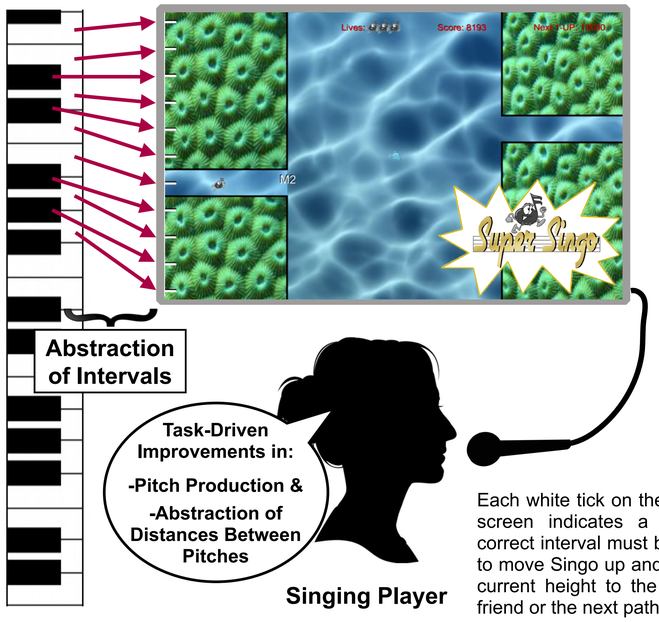
Pitch-Navigation Game with Temporal Constraints: Abstract Integration of Musical Intervals by Training Relative Separation Between Sung Pitches

Robert Colcord[1]; Jillian Frager[2]; Irán Román[1]
[1]Center for Computer Research in Music and Acoustics, Stanford, CA
[2]Science Technology and Society, Stanford University, Stanford, CA

Abstract

Training of pitch production through singing is a widespread practice of music curricula at higher education institutions across the world [1]. Accurate Interval recognition and production (through singing or by playing musical instruments) is a complex task that individuals developing relative pitch skills are trained to successfully carry out [2]. Although pitch production and matching can be improved if one's performance is not optimal, individuals living with amusia lack the ability to either hear or sing accurate pitches [3] [4] [5]. As amusia is a disorder with its origin in abnormal cognitive function, therapies that train the amusic individual to sign and improve pitch singing may lead to the better connection of brain areas that are relevant to pitch production and recognition [6]. Taking a similar approach to Hutchins and Peretz's 2010 study [7], we have developed a singing video game where accurate pitch production in the framework of musical interval matching is the controller of our game. The player can control pitch production with his or her own voice, by sliding a finger vertically on a touchpad, or by pressing the up and down arrows of a computer keyboard. Testing of the player performance pre and post gaming therapy was assessed through behavioral measurements of sung pitch divergence around a central target pitch. Additionally, we carried out electrophysiological measurements of the Event-Related Potential (ERP) abstract-feature mismatch negativity (absMMN) evoked by randomized musical intervals in our participants. RESEARCH QUESTION: Can a pitch-mediated controller lead to improved pitch production, abstract interval singing, and pre-attentive recognition of musical intervals (measured electrophysiologically) in both non-musicians and amusia patients?.

Game Design



# Semi-tones	Interval
1	m2
2	M2
3	m3
4	M3
5	P4
6	Aug5
7	P5
8	m6
9	M6
10	m7

Each white tick on the left side of the screen indicates a semitone. The correct interval must be sung in order to move Singo up and down, from his current height to the one where his friend or the next pathway is located.

Training Timeline

1. Assessment Before

i. Pitch Matching

ii. Abstract Interval Singing

iii. Abstract Interval Recognition

Figure 1. Assessment Procedure Before Gaming
Qualitative measurement of vocal pitch matching, melodic interval production and recognition before the training phase of our experimental timeline.

2. Training Period

Weeks: 1 2 3 4

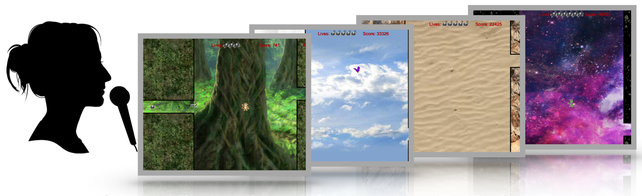


Figure 2. Gaming Period Driving Improvement in Performance
Individuals play Super-Singo 4 continuous weeks, 5 hours per week. Improvement in vocal pitch production and interval matching occurs. Behavior-driven neuroplasticity takes place in the temporal lobe.

3. Assessment After

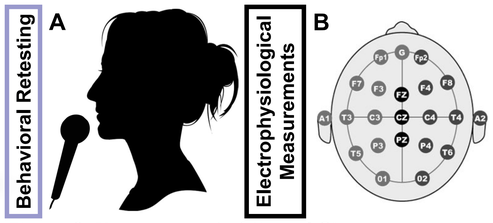
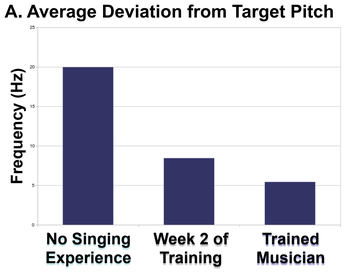


Figure 3. Measurement of Neural Changes
[A] Participants undergo reassessment of behavioral performance described in Fig.1. [B] Measurement of the absMMN evoked by musical intervals post-training.

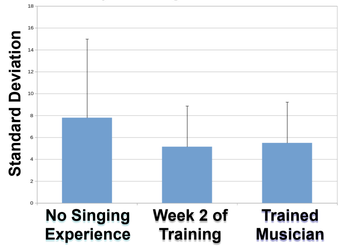
Results

4. Behavioral Measurements

A. Average Deviation from Target Pitch



B. Variability in Sung Pitch Across Trials



C. Intervalic Distances Sung by Each Participant

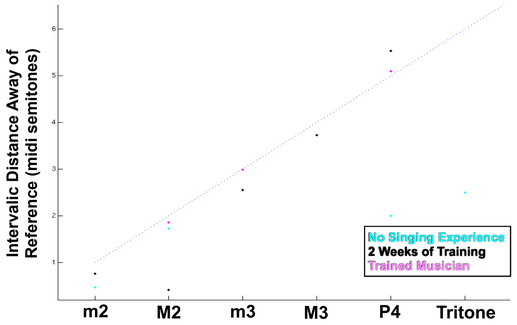


Figure 4. Results of Pilot Behavioral Data
[A] Pitch targeting performance in each subject category (no singing experience, 2 weeks of gaming, and trained musician); n=1 in each group. [B] Average variability in pitch sung across subject groups. [C] Dotted line = abstract intervals and their corresponding distances in midi numbers. The dots on the plot represent performance of each of the subject groups in a randomly generated interval singing task.

5. Electrophysiological Measurements

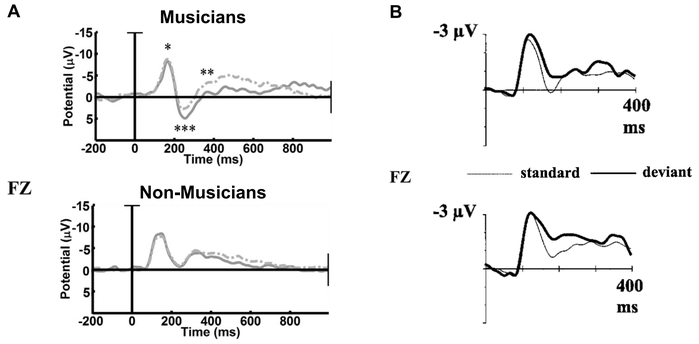


Figure 5. Cortical Changes in the Temporal Lobe Upon Completion of Training
[A] Expected difference in ERP topology upon completion of training through our video game. The electrophysiological differences between musicians and non-musicians to two different intervals (solid vs dotted lines) depict the changes in auditory brain responses in a group that has undergone musical training [8]. [B] Typical brain response to an absMMN task. This characteristic ERP will only be observed for abstract interval oddball paradigms upon completion of our training of interval sining under the temporal and spatial constraints of our video game.

Conclusion

6. Summary of Results

	Deviation Away of Target Pitch	Continuous Pitch Singing Variability	Sung Interval Matching Accuracy	Auditory Evoked Potential Aplitude	absMMN to Interval Oddball Paradigm
Before Training	>	>	Interval Sung Not Recognizable	<	No
Halfway through Training	~	~	Interval Sung Often Close but Not Accurate	~	~
After Training	<	~	Interval Sung Accurate and Identifiable	>	Yes

Fig 6. Summary of Results.
This analysis demonstrates the effects of our training in individuals with no previous accurate pitch singing training. The observed changes include improvements in pitch singing accuracy, abstract interval production abilities, as well as gaming-driven neuroplastic changes in the auditory cortex. We expect these effects to be also observed in amusia patients successfully completing our training.

Future Directions
- Make the game able to adjust to the singing range of the player.
- Implementing meaningful melodies as part of the game play.
- Implementing a multiplayer-mode for social-engagement of training.

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