Supplemental Material S1. Results of the complete statistical analysis (by including all factors).

Because there were several conditions included in this study, the interpretation of interactions could become challenging. Therefore, we simplified the statistical analysis in the result section to focus on the primary interactions and comparisons. However, for clarity and transparency, we provide the result of the complete analysis (by including all factors) in this section. As a dependent variable, we calculated the average adaptive responses based on (1) the 30 trials of the change phase, (2) the last 30 trials of the hold phase, (3) and the 30 trials of the end phase (see gray-shaded areas in Figure S1, Panels A and B). We then used a linear mixed-effect model with perturbation group (sudden and gradual), perturbation type (formant-shift and formant-clamp), and phase (change, hold, and end phases) as fixed factors and participant as a random intercept. Table S1 lists the results of the complete statistical analysis.

Table S1. Statistical results of all main effects and interactions.

	F-value	*p*-value
Phase	66.951	< .001
Perturbation Type	327.180	< .001
Perturbation Group	2.036	.159
Phase × Perturbation Type	6.094	.002
Phase × Perturbation Group	21.558	< .001
Perturbation Type × Perturbation Group	20.846	< .001
Phase × Perturbation Type × Perturbation Group	0.679	.507

The impact of the gradual or sudden introduction of perturbations on the difference between adaptive responses to formant-shift and formant-clamp perturbations

The normalized and baseline corrected adaptative responses for the gradual and sudden groups are shown in Figures S1 A and B, respectively. We found statistically significant main effects of phase, $F(2, 1010) = 66.951$, $p < .001$, and perturbation type, $F(1, 1010) = 327.180$, $p < .001$; however, the main effect of perturbation group was not statistically significant, $F(1, 58) = 2.036$, $p = .159$. We also found Phase × Perturbation Type interaction, $F(2, 1010) = 6.094$, $p = .002$, Phase × Perturbation Group interaction, $F(2, 1010) = 21.558$, $p < .001$, and Perturbation Type × Perturbation Group interaction, $F(1, 1010) = 20.846$, $p < .001$. However, the Phase × Perturbation Type × Perturbation Group interaction was not statistically significant, $F(2, 1010) = 0.679$, $p = .507$. As shown in Figure S1, Panels C and D, these interactions indicated that (a) the difference between adaptive responses to formant-shift and formant-clamp perturbations was the smallest when the perturbations were introduced suddenly ($p = .031$), (b) the difference between adaptive responses to formant-shift and formant-clamp perturbations was the smallest in the change phase ($p < .016$), and (c) regardless of the perturbation type, adaptive responses to

gradually introduced perturbations were smaller than responses to suddenly-introduced perturbations in the change phase ($p < .001$) but not in the hold and end phases ($p > .822$).

In the result and discussion sections, we discuss the significant main effect of perturbation type and the significant perturbation type by perturbation group interaction. Here, we focus on the significant effects involving the phase effect. Our analyses showed that (a) adaptive responses to gradual perturbations were smaller than responses to sudden perturbations in the change phase, and (b) the difference between adaptive responses to formant-shift and formant-clamp perturbations was the smallest in the change phase. These results are expected, and we attribute both results to the gradual vs. sudden introduction of the perturbations. The adaptive responses to the gradual perturbations gradually increased throughout the change phase (30 trials) until they reached a stable level at the end of the change phase. However, adaptive responses to the sudden perturbations increased rapidly, and after ~9 trials, they reached a relatively stable level. It should be noted that these patterns of responses were similar for both formant-shift and formant-clamp perturbations. Because we averaged responses in all 30 trials of the change phase, the overall responses were larger for the sudden perturbations than the gradual perturbations. Additionally, because the overall responses to formant-shift and formant-clamp perturbations were smaller in the change phase (compared with responses in other phases), the difference between these responses was also smaller. In addition to the difference in the overall perturbation magnitude in the change phase of the two perturbation groups, participants' acuity (the smallest perturbation magnitude that a participant can perceive) may also influence the results. Future studies can determine the contributions of perceptual acuity on adaptive responses by measuring participants' acuity of formant-shift and formant-clamp perturbations (e.g., using a discrimination procedure).

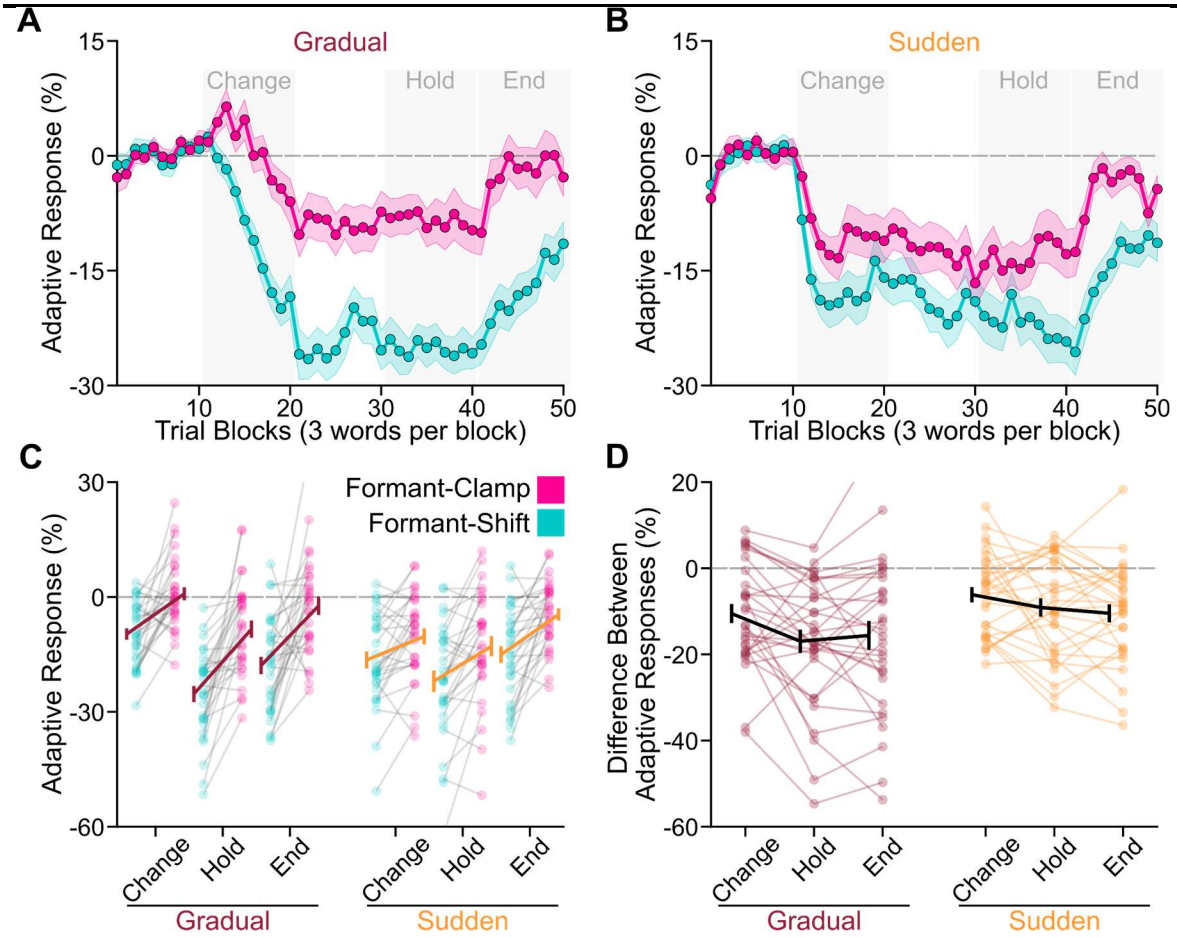

Figure S1. The group-average adaptive responses to formant-shift and formant clamp perturbations when perturbations were introduced gradually (A) and suddenly (B). Color-shaded areas in panels A and B correspond to the standard error of the mean. We calculated the average adaptive responses in the change, hold, and end phases (gray-shaded areas in panels A and B). Panel C shows the individual responses to different perturbation types (formant-shift and formant-clamp), perturbation groups (gradual and sudden), and phases (change, hold, and end). Panel D shows the difference between responses to formant-shift and formant-clamp perturbations (responses to formant-shift perturbations minus responses to formant-clamp perturbations) for different phases and groups. Error bars in panels C and D correspond to the standard error of the mean.

The similarity between adaptive responses to formant-shift and formant-clamp perturbations

We also conducted a series of correlational analyses to determine the relationship between adaptive responses to formant-shift and formant-clamp perturbations in different phases (change, hold, and end) and for different perturbation groups (sudden and gradual). Figure S2 shows the results of these correlational analyses. For the suddenly introduced perturbations, we found positive correlations between adaptive responses to formant-shift and formant-clamp perturbations in all three phases (change phase: $r = .665$, $p < .001$; hold phase: $r = .691$, $p < .001$; end phase: $r = .425$, $p = .019$); however, this was not the case for the gradually introduced perturbations. In other words, participants responded more similarly to formant-shift and formant-clamp perturbations when the perturbations were applied suddenly.

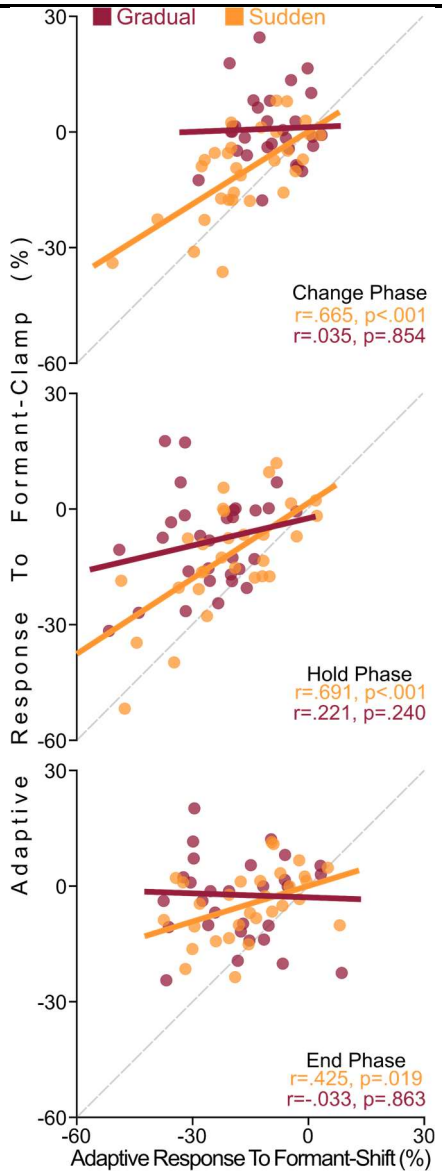

Figure S2. We examined the relationship between adaptive responses to formant-shift and formant-clamp perturbations in different phases (change, hold, and end) and for different perturbation groups (sudden and gradual). We found positive correlations between responses to formant-shift and formant-clamp perturbations in all three phases of the suddenly introduced perturbations; however, this was not the case for the gradually introduced perturbations. The gray dashed line is the identity line (i.e., a line with a slope of 1).