results are also supported by the results of Saygin et al. (2002), where a similar pattern of results were observed in aphasic patients. For this population, environmental sounds were processed faster than linguistic stimuli overall.

Although the results of the present study and those of Saygin et al. (2002) lend support to a non-verbally-mediated model of environmental sound recognition, we should add a few caveats as well. One is the presence of individual differences in processing style: in the post-experiment debriefing, some subjects indicated that they had to actively suppress naming of the sounds (e.g., they were involuntarily naming them while listening to the sounds), while others found the naming itself quite difficult, or often had to remind themselves to continue to name the sounds in the Name condition. In addition, results from a pilot study indicated that the 'default' strategy of a minority of subjects was to automatically name the item; one well-known scientist even declared it impossible to suppress her 'naming instinct'. It is also worthwhile mentioning that the range of reaction times over subjects for the two conditions was overlapping; in other words, the variation in overall reaction times was greater than the variation associated with naming (or with semantic relatedness, for that matter). In addition, the fact that accuracy is at such high levels in the current experiment suggests a ceiling effect, which weakens our ability to make strong conclusions about the effect of subvocal naming on recognition performance. Finally, 4 of 18 subjects showed essentially identical reaction times for both conditions, at the least suggesting that some of the subjects may not have strictly separated processing strategies. (However, it is worth noting that a minority of subjects fail to show effects even in such 'gold-standard' cognitive paradigms as semantic priming.)

While taking the above exceptions into account, the results presented here strongly suggest that, like other primates (see Kohler, Keysers, Umiltá, Fogassi, Gallese, & Rizzolatti, in press), humans can quickly and accurately recognize complex and meaningful environmental sounds without recourse to linguistic mediation. Indeed, in the present case, subvocal naming during sound recognition does nothing to facilitate greater recognition accuracy, and in fact slows processing considerably.

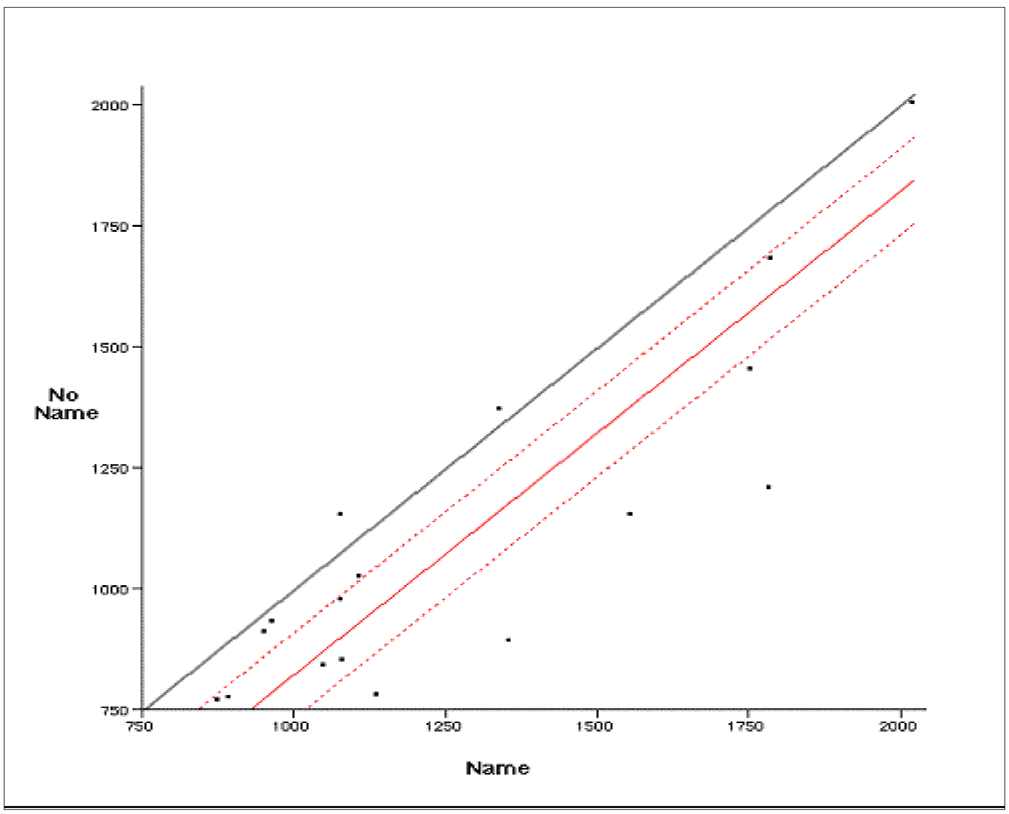

Figure 2. Difference in means in Naming and No-Naming conditions. Mean difference is shown by the rightward offset of the solid red line (true least-squares estimate of best fit) from the solid gray line (line of best fit if two means were equal). The dotted red lines indicate the 95% confidence interval for the least-squares estimate, while the black dots represent the mean reaction time in the two conditions for each of the 18 subjects. X and Y axes are plotted in milliseconds, and are scaled equally.

References

American Psychological Association (1992). Ethical principles of psychologists and code of conduct. *American Psychologist, 47*, 1597-1611.

Ballas, J.A. (1993) Common factors in the identification of an assortment of brief everyday sounds. Journal of Experimental Psychology: Human Perception and Performance,19, 250-267.

Ballas, J.A., & Howard, J.H. (1987) Interpreting the language of environmental sounds. *Environment & Behavior,19* (1), 91-114.

Bartlett, J.C. (1977). Remembering environmental sounds: The role of verbalization at input. *Memory & Cognition, 5*(4), 404-414.

Bates, E., Federmeier, K., Herron, D., Iyer, G., Jacobsen, T., Pechmann, T., D'Amico, S., Devescovi, A., Wicha, N., Orozco-Figueroa, A., Kohnert, K., Gutierrez, G., Lu, C., Hung, D., Hsu, J., Tzeng, O., Andonova, E., Gerdjikova, I., Mehotcheva, T, Székely, A., Pléh, C. (2000). Introducing the CRL International Picture-Naming Project (CRL-IPNP). *CRL Newsletter, 12*(1).

Binder, J. (1997). Functional magnetic resonance imaging. Language mapping. *Neurosurgery Clinics of North America, 8*, 383-92.

Cohen, J.D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments & Computers, 25*, 257-271.

Démonet, J.F., Chollet, F., Ramsay, S., Cardebat, D., Nespoulous, J.L., Wise, R., Rascol, A., Frackowiak, R. (1992). The anatomy of phonological and semantic processing in normal subjects*.* *Brain, 115*, 1753-68

Faglioni, P., Spinnler, H., Vignolo, L.A (1969). Contrasting behavior of right and left hemisphere-damaged patients on a discriminative and a semantic task of auditory recognition. *Cortex ,5*, 366-89.

Gygi, B. (2001). Factors in the identification of environmental sounds. Unpublished Doctoral Dissertation, Department of Psychology and Cognitive Science, Bloomington: Indiana University, 187.

Humphries, C., Buchsbaum, B., & Hickok, G. (2001). Perception of Speech, Music, and Sounds: an fMRI Study. *Society for Neuroscience Abstracts, 27,* 949.9.

Janata, P., & Adams, R.B. (2001). An fMRI comparison of neural circuits underlying auditory and visual object categorization. *Society for Neuroscience Abstracts, 27,* 849.11.

Kohler, E., Keysers, C., Umiltà, M., Fogassi, L., Gallese, V., & Rizzolatti, G. (in press). Hearing sounds, understanding actions: Action representation in mirror neurons. *Science.*

Landauer, T.K., Foltz, P.W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes, 25*, 259-284.

Lewis, J., Wightman, F., Junion Dienger, J., & DeYoe, E. (2001). fMRI activation in response to the identification of natural sounds. *Society for Neuroscience Abstracts, 27*, 512.9.

Maeder, P.P., Meuli, R.A., Adriani, M., Bellmann, A., Fornari, E., Thiran, J.P. Pittet, A, & Clarke, S. (2001). Distinct pathways involved in sound recognition and localization: a human fMRI study. *Neuroimage, 14*, 802-16.

Saygin, A.P. (2001) Contrasting verbal and nonverbal auditory processing in aphasia. Unpublished M.S. Thesis, Department of Cognitive Science. La Jolla: UCSD.

Saygin, A.P., Dick, F., Dronkers, N. & Bates, E. (2002). Shared neural resources for processing language and nonverbal environmental sounds: Evidence from patients with unilateral stroke and aphasia. Manuscript submitted for publication.

Schnider, A., Benson, F., Alexander, D.N., Schnider-Klaus, A.(1994). Nonverbal environmental sound recognition after unilateral hemispheric stroke. *Brain, 117*, 281-287.

Van Petten, C., & Rheinfelder , H. (1995). Conceptual relationships between spoken words and environmental sounds: event-related brain potential measures. *Neuropsychologia, 33*, 485-508.

Varney, N.R (1980). Sound recognition in relation to aural language comprehension in aphasic patients. *Journal of Neurology, Neurosurgery and Psychiatry, 43*, 71-5.

Wise, R., Chollet, F., Hadar, U., Friston, K., Hoffner, E., & Frackowiak, R.(1991). Distribution of cortical neural networks involved in word comprehension and word retrieval. *Brain, 114*, 1803-17.

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