

NEUROSYSTEMS

Two crossed axonal projections contribute to binaural unmasking of frequency-following responses in rat inferior colliculus

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Keywords: binaural unmasking, dorsal nucleus of the lateral lemniscus, frequency-following response, inferior colliculus

Abstract

Frequency-following responses (FFRs) are sustained potentials based on phase-locked neural activities elicited by low- to medium-frequency periodical sound waveforms. Human brainstem FFRs, which are able to encode some critical acoustic features of speech, can be unmasked by binaural processing. However, the underlying unmasking mechanisms have not previously been reported. In rats, most neurons in the inferior colliculus (IC) exhibit binaural responses which are affected by axonal projections from both the contralateral dorsal nucleus of the lateral lemniscus (DNLL) and the contralateral IC. The present study investigated whether the contralateral DNLL and the contralateral IC modulate binaural unmasking of FFRs recorded in the rat IC. The results show that IC FFRs to the rat pain call (chatter) were enhanced by local injection of the excitatory glutamate receptor antagonist kynurenic acid (KYNA) into the contralateral DNLL but were reduced by KYNA injection into the contralateral IC. Introducing a disparity between the interaural time difference (ITD) of the FFR-eliciting chatter and the ITD of the masking noise enhanced IC FFRs. Moreover, the ITD-disparity-induced FFR enhancement was weakened by injection of KYNA into either the contralateral DNLL or the contralateral IC when the ipsilateral chatter preceded the contralateral chatter. Thus, binaural hearing can improve IC FFRs against noise masking. More importantly, both inhibitory projections from the contralateral DNLL and excitatory projections from the contralateral IC modulate IC FFRs and play a role in forming binaural unmasking of IC FFRs.

Introduction

Frequency-following responses (FFRs) are sustained potentials based on phase-locked neural activities elicited by low- to medium-frequency periodical sound waveforms. Human brainstem FFRs, which are able to encode some critical acoustic features of speech, can be unmasked by binaural processing. However, the underlying unmasking mechanisms have not previously been reported. In rats, most neurons in the inferior colliculus (IC) exhibit binaural responses which are affected by axonal projections from both the contralateral dorsal nucleus of the lateral lemniscus (DNLL) and the contralateral IC. The present study investigated whether the contralateral DNLL and the contralateral IC modulate binaural unmasking of FFRs recorded in the rat IC. The results show that IC FFRs to the rat pain call (chatter) were enhanced by local injection of the excitatory glutamate receptor antagonist kynurenic acid (KYNA) into the contralateral DNLL but were reduced by KYNA injection into the contralateral IC. Introducing a disparity between the interaural time difference (ITD) of the FFR-eliciting chatter and the ITD of the masking noise enhanced IC FFRs. Moreover, the ITD-disparity-induced FFR enhancement was weakened by injection of KYNA into either the contralateral DNLL or the contralateral IC when the ipsilateral chatter preceded the contralateral chatter. Thus, binaural hearing can improve IC FFRs against noise masking. More importantly, both inhibitory projections from the contralateral DNLL and excitatory projections from the contralateral IC modulate IC FFRs and play a role in forming binaural unmasking of IC FFRs.

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Materials and methods

Animal preparation

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Experimental procedures

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Acoustic stimulation and recording

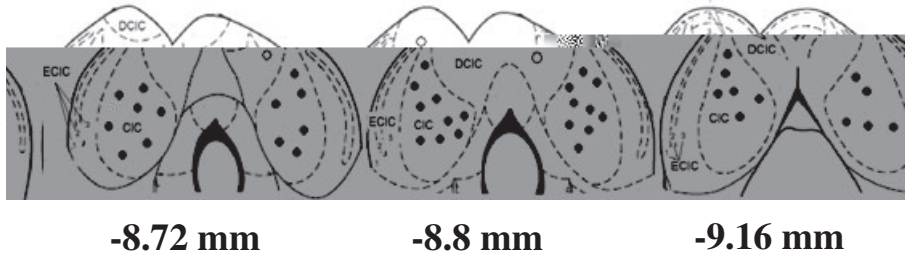
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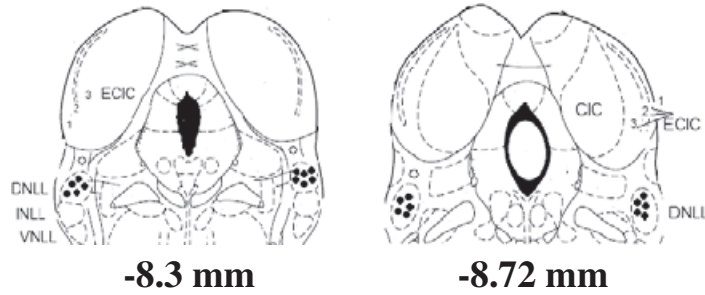
Data analyses

a,c ,a y a ,c , a z

Electrodes in IC



Cannulae in DNLL



Cannulae in IC

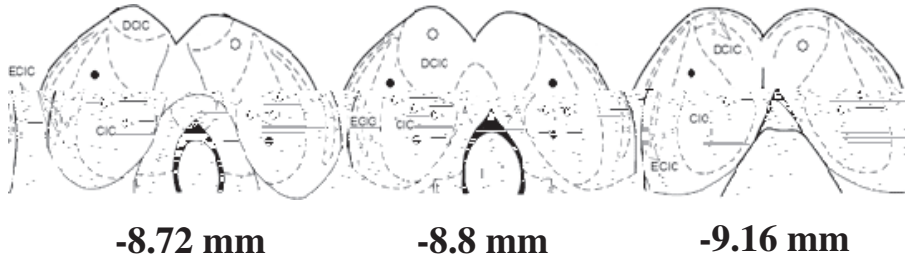


FIG. 1. *(a)* Coronal sections of the rat brainstem at three different levels (-8.72, -8.8, and -9.16 mm) showing the locations of the electrodes in the IC. *(b)* Coronal sections at -8.3 and -8.72 mm showing the locations of the cannulae in the DNLL. *(c)* Coronal sections at -8.72, -8.8, and -9.16 mm showing the locations of the cannulae in the IC. Labels: DCIC, ECIC, DNLL, INLL, VNLL, CIC.

ANOVA ($F_{2,12} = 10.5, P < 0.001$), a significant difference was found between the groups ($F_{2,12} = 10.5, P < 0.001$), indicating that the response was significantly different between the groups. The results show that the response was significantly different between the groups ($F_{2,12} = 10.5, P < 0.001$), indicating that the response was significantly different between the groups.

Binaural unmasking of FFRs
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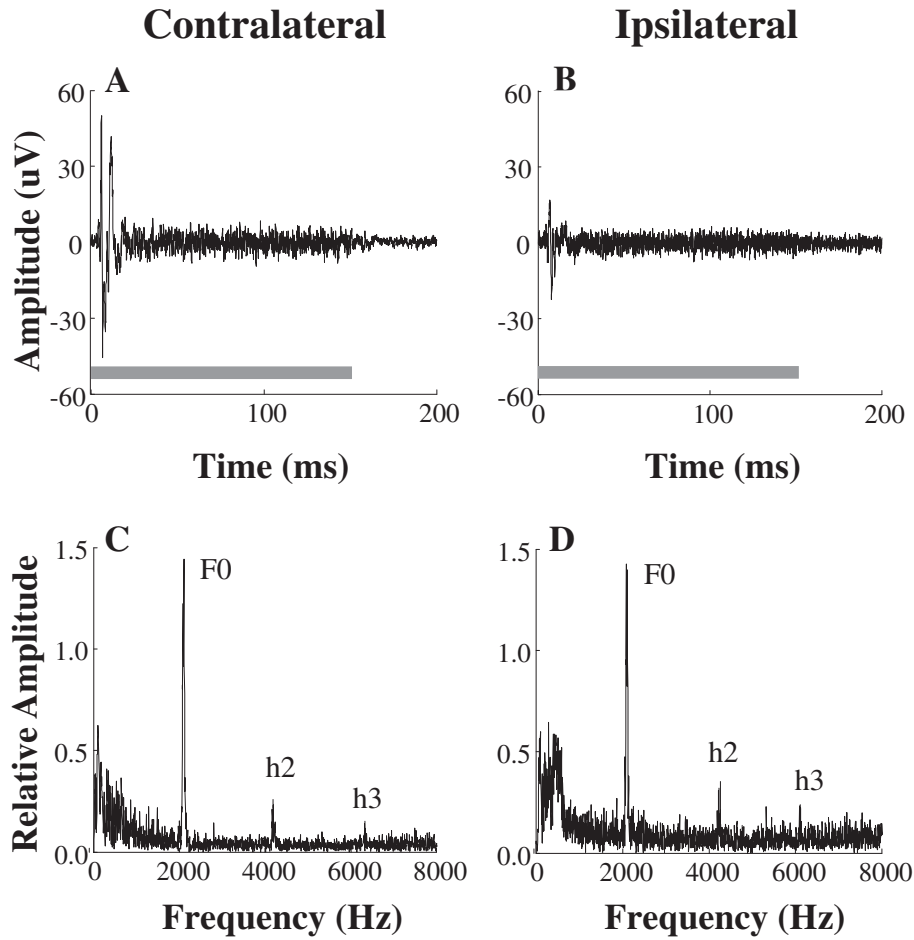


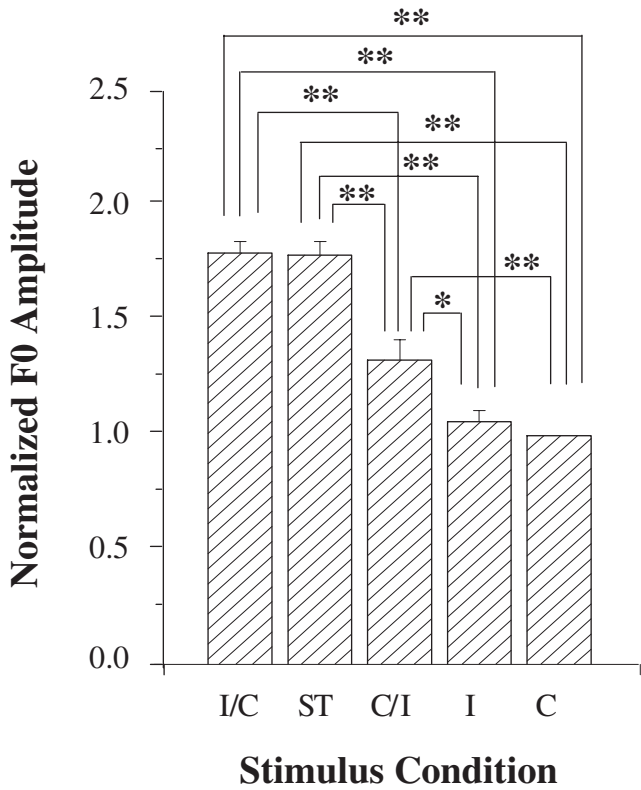
FIG. 2. y ,a a í ,ca (a)a ía ,ca a a í (a) . a ,c g ,c a a a . . a a (a) . . a ,c a g z a a a . . a a í a a (a) , .c a a a a . a a a a . a . a z a a a . . a a í ,ca . . .

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Effects of blocking DNLL or IC on binaural unmasking of FFRs

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Contribution of EE neurons to FFRs in the IC

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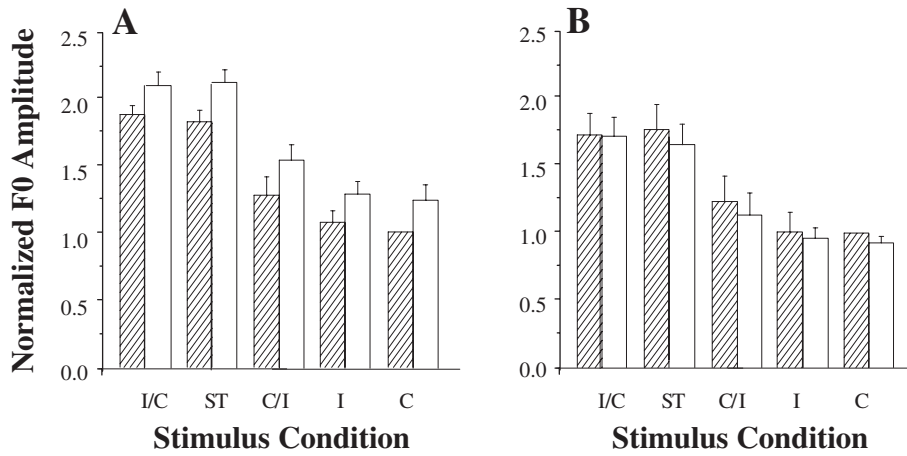
Discussion

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Binaural unmasking of IC FFRs

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KYNA Locke's Contralateral DNLL Injection



Contralateral IC Injection

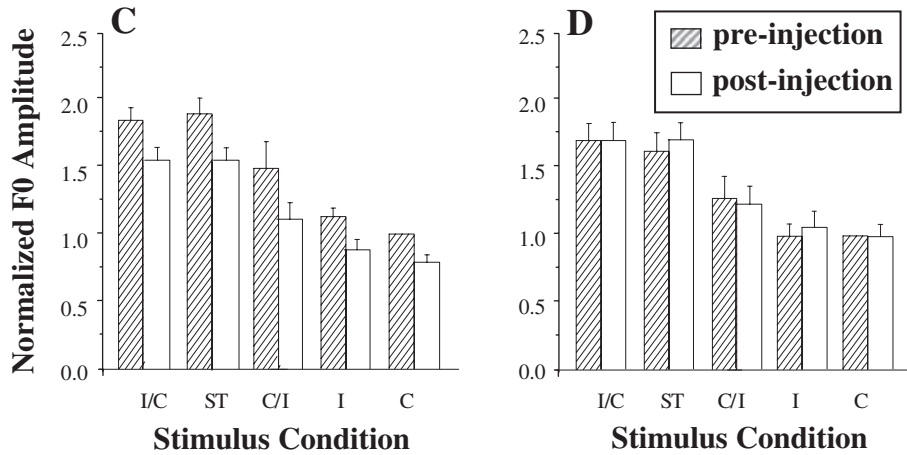
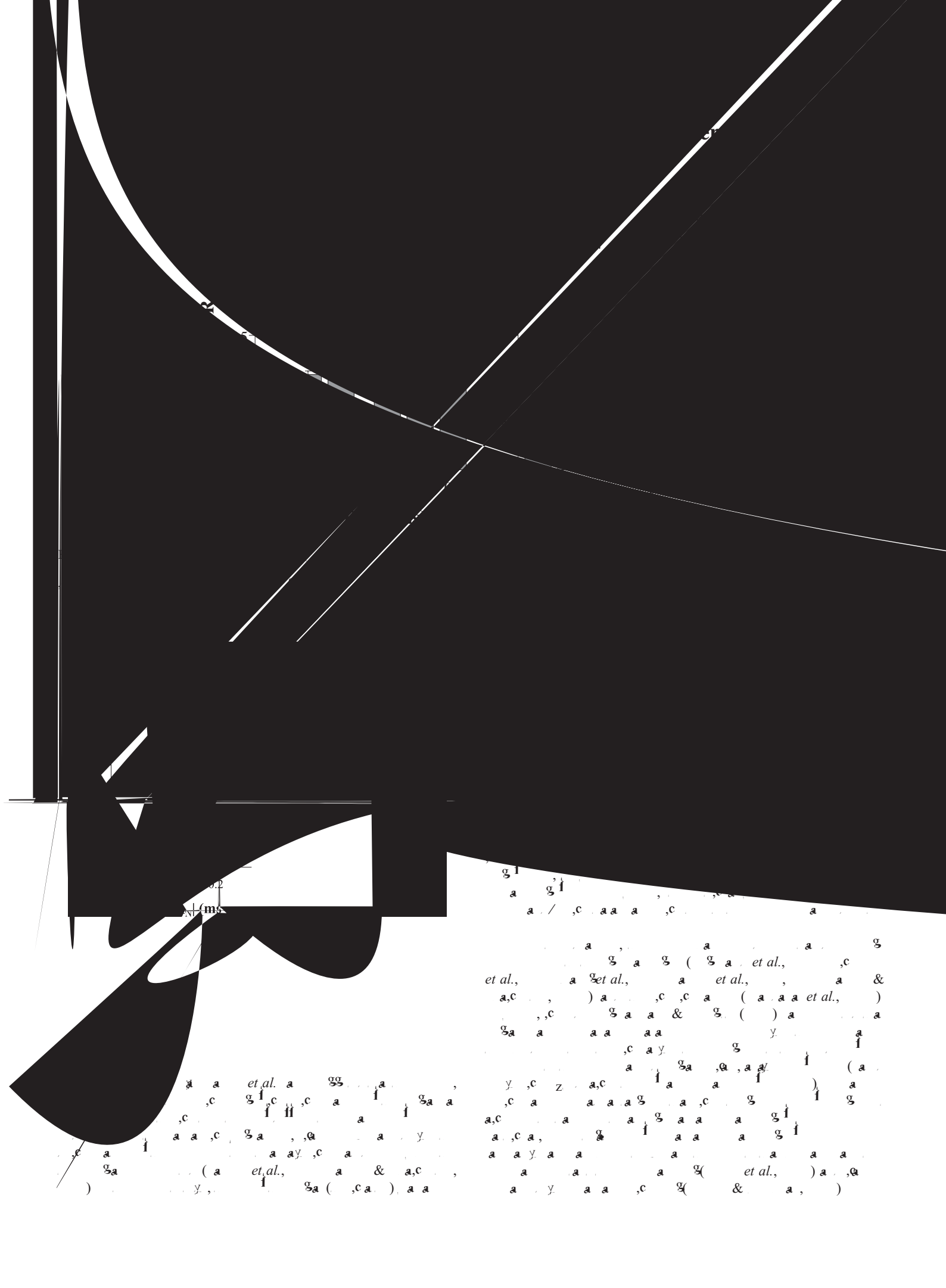


FIG. 4. F_0 amplitude changes in response to contralateral DNLL and IC injections. *Figure 4 shows the effects of contralateral DNLL and IC injections on F_0 amplitude. The data are presented as mean \pm SEM. The hatched bars represent the pre-injection values, and the white bars represent the post-injection values. The stimulus conditions are I/C, ST, C/I, I, and C. The ANOVA results are shown in the table below.*

Stimulus Condition	Pre-injection	Post-injection	ANOVA (P)
I/C	1.9	2.1	0.05
ST	1.9	2.1	0.05
C/I	1.3	1.6	0.05
I	1.1	1.3	0.05
C	1.0	1.3	0.05

Figure 4 shows the effects of contralateral DNLL and IC injections on F_0 amplitude. The data are presented as mean \pm SEM. The hatched bars represent the pre-injection values, and the white bars represent the post-injection values. The stimulus conditions are I/C, ST, C/I, I, and C. The ANOVA results are shown in the table below.



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Acknowledgements

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Abbreviations

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