Supporting Information

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Supporting Results

AVFear > (AFear + VFear). ***Gamma (30–80 Hz).*** We observed three clusters of significant supra-additive increases in power for the fear condition in the gamma frequency band. We observed one large cluster peaking in the right STG (BA 22) with activation spreading to the right STS and other regions (BA 13) (Fig. S1). Other clusters of significant supra-additive gamma activity are presented in Table S1. Table S2 and Fig. S2 depict significant clusters of gamma activity for the AFear and VFear conditions.

Beta (13–30 Hz). The beta frequency band did not display any clusters of activity representing significant supra-additive increases in power for the fear condition (Table S1, Fig. S1).

Alpha (8–13 Hz). Several clusters of significant supra-additive increases in power for the fear condition were observed in the alpha frequency band. We observed one large cluster peaking in the right insula, with activation extending to encompass the STG/right STS (BA 42) among other regions (Fig. S1). Other regions of significant supra-additive increases in power observed in the alpha frequency band are reported in Table S1.

Theta (4–8 Hz). The theta frequency band showed several clusters of significant supra-additive increases in power for the fear condition. A large cluster of activity peaked in the right inferior parietal lobule (BA 40), with activation spreading ventrally to encompass the right STG (Fig. S1). Other regions of significant supra-additive increases in power observed in the theta frequency band are reported in Table S1.

AVNeutral > (ANeutral + VNeutral). ***Gamma (30–80 Hz).*** Several significant supra-additive increases in power for the neutral condition were observed for the gamma frequency band. Interestingly, one large cluster of activity was observed in right anterior STS (BA 22), with a peak in the right STG (BA 21) and activity extending to other regions. Additional regions displaying significant supra-additive increases in power observed in the gamma frequency band are reported in Table S1. Table S3 depicts significant clusters of gamma activity for the ANeutral and VNeutral conditions.

Beta (13–30 Hz). No significant supra-additive increases in power for the neutral condition were observed for the beta frequency band (Table S1).

Alpha (8–13 Hz). Although several small, circumscribed clusters of activity representing significant supra-additive increases in power for the neutral condition were observed in the alpha frequency band, only one of these clusters was observed peaking in the right STG (BA 42). Additional regions displaying significant supra-additive increases in power observed in the alpha frequency band are reported in Table S1.

Theta (4–8 Hz). No significant clusters of activity representing significant supra-additive increases in power for the neutral condition were observed in the theta frequency band (Table S1).

Supporting Discussion. In the four frequency bands examined, the band that contributed most to the broadband supra-additivity in the STS was the gamma band. Gamma band activity has been implicated in the integration of features comprising a visual stimulus and may underlie the integration of features of other sensory modalities, such as touch and audition (1). A recent review suggests that coherent gamma oscillations may serve as a binding mechanism across uni- and multisensory cortical regions for congruent multisensory signals (2), a suggestion that is in line with the object representation hypothesis of the gamma band (3). Interestingly, both congruent fear and minimally congruent neutral conditions elicited supra-additive gamma responses in the right STS, although the gamma response was more posterior for AVFear stimuli and more anterior for AVNeutral stimuli. An ERP study of crossmodal emotion showed no significant difference in mismatch negativity evoked under emotion-congruent and emotion-incongruent conditions (4), a finding that perhaps is similar to the gamma results we report here. Supra-additive gamma activity therefore may underlie the general integration of faces and voices.

Supra-additive power increases also were observed in the theta and alpha frequency bands. Activity in the theta frequency band could represent processing related to the auditory channel of the AV signal (5), and activity in the alpha frequency band could underlie the functional inhibition of regions processing the visual channel of the AV signal (6). No supra-additive increases in power were observed in the beta frequency band for either the fear or the neutral condition. Given the suggested involvement of beta activity in sensory-motor processing (7), our beta results could reflect that participants were requested to attend passively to the crossmodal emotion stimuli presented.

1. Singer W, Gray CM (1995) Visual feature integration and the temporal correlation hypothesis. *Annual Reviews Neuroscience* 18:555–586.
2. Senkowski D, Schneider TR, Foxe JJ, Engel AK (2008) Crossmodal binding through neural coherence: Implications for multisensory processing. *Trends Neurosci* 31:401–409.
3. Tallon-Baudry C, Bertrand O (1999) Oscillatory gamma activity in humans and its role in object representation. *Trends in Cognitive Sciences* 3:151–162.
4. De Gelder B, Böcker KB, Tuomainen J, Hensen M, Vroomen J (1999) The combined perception of emotion from voice and face: Early interaction revealed by human electric brain responses. *Neurosci Lett* 260:133–136.
5. Fingelkurts AA, Fingelkurts AA, Krause CM (2007) Composition of brain oscillations and their functions in the maintenance of auditory, visual and audio-visual speech percepts: An exploratory study. *Cogn Process* 8:183–199.
6. Jokisch D, Jensen O (2007) Modulation of gamma and alpha activity during a working memory task engaging the dorsal or ventral stream. *J Neurosci* 27:3244–3251.
7. Classen J, Gerloff C, Honda M, Hallett M (1998) Integrative visuomotor behavior is associated with interregionally coherent oscillations in the human brain. *J Neurophysiol* 79:1567–1573.

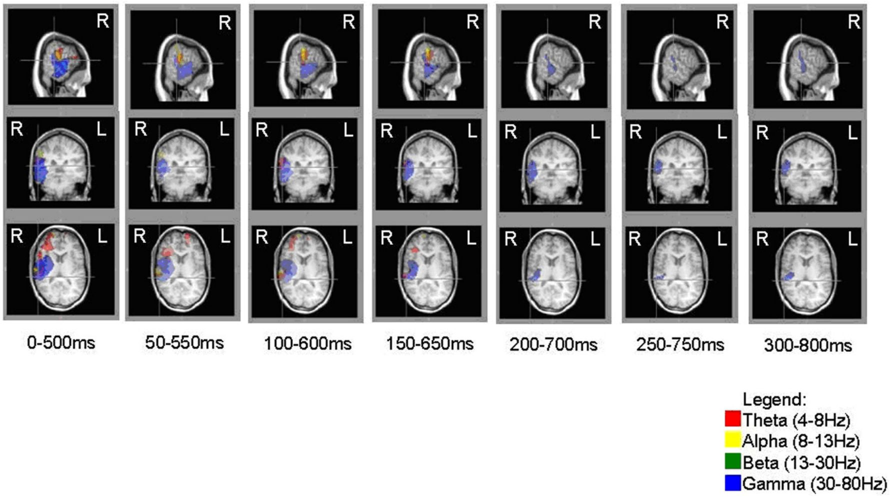

Fig. S1. Supra-additive increase in power observed in all frequency bands across the entire duration of the AVFear stimulus (i.e., from 0 to 800 ms, from stimulus onset through stimulus offset). Each column depicts the supra-additive response observed in a 500-ms time window beginning at 0 ms, with time windows of subsequent columns increasing in increments of 50 ms up to 300 ms. Crosshairs are placed at the MNI coordinate in the right STG (60, −36, 10) with activation thresholded from $P < 0.05$ to $P < 0.005$. Gamma t-values observed at the coordinate are as follows: 0–500 ms = 2.79; 50–550 ms = 2.70; 100–600 ms = 2.52; 150–650 ms = 2.31; 200–700 ms = 2.24; 250–750 ms = 2.13; 300–800 ms = 2.21. Beta t-values observed at the coordinate are 0 across all time windows. The alpha t-value observed at the coordinate is 2.59 for the 0–500 ms time window and 0 for all other time windows. Theta t-values observed at coordinate are as follows: 0–500 ms = 1.66; 50–550 ms = 1.19; 100–600 ms = 1.88; 150–650 ms = 1.89; 200–700 ms = 0; 250–750 ms = 0; 300–800 ms = 0.

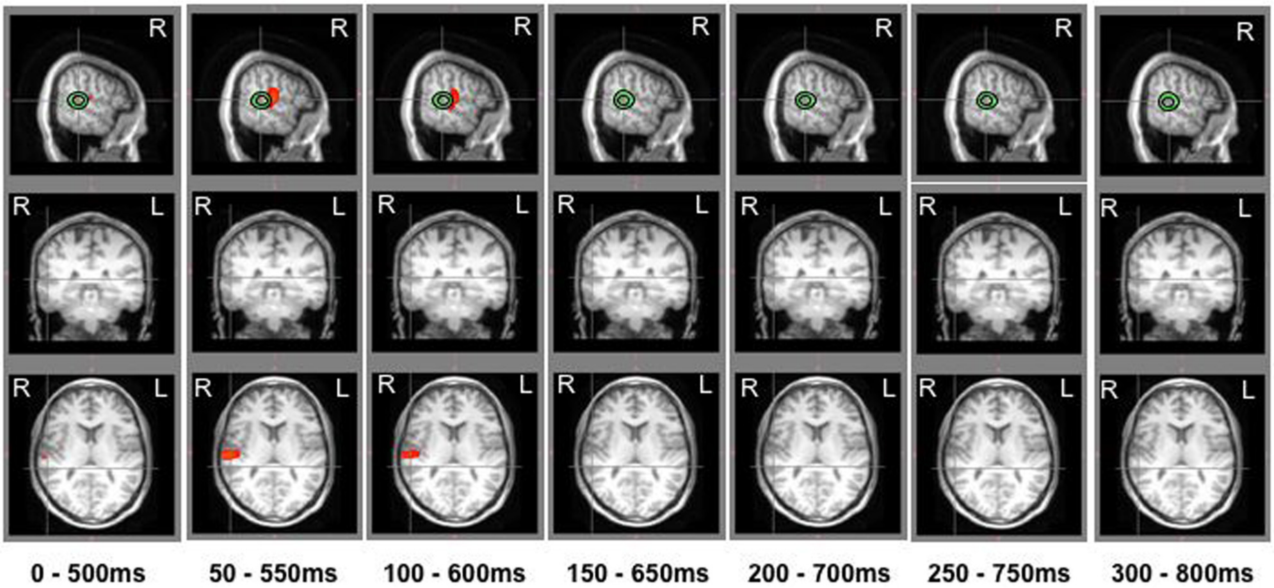

Fig. S2. Significant increases in gamma power observed across the entire duration of the AFear stimulus (i.e., from 0 to 800 ms, from stimulus onset through stimulus offset). Each column depicts the significant response observed in a 500-ms time window beginning at 0 ms, with time windows of subsequent columns increasing in increments of 50 ms up to 300 ms. Crosshairs are placed at the MNI coordinate in the right STG (60, −36, 10) with activation thresholded from $P < 0.05$ to $P < 0.005$. Gamma t-values observed at the coordinate are as follows: 0–500 ms = 0.70; 50–550 ms = 0.92; 100–600 ms = 0.89; 150–650 ms = 0.71; 200–700 ms = 0.51; 250–750 ms = 0.29; 300–800 ms = 0.27.

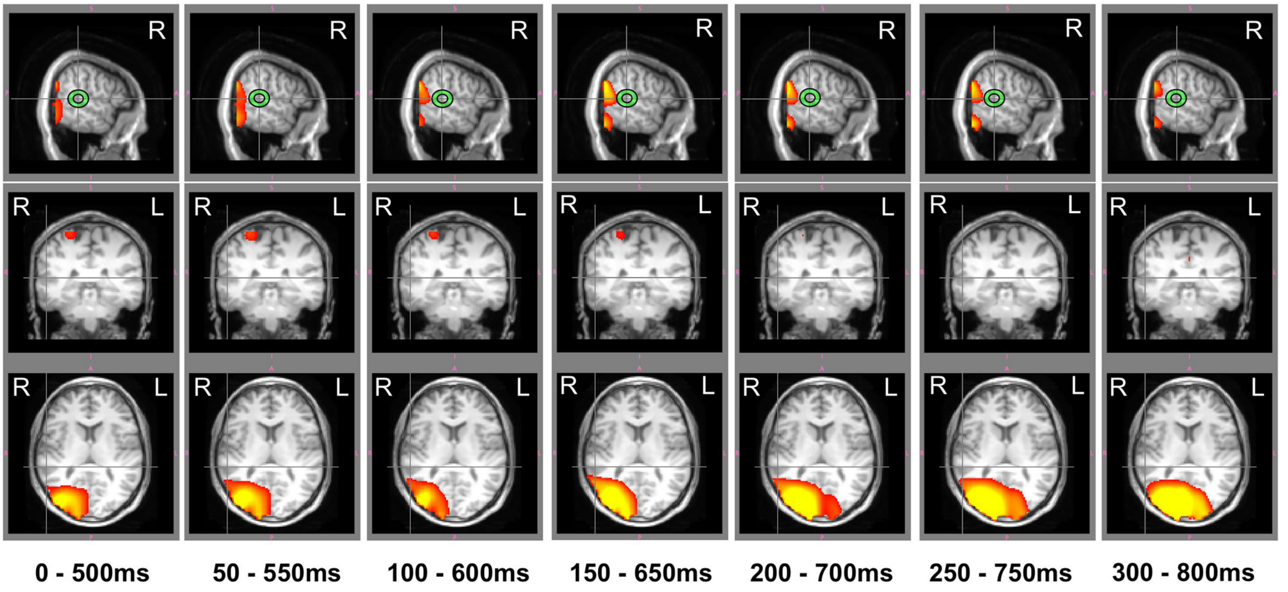

Fig. S3. Significant increases in gamma power observed across the entire duration of the VFear stimulus (i.e., from 0 to 800 ms, from stimulus onset through stimulus offset). Each column depicts the significant response observed in a 500-ms time window beginning at 0 ms, with time windows of subsequent columns increasing in increments of 50 ms up to 300 ms. Crosshairs are placed at the MNI coordinate in the right STG (60, −36, 10) with activation thresholded from $P < 0.05$ to $P < 0.005$. Gamma t-values observed at the coordinate are as follows: 0–500 ms = −1.95; 50–550 ms = −1.52; 100–600 ms = −1.45; 150–650 ms = −0.95; 200–700 ms = −0.98; 250–750 ms = −0.55; 300–800 ms = −0.81.

Table S1. Coordinates in MNI space and associated peak t-scores showing the significant differences (1-tailed) in power observed in each frequency band for the main effects of audio-visual fear minus (auditory fear + visual fear) and audio-visual neutral minus (auditory neutral + visual neutral)

Brain regions	BA	P-value	T-scores	Coordinates x	y	z
Theta (4–8 Hz) AVFear versus (AFear + VFear) 0–500 ms						
R inferior parietal lobule, R superior temporal gyrus, R middle frontal gyrus	40/10	<0.001	3.77	54	−26	24
R insula, R inferior frontal gyrus, R middle frontal gyrus	13/45/10	<0.001	3.74	34	24	14
L superior frontal gyrus, L medial frontal gyrus	10	<0.005	3.04	−16	70	4
L inferior frontal gyrus, L middle frontal gyrus	47	<0.005	3.00	−56	40	−2
L superior frontal gyrus, L medial frontal gyrus	10	<0.005	2.97	−16	60	14
R superior frontal gyrus	6	<0.025	2.40	6	20	66
L inferior parietal lobule	40	<0.025	2.20	−62	−30	38
R superior frontal gyrus	9	<0.025	2.20	14	54	38
R superior frontal gyrus, R middle frontal gyrus, R inferior frontal gyrus	9/10/46	<0.025	2.14	34	44	38
R precentral gyrus	6	<0.05	1.96	50	−6	54
L superior temporal gyrus	22	<0.05	1.96	−70	−26	−2
R Postcentral gyrus	3	<0.05	1.86	20	−30	48
Theta (4–8 Hz) AVNeutral versus (ANeutral + VNeutral) 0–500 ms						
R precentral gyrus	4	<0.025	−2.35	50	−20	38
R middle frontal gyrus	9	<0.025	−2.31	50	20	38
R postcentral gyrus	3	<0.05	−2.08	50	−16	54
L middle frontal gyrus	46	<0.05	−1.98	−50	30	24
Alpha (8–13 Hz) AVFear versus (AFear + VFear) 0–500 ms						
R insula, R postcentral gyrus, R superior temporal gyrus, R superior temporal sulcus, R inferior parietal lobule	13/42/40	<0.005	3.45	54	−30	18
L anterior cingulate cortex, L dorsal anterior cingulate cortex	32	<0.005	2.98	−10	24	34
R Middle temporal gyrus	21	<0.01	2.61	54	10	−36
R superior frontal gyrus, R medial frontal gyrus	10	<0.025	2.49	20	70	14
R postcentral gyrus, R superior temporal gyrus, R insula	43/42/22/41	<0.025	2.34	70	−16	18
L precentral gyrus	6	<0.025	2.29	−60	0	28
R supramarginal gyrus	40	<0.025	2.26	64	−50	28
R inferior parietal lobule	40	<0.025	2.22	60	−40	48
L middle frontal gyrus	6	<0.025	2.18	−46	10	48
R inferior parietal lobule	40	<0.025	2.11	54	−56	54
L inferior parietal lobule, L postcentral gyrus, L precentral gyrus	-	<0.05	1.82	−30	−24	28
L precentral gyrus	6	<0.05	1.82	−36	−6	38
R precentral gyrus	6	<0.05	1.78	54	0	54
R medial frontal gyrus	6	<0.05	1.74	4	−26	68
Alpha (8–13 Hz) AVNeutral versus (ANeutral + VNeutral) 0–500 ms						
R postcentral gyrus, R inferior parietal lobule	2/40	<0.01	2.81	64	−30	44
R middle frontal gyrus, R inferior frontal gyrus	46/9/45	<0.025	2.54	50	20	28
R supramarginal gyrus	40	<0.025	2.21	60	−56	34
R inferior temporal gyrus	20	<0.025	2.19	60	−40	−22
R superior temporal gyrus	42	<0.05	1.98	70	−20	8
R hippocampus	-	<0.05	1.96	32	−42	−2
R inferior parietal lobule	40	<0.05	1.93	56	−60	44
R rectal gyrus, R orbital gyrus, R medial frontal gyrus, R inferior frontal gyrus, R subcallosal gyrus	11/25	<0.05	1.91	10	24	−26
R insula	13	<0.05	1.83	40	14	4
R superior frontal gyrus	10	<0.05	1.72	20	64	14
R precuneus	7	<0.05	−2.06	30	−50	48
Beta (13–30 Hz) AVFear versus (AFear + VFear) 0–500 ms						
R precuneus, R middle occipital gyrus	7/19	<0.00001	−5.74	14	−70	48
L inferior occipital gyrus, L middle temporal gyrus	18/19	<0.025	−2.44	−40	−96	−16
R middle temporal gyrus	-	<0.025	−2.31	30	−70	45
L middle occipital gyrus	-	<0.025	−2.30	−30	−76	14
L middle occipital gyrus	19	<0.025	−2.18	−40	−90	18
L cerebellum	-	<0.025	−2.11	−16	−66	−56
L superior parietal lobule	7	<0.05	−2.00	−6	−70	54
L superior parietal lobule	7	<0.05	−1.93	−20	−76	54
L precuneus	7	<0.05	−1.91	−10	−60	48

Brain regions	BA	P-value	T-scores	Coordinates		
				x	y	z
L precuneus	19	<0.05	−1.90	−30	−86	38
R inferior occipital gyrus	18	<0.05	−1.81	34	−96	−16
Beta (13–30 Hz) AVNeutral versus (ANeutral + VNeutral) 0–500 ms						
L cerebellum, L lingual gyrus, L inferior occipital gyrus, L middle occipital gyrus, L precuneus, L cuneus, L middle temporal gyrus, L fusiform gyrus, R lingual gyrus, R inferior occipital gyrus, R middle occipital gyrus, R precuneus, R middle temporal gyrus, R fusiform gyrus	18/19/31/37/39	<0.0001	−4.82	−36	−80	−42
L cerebellum	-	<0.0005	−4.18	−6	−70	−42
L cerebellum	-	<0.001	−3.86	0	−86	−22
L inferior occipital gyrus	19	<0.001	−3.74	−46	−86	−12
R middle occipital gyrus	18	<0.005	−3.57	34	−90	8
R precuneus	39	<0.005	−3.44	44	−76	34
R superior parietal lobule, R middle temporal gyrus, R precuneus, L precuneus	7/39	<0.005	−3.42	30	−70	54
L middle occipital gyrus	19	<0.005	−3.36	−56	−76	4
R superior parietal lobule	7	<0.005	−3.20	40	−76	44
L cuneus	7	<0.005	−2.85	−20	−80	28
L precuneus	19	<0.01	−2.81	−36	−86	38
L precuneus	31	<0.01	−2.81	−16	−56	34
L middle occipital gyrus	19	<0.01	−2.69	−40	−90	18
L middle frontal gyrus	10	<0.05	−1.93	−34	52	24
L caudate tail	-	<0.05	−1.82	−30	−32	2
L claustrum	-	<0.05	−1.82	−30	−26	8
L thalamus, pulvinar	-	<0.05	−1.78	−20	−26	−2
L lateral geniculum body	-	<0.05	−1.74	−20	−26	−4
Gamma (30–80 Hz) AVFear versus (AFear + VFear) 0–500 ms						
R superior temporal gyrus, R superior temporal sulcus, R middle temporal gyrus, R inferior temporal gyrus, R fusiform gyrus, R precentral gyrus, R thalamus, R insula	22/21/20/6/ 13	<0.001	3.63	54	−10	−2
R insula	13	<0.005	3.27	44	−36	18L
L superior temporal gyrus	22	<0.05	1.93	−66	−40	8
Gamma (30–80 Hz) AVNeutral versus (ANeutral + VNeutral) 0–500 ms						
R middle temporal gyrus, R fusiform gyrus	21/37	<0.01	2.76	70	−46	−12
R superior temporal gyrus	39	<0.01	2.71	54	−56	8
R middle temporal gyrus	21	<0.01	2.69	54	−46	−2
R middle temporal gyrus, R superior temporal gyrus	19/39	<0.025	2.40	54	−66	14
R superior temporal gyrus, R superior temporal sulcus, R middle temporal gyrus, R insula, R claustrum, R transverse temporal gyrus, R precentral gyrus, R postcentral gyrus	21/22/13/44/41	<0.025	2.38	64	−6	−2
R inferior parietal lobule	40	<0.025	2.31	66	−30	38
R orbital gyrus, R rectal gyrus	11	<0.05	2.08	20	40	−26
R cerebellum	-	<0.05	2.02	60	−60	−32
L caudate, caudate head	-	<0.05	2.01	−16	14	8
R inferior temporal gyrus	20	<0.05	1.97	44	−6	−46
L postcentral gyrus	2	<0.05	1.92	−44	−36	64
R uncus, R inferior temporal gyrus, R middle temporal gyrus	20/38	<0.05	1.82	30	0	−42

Positive t-scores reflect significant increases in power; negative t-scores reflect significant decreases in power.
BA = Brodmann area; L = left; R = right.

Table S2. Coordinates in MNI space and associated peak t-scores showing the significant differences (1-tailed) in power observed in the gamma frequency band (30–80 Hz) for the main effects of Auditory Fear and Visual Fear

Brain regions	BA	P-value	T-scores	Coordinates x	y	z
AFear						
R superior temporal gyrus	42	<0.05	1.82	70	−20	8
L middle occipital gyrus, L cuneus, L middle temporal gyrus, L cerebellum, L midbrain, L thalamus, R middle occipital gyrus, R cuneus, R inferior occipital gyrus, R middle temporal gyrus	18/19	<0.00025	−4.49	−30	−76	4
L cuneus, L middle occipital gyrus, L middle temporal gyrus, L cerebellum, L midbrain, L thalamus, R middle occipital gyrus, R cuneus, R inferior occipital gyrus, R middle temporal gyrus	18/19	<0.0005	−4.09	−16	−104	−2
R middle occipital gyrus, R cuneus, R inferior occipital gyrus, R middle temporal gyrus, L middle occipital gyrus, L cuneus, L middle temporal gyrus, L cerebellum, L midbrain, L thalamus	18/19	<0.0005	−4.04	24	−96	4
R cuneus, R middle occipital gyrus, R inferior occipital gyrus, R middle temporal gyrus, L middle occipital gyrus, L cuneus, L middle temporal gyrus, L cerebellum, L midbrain, L thalamus	18/19	<0.0005	−3.94	14	−104	−2
R inferior occipital gyrus, R cuneus, R middle occipital gyrus, R middle temporal gyrus, L middle occipital gyrus, L cuneus, L middle temporal gyrus, L cerebellum, L midbrain, L thalamus	18/19	<0.0025	−3.50	40	−90	−6
R inferior parietal lobule, R superior parietal lobule	40/7	<0.025	−2.60	42	−56	44
L medial frontal gyrus, L anterior cingulate cortex, R medial frontal gyrus, L middle frontal gyrus	9/10	<0.005	−3.11	−10	40	34
L cingulate gyrus	24	<0.05	−1.81	−10	−10	38
VFear						
R middle occipital gyrus, R angular gyrus, R cuneus, cerebellum	19	<0.0025	3.67	44	−86	14
R cuneus, R middle occipital gyrus, R angular gyrus, cerebellum	18	<0.0025	3.21	14	−106	4
R angular gyrus, R middle occipital gyrus, R cuneus, cerebellum	39	<0.025	2.58	54	−70	34
R middle occipital gyrus, R angular gyrus, R cuneus, cerebellum	19	<0.025	2.50	54	−76	−12
R medial frontal gyrus	6	<0.025	2.20	8	−30	70
R postcentral gyrus	2	<0.05	1.94	30	−38	68
R superior temporal gyrus, R superior temporal sulcus, R transverse temporal gyrus, R middle temporal gyrus, R insula, R precentral gyrus, R middle frontal gyrus	22/42/21/9/8	<0.005	−3.13	64	10	4
R superior temporal gyrus, R superior temporal sulcus, R transverse temporal gyrus, R middle temporal gyrus, R insula, R precentral gyrus, R middle frontal gyrus	42/22/21/9/8	<0.025	−2.72	60	−30	14
L middle frontal gyrus, L inferior frontal gyrus	10/47	<0.025	−2.45	−50	44	−2
R precentral gyrus, R middle frontal gyrus, R superior temporal gyrus, R superior temporal sulcus, R transverse temporal gyrus, R middle temporal gyrus, R insula	9/8/21/22/42	<0.025	−2.32	44	24	38
R middle temporal gyrus, R insula, R precentral gyrus, R middle frontal gyrus, R superior temporal gyrus, R superior temporal sulcus, R transverse temporal gyrus	21/22/42/9/8	<0.05	−1.911	70	−26	−12

Positive t-scores reflect significant increases in power; negative t-scores reflect significant decreases in power.
BA = Brodmann area; L = left; R = right.

Table S3. Coordinates in MNI space and associated peak t-scores showing the significant differences (1-tailed) in power observed in the gamma frequency band (30–80 Hz) for the main effects of Auditory Neutral and Visual Neutral

Brain regions	BA	P-value	T-scores	Coordinates		
				x	y	z
ANeutral						
L Postcentral gyrus	1	<0.025	2.39	−66	−20	28
R Postcentral gyrus	5	<0.05	2.07	44	−46	62
R Anterior cingulate	24	<0.05	1.79	4	30	14
R middle temporal gyrus	-	<0.05	1.76	54	−30	−12
L cuneus, L precuneus, L posterior cingulate, L inferior parietal lobule, L lingual gyrus, L middle occipital gyrus, R middle occipital gyrus, R cuneus, R precuneus, R inferior temporal gyrus, cerebellum	19/7	<0.00005	−5.52	−26	−96	24
L cuneus, L precuneus, L posterior cingulate, L inferior parietal lobule, L lingual gyrus, L middle occipital gyrus, R middle occipital gyrus, R cuneus, R precuneus, R inferior temporal gyrus, cerebellum	18/40	<0.00025	−4.85	−16	−106	−2
L lingual gyrus, cerebellum, L cuneus, L precuneus, L posterior cingulate, L inferior parietal lobule, L middle occipital gyrus, R middle occipital gyrus, R cuneus, R precuneus, R inferior temporal gyrus	18	<0.00025	−4.71	−6	−96	−22
L middle occipital gyrus, L lingual gyrus, L cuneus, L precuneus, L posterior cingulate, L *i*nferior parietal lobule, R middle occipital gyrus, R cuneus, R precuneus, R inferior temporal gyrus	19	<0.00025	−4.68	−46	−86	14
R cuneus, R precuneus, R inferior temporal gyrus, R middle occipital gyrus, cerebellum, L middle occipital gyrus, L lingual gyrus, L cuneus, L precuneus, L posterior cingulate, L inferior parietal lobule	18	<0.0005	−4.13	14	−106	−2
R superior frontal gyrus	9/10	<0.025	−2.13	30	52	32
L superior frontal gyrus, L middle frontal gyrus	9	<0.05	−2.01	−34	44	38
VNeutral						
R cuneus	18	<0.05	1.89	14	−86	18
R superior temporal gyrus, R superior temporal sulcus, R inferior temporal gyrus, L superior frontal gyrus, midbrain, R insula, R caudate, R anterior cingulate, R inferior frontal gyrus, R middle frontal gyrus, R orbital gyrus, R superior frontal gyrus	22	<0.00025	−4.56	64	6	0
R superior temporal gyrus, R superior temporal sulcus, R inferior temporal gyrus, L superior frontal gyrus, midbrain, R insula, R caudate, R anterior cingulate, R inferior frontal gyrus, R middle frontal gyrus, R orbital gyrus, R superior frontal gyrus	38	<0.00025	−4.45	24	18	−42
R inferior frontal gyrus, R middle frontal gyrus, R orbital gyrus, R superior frontal gyrus, R superior temporal gyrus, R superior temporal sulcus, R inferior temporal gyrus, L superior frontal gyrus, midbrain, R insula, R caudate, R anterior cingulate	47/45/11/10	<0.0025	−3.74	54	40	−6
R superior temporal gyrus, R superior temporal sulcus, R inferior temporal gyrus, L superior frontal gyrus, midbrain, R insula, R caudate, R anterior cingulate, R inferior frontal gyrus, R middle frontal gyrus, R orbital gyrus, R superior frontal gyrus	38	<0.0025	−3.62	22	22	−36
R inferior temporal gyrus, L superior frontal gyrus, midbrain, R insula, R caudate, R anterior cingulate, R inferior frontal gyrus, R middle frontal gyrus, R orbital gyrus, R superior frontal gyrus, R superior temporal gyrus, R superior temporal sulcus	20	<0.0025	−3.47	66	−20	−22
L superior temporal gyrus, L superior temporal sulcus, L middle temporal gyrus, L insula, L inferior temporal gyrus	22	<0.025	−2.83	−60	8	−2
L superior frontal gyrus	9/10/8	<0.025	−2.83	−22	48	42
L superior parietal lobule	7	<0.05	−1.79	−20	−62	64

Positive t-scores reflect significant increases in power; negative t-scores reflect significant decreases in power.
BA = Brodmann area; L = left; R = right.