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# **CROSS-MODAL PROJECTIONS FROM AUDITORY TO VISUAL CORTICES IN THE FERRET**

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

by

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# Abstract

## CROSS-MODAL PROJECTIONS FROM AUDITORY TO VISUAL CORTICES IN THE FERRET

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Recent studies have shown that neuronal connections occur between primary auditory and visual cortices of the primate (Falchier et al., 2002; Rockland and Ojima, 2003), and it has been suggested that these projections are involved in multisensory processing in these lower-level, core areas of cortex. The present study was conducted to determine if similar connections occur in other higher mammals such as carnivores (ferrets; *Mustela putorius*). Large injections of sensitive neuroanatomical tracer were placed within the core areas of auditory cortex in 3 ferrets. After transport and processing, labeled axon terminals were

found not in primary visual cortex, but in area 19, or V3. Injection of tracer into V3 of 3 additional ferrets produced retrogradely labeled neurons not in the core region of auditory cortex, but along its posterior borders. These data indicate that cross-modal connections occur in the ferret cortex, but do not support the notion that they exist between the primary representations of the different sensory modalities.

## **Introduction**

Even the most recent neuroscience textbooks describe the different sensory systems separately. Contained within these books are individual chapters for vision, hearing and somatosensation, while other subchapters detail the properties of taste and smell on their own. By reducing the variables that accompany the different sensory modalities, it is probably assumed that it is easier to learn about these topics in this segregated fashion. Similarly, the research laboratory strives to conduct controlled experiments in which a single parameter is systematically manipulated. Introduction of stimuli from more than one modality during experimentation can be difficult to control experimentally, and consequently the vast majority of investigations into sensory processing have dealt with the features of a single modality. The brain, however, is not such a privileged organ. It must deal with a constantly changing environment in which multiple stimuli often occur at the same time.

How the brain processes simultaneous information from different sensory modalities has been the topic of numerous recent studies. It has been shown that multisensory stimulation can improve detection of weak stimuli, as in the hunting behavior of some predators (Stein et al., 1989). Multisensory stimulation also improves speech perception, and watching lips move while listening to speech not only helps in understanding speech, it also helps in sorting out the source of the speaker if in a crowded, noisy room (Sumby and Pollack, 1954). In fact, there are myriads of multisensory perceptual and behavioral effects that have been documented across the animal kingdom

(Stein and Meredith, 1993). Given the universality of multisensory processing, it is somewhat surprising that so little attention is given to it in neuroscience instruction and textbooks.

The first requisite step in multisensory processing is for information (synaptic input) from more than one sensory modality to converge onto individual neurons. This is also an apparently widespread phenomenon, and has been observed at various locations throughout the brain (Stein and Meredith, 1993). When these different inputs converge onto individual neurons and arrive within an appropriate time frame, then the responses from one modality are merged with those from the other to produce an integrated response. This integrated response can either be elevated—as in multisensory response enhancement, or reduced—as in multisensory response depression (Meredith and Stein, 1983). These integrated response products are not random, but are predictable based on the spatial and temporal relationships of the stimuli evoking the response (Meredith and Stein, 1986; 1996; Meredith et al., 1987). These same stimulus factors, which control multisensory integration at the neuronal level, also function to determine multisensory orientation and detection behaviors (Stein et al., 1989). Thus, multisensory convergence leads to multisensory integration that influences behavioral or perceptual outcomes. However, it is curious that very little is known about multisensory convergence at the neuronal level.

Multisensory convergence is known to occur in a large number of brain areas. Most notably, these multisensory areas include the superior colliculus in the midbrain and higher-level polysensory cortical regions (Stein and Meredith, 1993). Not only have anatomical studies demonstrated that inputs from different modalities converge in these

areas, but physiological studies have identified individual neurons that responded to stimuli from more than one modality (i.e., multisensory neurons). For many years, multisensory areas have been exclusively regarded as those higher-level areas close to the initiation of behavior or perception, leaving the lower-, primary cortices as reservoirs of modality-specific (unimodal) information. However, recent studies have shown that multisensory convergence not only occurs in lower levels of cortex (Schroeder et al., 2001) but also within of the primary sensory representations themselves (Falchier et al., 2002; Rockland and Ojima, 2003). These studies show that inputs from auditory and somatosensory cortices directly access portions of primary visual cortex in primates. These findings have had profound effect on our understanding of the organization of the brain. However, they have not been repeated in less complex animals or in other classes of mammals, such as carnivores. Therefore, the present experiment sought to determine whether direct connections between auditory and primary visual cortex can be demonstrated in the ferret.

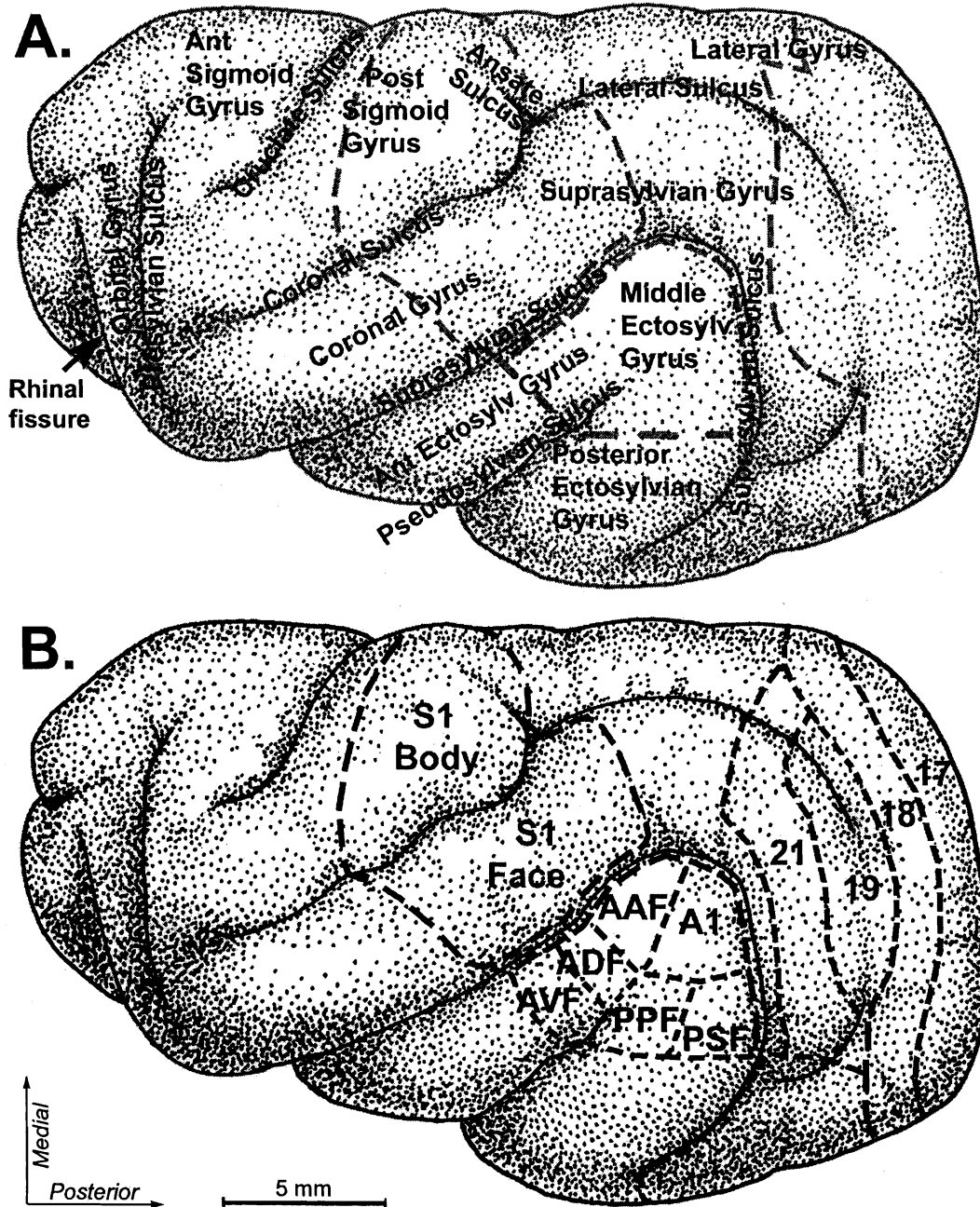
The primary sensory cortices of the ferret have been mapped, as has many of their higher-level regions. The entire extent of the auditory cortex of the ferret is centered on the ectosylvian gyrus, as depicted in Figure 1. It has been anatomically divided into 3 areas, one located on the middle ectosylvian gyrus (MEG), one on the posterior ectosylvian gyrus (PEG), and another one on the anterior ectosylvian gyrus (AEG) (Wallace et al., 1997). These cortices have now been divided into 6 distinctive areas. The first of these to be identified were the primary auditory cortex A1, and the anterior auditory field, AAF, both of which were located in the middle ectosylvian gyrus. A later study found four other

areas. Posteriorly, the PEG was divided into two auditory areas: the posterior pseudosylvian field (PPF), and the posterior suprasylvian field (PSF). Anteriorly, the AEG was subdivided into two additional auditory areas, which were named the anterior dorsal field (ADF), and the anterior ventral field (AVF) (Bizley, et al., 2005). Aside from A1 and AAF, homologies with similar areas in cats or other mammals have not been determined. In contrast, a ferrets' visual system very closely resembles that of the cat, which has been studied and characterized extensively. Using different techniques to study cytoarchitecture, myeloarchitecture, and cytochrome oxidase reactivity, the visual areas of the ferret (areas 17, 18, 19, and 21) can be clearly distinguished (Innocenti, et al., 2002; Manger, et al., 2002). As depicted in Figure 1, these visual areas reside in or near the occipital pole of the ferret cortex and occupy the posterior portions of the lateral and suprasylvian gyri and the lateral sulcus.

Given the established sensory organization of the ferret cortex, the present experiments used sensitive neuroanatomical tracers to examine whether the auditory regions, in particular the core auditory areas of AI/AAF, project to the primary visual area of V1/area 17, as depicted in Figure 2.

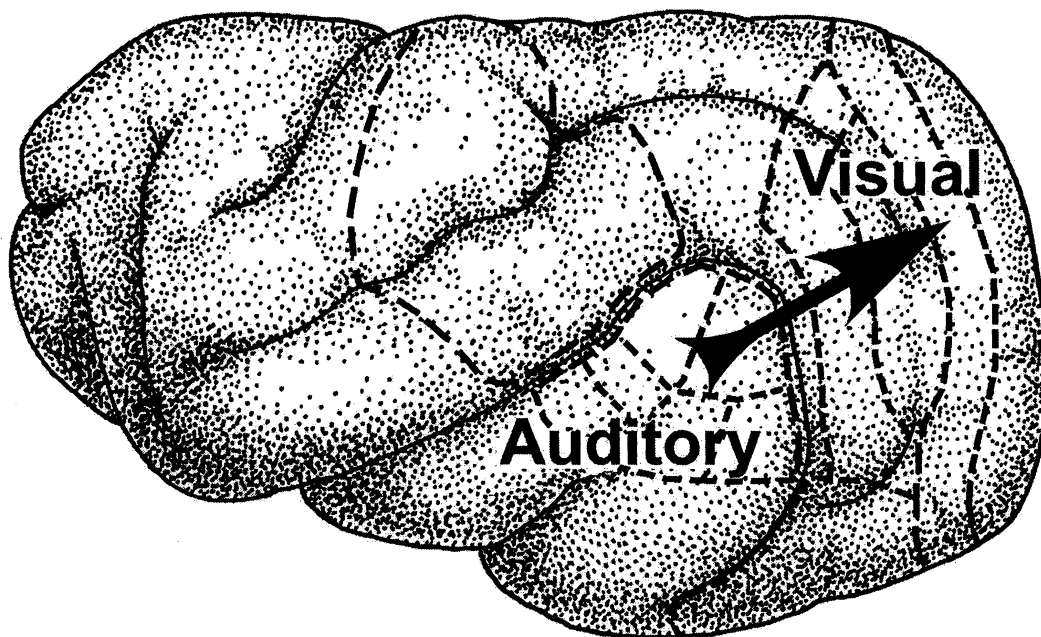
**Figure 1:** Anatomical and functional representation of the ferret cerebral cortex. The top figure displays the anatomical names of the gyri and the sulci of the ferret cerebral cortex. The auditory cortex is concentrated mostly in the middle ectosylvian gyrus. The visual cortex is concentrated mostly in the posterior part of the lateral sulcus. The bottom figure displays the functional representation of the ferret cerebral cortex. Brodmann's areas 17, 18, 19, and 21 represent the visual cortex. The somatosensory regions are represented by S1 of the body and S2 of the face. The auditory cortex are represented by the following: anterior auditory field (AAF); anterior dorsal field (ADF); anterior ventral field (AVF); primary auditory cortex (A1); posterior pseudosylvian field (PPF); and posterior suprasylvian field (PSF).

**Figure 1:** Anatomical and functional representation of the ferret cerebral cortex.



**Figure 2.** The research question: Do primary auditory and visual cortical regions in the ferret connect?

**Figure 2.** The research question



## **MATERIALS AND METHODS**

All procedures were performed in compliance with the Guide for Care and Use of Laboratory Animals (NIH publications 86-23) and approved by the Institutional Animal Care and Use Committee at Virginia Commonwealth University.

### **Surgical Preparation**

Pigmented ferrets (n=6) were anaesthetized (sodium pentobarbital; 40 mg/kg) and their head were positioned within a stereotaxic frame. Under aseptic surgical conditions, a craniotomy and durectomy were performed to expose either primary visual or auditory cortical regions. A Hamilton syringe (5  $\mu$ l, 31-gauge needle), supported by a modified electrode carrier, was inserted into the selected cortical area to a depth of between 1.0 mm and 2.0 mm. The neuroanatomical tracer biotinylated dextran amine (BDA; 10,000 mol.wt; lysine fixable; 10% in 0.1 M phosphate buffer) was pressure injected at a rate of 15 nl/min. BDA was chosen because its properties – good solubility in water, low toxicity, and uncommon  $\alpha$ -1,6-polyglucose linkages – make it an ideal long-term tracer of neuronal projections, both in the anterograde and retrograde directions. The specific injection sites and volume of each injection are detailed in Table 1. Three animals were used to trace orthograde projections from auditory to visual cortices; three other animals were used to identify the location of auditory neurons retrogradely labeled from visual cortex. Cortical landmarks, such as gyri and sulci, were used to guide the positioning of each injection. These landmarks are summarized for auditory and visual cortices in the ferret in Figure 1. Auditory cortical injections were focused on the middle ectosylvian gyrus; visual cortical

injections targeted the posterior end of the lateral sulcus. Once the desired volume of tracer was injected, the needle was retracted, the cortex was covered with gel foam, the scalp was sutured closed and standard post-operative procedures were provided.

### **Histological Processing**

There was a 7-9 day survival period, in which then the animals were overdosed (120 mg/kg sodium pentobarbital) and perfused intracardially with heparinized saline followed by fixative (4.0% paraformaldehyde, 0.1% glutaraldehyde). The brain was exposed, blocked stereotaxically and cryoprotected in 25% sucrose in 0.1 M phosphate buffer at 4°C. Coronal sections were cut at 50 µm using a freezing microtome and collected serially. One series of sections, saved at 250 µm intervals, was processed for visualization of BDA using the avidin-biotin peroxidase method, according to the protocol of Veenman et al. (1992) and intensified using nickel-cobalt.

### **Data Analysis**

The BDA labeled neurons or processes (e.g., axons, boutons, axon terminals) were visualized using a light microscope (Nikon Eclipse 600) and their location in their respective tissue section plotted using a PC-driven digitizing stage controlled by Neurolucida software (MicroBrightfield, Inc., Williston, VT, USA). Sections selected for plotting were serially arranged and were approximately 750 µm apart through the target area. Each tracing included the section outline, the border between gray and white matter, the position of the injection site, labeled neurons, and axonal boutons. Labeled axonal boutons appeared as sharp, black swellings at the end of thin axonal stalks or equal-sized

swellings along each side of the axon length. BDA-labeled neurons were identified as densely black in their core that sometimes spread into the distal dendrites. Some neurons were of a lighter, reddish-brown label. Tissue outlines, gray and white border, and injection sites were plotted using a 40X magnification. Labeled neurons and axonal boutons were plotted using a 200X magnification. The Neuroleucida software kept a count of numbers of identified neurons and axonal boutons. The plotted sections from each animal case were then arranged serially and graphically displayed using Adobe Photoshop software (Adobe Systems, Inc., San Jose, CA, USA). Gyrus and sulcal landmarks were used to identify labeled regions and to correlate them with functionally distinct regions of cortex.

**Table 1. Injection Sites and Volumes of Auditory and Visual Cortices**

ORTHODGRADE: To identify labeled boutons in visual cortex

	# of Injections	Amount per injection
Ferret AI #1	3 injections	0.4; 0.7, 0.8 $\mu$ l
Ferret AI #2	3 injections	0.4; 1.1; 0.6 $\mu$ l
Ferret AI #3	4 injections	0.5; 0.75; 0.7 0.5 $\mu$ l

RETROGRADE: To identify labeled neurons in auditory cortex

	# of Injections	Amount per injection
AudCTX#7	1 injection VIS CTX	0.8 $\mu$ l
AudCTX#8	1 injection VIS CTX	0.9 $\mu$ l
AudCTX#9	6 injections VIS CTX	1.8 $\mu$ l total

## RESULTS

### Orthograde projections from auditory cortex

Three adult ferrets were used to examine orthograde projections from auditory to visual cortex. In each case, sulcal and gyral landmarks were used to identify the location of primary auditory cortex and multiple injections were centered upon, but did not exclusively label this region. In fact, most of the cases involved injections that not only filled portions of primary auditory cortex (AI), but also included its adjoining neighbors of AAF, ADF, PPF and PSF.

Examples of labeled auditory boutons in visual cortex are illustrated in the micrographs shown in Figure 3. In these and the other cases, long filled axons were often interrupted by symmetrical swellings, or boutons in passage. In addition, labeled boutons at the ends of short axon stalks, or terminal boutons, were also observed. Tracer injections into ferret auditory cortices consistently produced terminal labeling in a restricted area of visual cortex. The area in which labeled boutons were most reliably found was in or around the posterior end of the lateral sulcus, corresponding to area 19/V3. In the three cases examined, a total of 27565 boutons were plotted in this area from 18 coronal sections. In the first case, a total of 3710 boutons were plotted. In the second case, a total of 12929 boutons were plotted. In the third case, a total of 10926 boutons were plotted. These data are illustrated in Figure 4. In each case, labeled boutons were found primarily in the banks and fundus of the posterior end of the lateral sulcus, corresponding to the

location of area 19/V3. In no case were there boutons observed on the posterior aspects of the lateral gyrus, where area 17/V1 is located. In relation to the boutons found in area 19/V3, there were almost twice as many found in the lateral part of the fundus than the medial part (19246 versus 8318, respectively; see Table 2) and this difference was statistically significant (paired student's T- test;  $p < 0.001$ ). Figure 5 summarizes difference in the percentage of boutons found in the medial versus the lateral parts of the sulcus. In addition, the three cases consistently showed fewer boutons at the far anterior and posterior ends of the lateral sulcus, while the highest number of boutons was found in between the two ends (see Table 2).

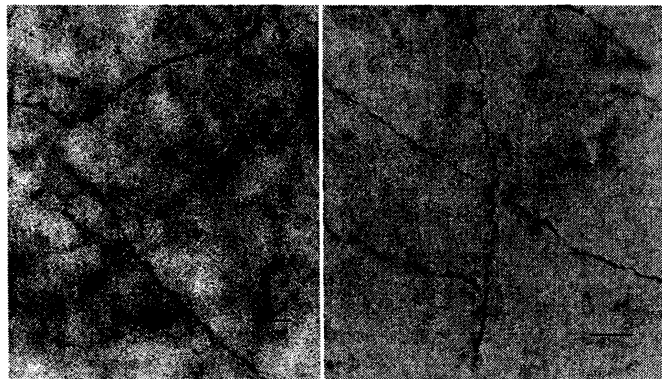
### **Retrograde labeling from visual cortex**

Three adult ferrets were used to confirm the auditory cortical origin of projections to visual cortices. Tracer was injected into area 19 (see Table 1 for injection volume) and retrogradely labeled neurons were identified in sections through the auditory cortex. As illustrated in Figure 6, these labeled neurons had the morphology typical of pyramidal neurons, which are known to be the projection neurons of the cortex. A total of 114 neurons were identified and plotted, almost all of which occurred in the only posterior parts of the auditory cortices. The distribution of neurons in auditory cortex retrogradely labeled from visual area 19/V3 is illustrated in Figure 1. Only a few retrogradely labeled neurons were found in auditory areas outside this posterior portion of auditory cortex. In

the two remaining cases, very small, restricted injections were made into area 19 and no retrogradely labeled neurons were observed in the auditory cortex in these animals.

**Figure 3. Micrographs depicting the labeled auditory axons and terminals in visual cortex.** Photomicrographs taken through the lateral sulcus/area 19 showing labeled axons and boutons resulting from injections made in auditory cortex (x 1000/oil; bar = 10  $\mu$ m).

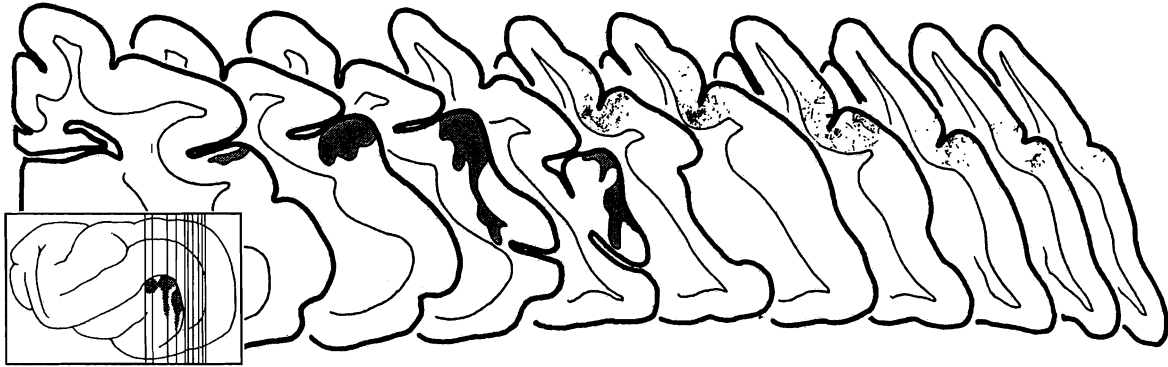
**Figure 3. Micrographs depicting the labeled auditory axons and terminals in visual cortex**



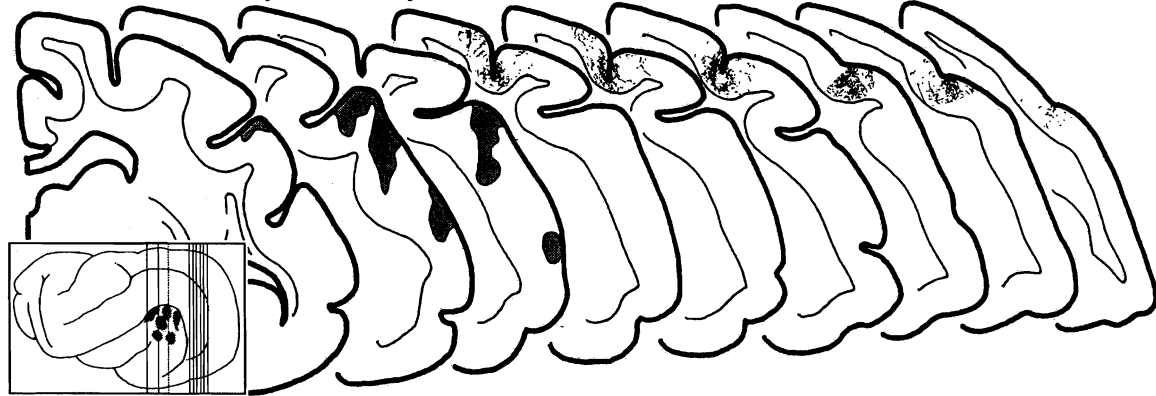
**Figure 4. Orthograde projections from auditory to visual cortex.** This figure summarizes the tracer injection sites and distribution, as well as resulting projection termination, for 3 cases (A-C). In each case, coronal sections through auditory and visual cortices show either the extent of the tracer injection (dark grey areas) in auditory cortex or the location of labeled axon terminals (each dot = 1 bouton) in visual cortex. Note that in each case labeled boutons were found within the banks of the posterior end of the lateral sulcus; this area corresponds to area 19 of the ferret visual cortex. The density of labeled boutons diminished at more posterior levels; few labeled boutons were found outside this region anywhere else in visual cortex. The inset (box) shows a lateral view of the brain and summarizes the location of auditory cortical injection sites as well as the location (vertical lines) through the brain from which the coronal sections were taken. Sections derived from more anterior portions of the brain are on left, while the posterior is on the right.

**Figure 4. Orthograde projections from auditory to visual cortex**

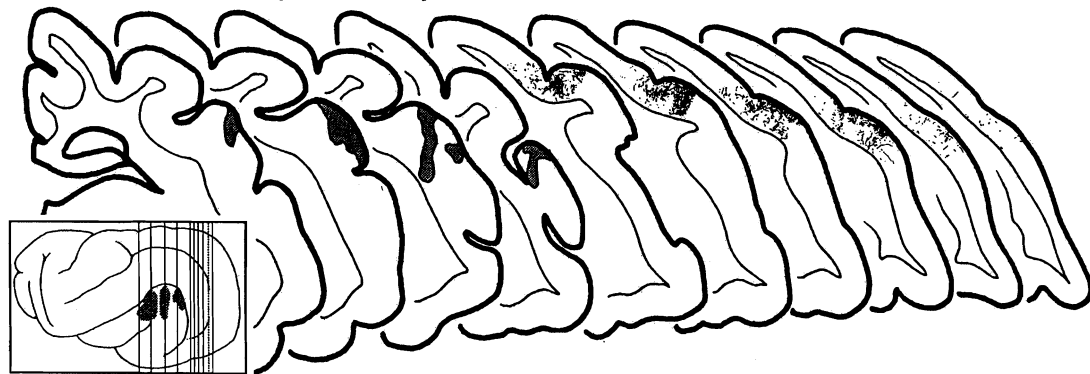
**A. Case 1 Auditory Cortex Injection**



**B. Case 2 Auditory Cortex Injection**



**C. Case 3 Auditory Cortex Injection**

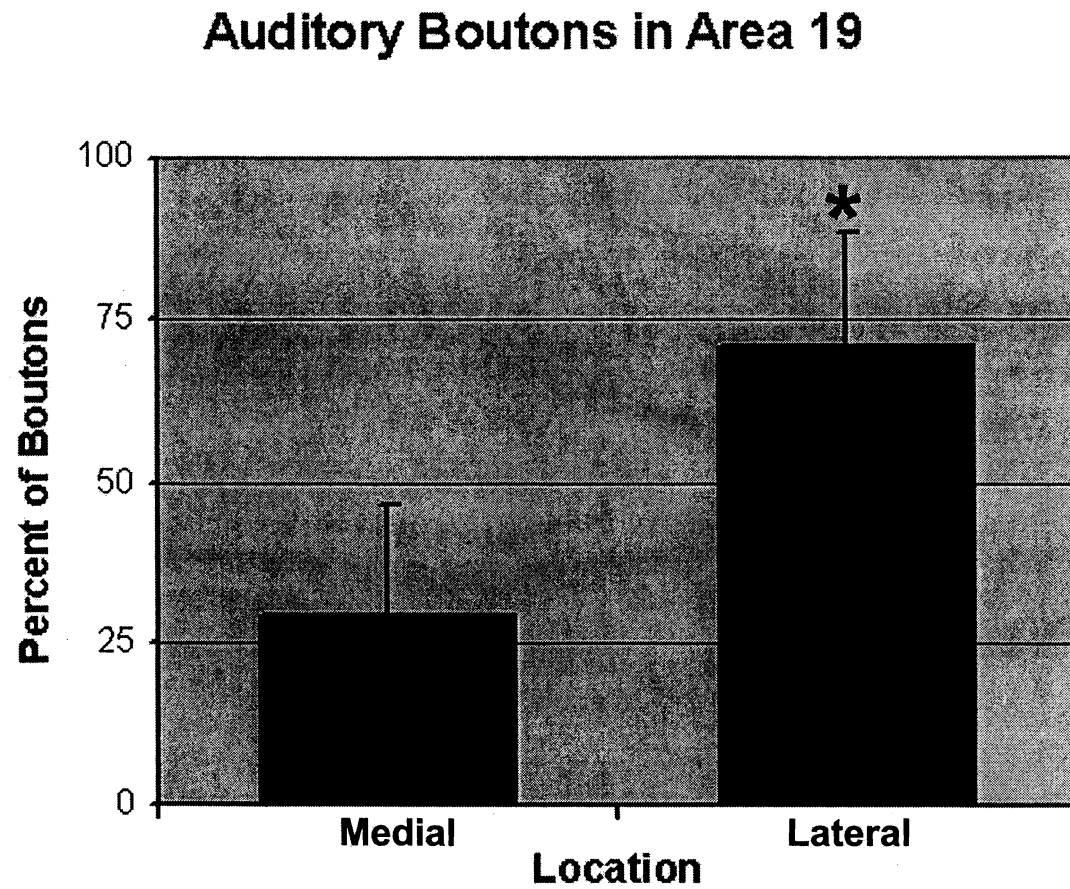


**Table 2: Counts of boutons in visual area 19 labeled from auditory cortex: medial versus lateral distribution**

<b>ID</b>	<b>Medial</b>	<b>Lateral</b>	<b>Total</b>
Audferret1-6-6 sulcus (most anterior)	114	748	862
Audferret1-7-1 sulcus	399	438	837
Audferret1-7-3 sulcus	377	799	1176
Audferret1-7-5 sulcus	71	304	375
Audferret1-7-7 sulcus	101	266	367
Audferret1-7-9 sulcus (most posterior)	10	83	93
<b>Total for AudFerret 1</b>	<b>1072</b>	<b>2638</b>	<b>3710</b>
Audferret2-5-3 sulcus (most anterior)	864	1129	1993
Audferret2-5-5 sulcus	1438	1122	2560
Audferret2-5-7 sulcus	1137	1028	2165
Audferret2-6-1 sulcus	2837	1466	4303
Audferret2-6-3 sulcus	204	1495	1699
Audferret2-6-5 sulcus (most posterior)	38	171	209
<b>Total for AudFerret 2</b>	<b>6518</b>	<b>6411</b>	<b>12929</b>
Audferret3-6-6 sulcus (most anterior)	379	1859	2238
Audferret3-6-8 sulcus	339	2896	3235
Audferret3-7-1 sulcus	308	2416	2725
Audferret3-7-3 sulcus	416	1545	1961
Audferret3-7-5 sulcus	163	392	555
Audferret3-7-7 sulcus (most posterior)	51	161	212
<b>Total for AudFerret 3</b>	<b>1656</b>	<b>9269</b>	<b>10926</b>

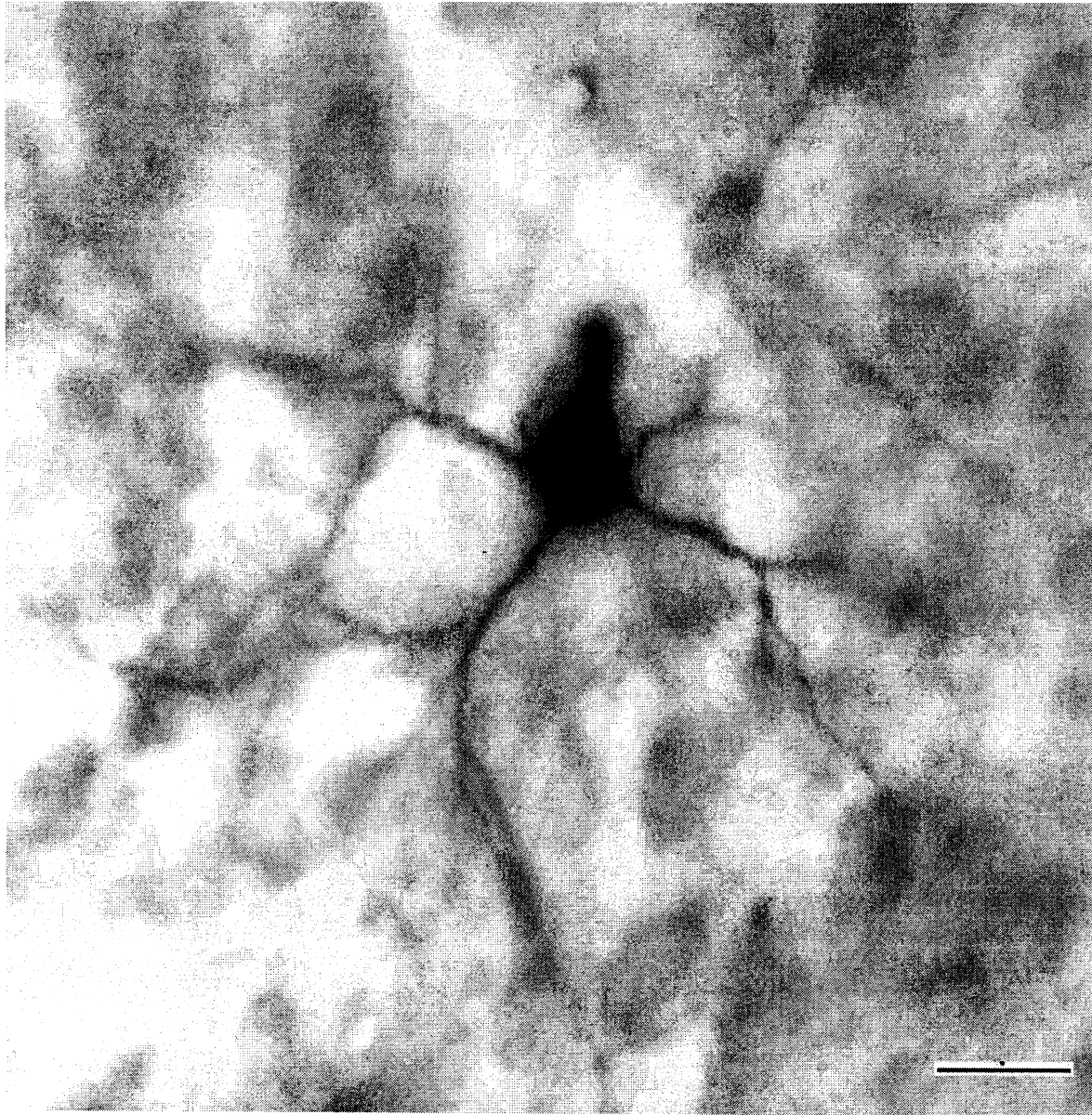
**Figure 5. Auditory boutons tend to target the lateral bank of Area 19.** This graph summarizes the medial-lateral distribution of auditory boutons observed in the banks and the fundus part of the posterior end of the lateral sulcus. Proportionally more auditory boutons were found in the lateral than medial parts of the lateral sulcus, and this difference was statistically significant (asterisk; paired 't'-test;  $p < 0.001$ ).

**Figure 5. Auditory boutons tend to target the lateral bank of Area 19**



**Figure 6. Micrograph depicting an auditory neuron retrogradely labeled from visual cortex.** The micrograph shows a typical pyramidal neuron in posterior auditory cortex with filled apical and basilar dendrites, retrogradely labeled from visual area 19/V3 (1000x/oil; scale bar = 10  $\mu\text{m}$ ).

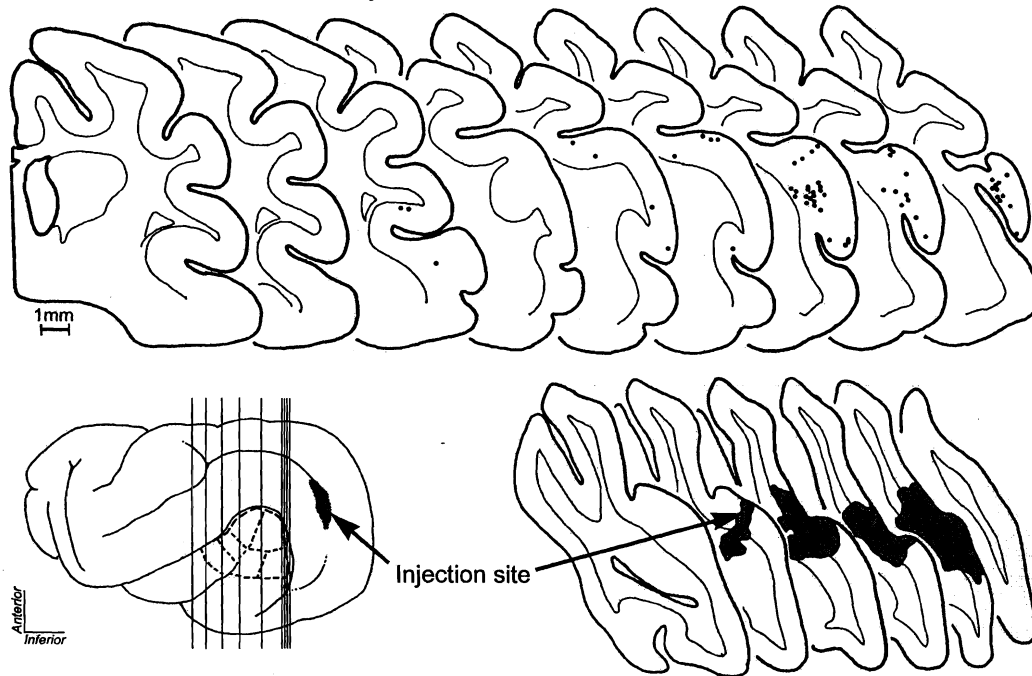
**Figure 6. Micrograph depicting an auditory neuron retrogradely labeled from visual cortex**



**Figure 7. Neurons in auditory cortex retrogradely labeled from a visual cortical injection.** The top row shows coronal sections through the auditory cortices (anterior= left); each dot represents the location of one retrogradely labeled neuron. The coronal sections on the bottom-right show the location and distribution of the tracer injection (dark grey areas) placed within the posterior end of the lateral sulcus (visual area 19). The schematic of the ferret brain (bottom-left) shows the location of the auditory cortices (dashed lines), the injection site (dark grey area), and the level from which the auditory cortical coronal sections (top) were taken.

**Figure 7. Neurons in auditory cortex retrogradely labeled from a visual cortical injection**

Audferret 9, Visual Cortex Injection



## DISCUSSION

The results of these experiments show that direct, cross-modal connections do occur within the ferret cerebral cortex. Specifically, projections arising in relation to auditory cortex terminate within other areas well established to represent the visual modality. Although the injections used to demonstrate these projections were multiple and quite large, the retrograde experiments established that the projection actually originates in the posterior aspects of the auditory cortex, within the posterior limb of the Suprasylvian sulcus and posterior to the areas designated as AI and PSF. In fact, the region(s) giving rise to this cross-modal projection correspond with areas of the ferret cortex, buried in the banks of the posterior limb of the Suprasylvian sulcus, which have not yet been investigated. Nonetheless, given their position in relation to the major auditory cortical areas, it is very reasonable to expect that they also represent the auditory modality. Because these areas are not yet defined, they will be referred to hereon as the “Posterior Auditory Cortices (PAC)”

Injections into the auditory cortices that included the PAC produced orthograde labeling and labeled axon terminals within aspects of the occipital lobes known to process visual signals. This terminal labeling was found along axons as well as in boutons of both the “in passage” and “terminal ending” types. However, terminal labeling was not found throughout the occipital cortices, but was restricted to only a small region on the lateral aspect of the lobe. The labeled region corresponds to the banks and the fundus of the posterior end of the lateral sulcus. This region (as well as the adjoining cortical areas) has been well examined in both functional and mapping studies (Wallace et al., 1997; Bizley,

et al., 2005; Innocenti, et al., 2002; Manger, et al., 2002) and has been designated as Area 19 or the third visual area (V3). Therefore, because the projection arose in the auditory cortices and terminated in a well-documented visual area, this projection represents a cross-modal connection.

*Comparison with other cross-modal anatomical studies:*

The field of multisensory processing is a new field of neuroscience research that has seen an intense burst of recent interest. In fact, more papers have been published on multisensory processing since 1996 than in all previous years combined, (1276 vs. 844, respectively, as determined by PubMed search). However, very few studies have examined the anatomical basis for multisensory processing: multisensory convergence. All such studies have documented a form of multisensory convergence termed “areal convergence,” where inputs from two different sensory modalities target the same neural area but possibly not the same neurons (e.g., “neuronal convergence”). Initially, such investigations revealed the now classic polymodal areas such as the Superior Temporal Sulcus (STS) in primates (Seltzer and Pandya, 1994) or the Anterior Ectosylvian Sulcus in cats (Reinoso-Suarez and Roda, 1985). These observations have been replicated and enhanced by numerous subsequent investigations (Dehner et al., 2004; Meredith et al., 2006). More recently, attention has been focused on cross-modal connections between primary sensory areas, such as AI and VI. In fact, injections into primary auditory cortex in primates produced labeling in V1 (Falchier et al., 2002). However, these projections did not fill the entire V1 representation but targeted the representation of peripheral visual space to the exclusion of the central visual representation. Similarly, another study that

injected higher-level auditory areas (association areas) in primates found terminal labeling within the peripheral representation of visual space in both V1 and V2 of primates (Rockland and Ojima, 2003). By comparison, the present study found no evidence for projections from primary auditory cortex (AI) to the primary and secondary visual areas (V1, V2). Instead, the ferret cross-modal projection arose from higher-level auditory areas (PAC) and terminated in visual Area 19, or V3. Furthermore, the auditory projection to V3 in ferrets primarily innervated representations of inferior visual space, and labeled boutons in the central and superior representations were rarely observed. Thus, while the cross-modal projections in different species apparently do not influence the entire representation of visual space, significant differences among their targets (V1 vs. V2 or V3) justifies continued examination of this issue.

#### Functional Implications:

A projection from the representation of one sensory modality to that of another implicitly suggests that the activity in one will influence the responses of the other. This notion has been supported by numerous studies over the last 2 decades. Possibly the best studied multisensory structure is not in the cortex, but the midbrain: the superior colliculus. In this structure, inputs from visual, auditory and somatosensory modalities converge onto individual neurons. These neurons respond to each of these sensory inputs independently and, when stimuli from different sensory modalities are combined, produce an integrated response. Multisensory integration has been defined as a significant response change when activity evoked by the combined modality stimuli is compared to that elicited by the

individual component stimuli presented alone (Meredith and Stein, 1983; 1986).

Multisensory integration can take the form of a response increase (response enhancement) or decrease (response depression)(Meredith and Stein, 1983). More recently, other forms of multisensory processing have been identified in cortex, whereby neurons responsive to one sensory modality (e.g., somatosensory) are unresponsive to others (e.g., vision, audition) but have their normal activity modulated (facilitated or suppressed) by the presence of stimuli from the otherwise 'uneffective' modality. In this fashion, cross-modal inputs produce a subthreshold effect that is apparent only when stimuli from different sensory modalities are combined (Dehner et al., 2004; Meredith et al., 2006). In summary, multisensory convergence can result in a wide range of functional effects that span a continuum from suprathreshold excitation to subthreshold inhibition. Given this range of possible effects, without any concrete observations, it is not possible to guess the functional effect of the cross-modal projection described in the present study. However, electrophysiological recording experiments are currently being conducted to directly test this question.

## **CONCLUSION**

This study shows that a higher-level region of the posterior auditory cortex projects to the V3 visual area of the ferret. Although the effect of this projection is not known at this time, such a cross-modal connection can underlie a variety of multisensory behavioral and/or perceptual processes and may provide a model upon which further experiments can be conducted.

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## VITA

Meng Y. Wang was born in Ningbo, China on May 26, 1980. She came to the United States with her parents at the age of 10 and grew up in Wilmington, NC. Meng graduated from the University of North Carolina at Chapel Hill in December of 2002 with dual degrees of Bachelors of Science in Biology and Bachelors of Arts in Asian Studies.

Since graduation, Meng has become certified as an Emergency Medical Technician-Basic and worked for the Orange County EMS for a year before moving to Richmond, VA in 2004. She completed the certificate program in the Department of Anatomy and Neurobiology at VCU School of Medicine and is currently working on her Masters of Science degree. Meng will be matriculating into medical school at Virginia Commonwealth University in the fall of 2006.