# Theoretical Perspectives on Singing Accuracy: An Introduction to the Special Issue on Singing Accuracy (Part 1)

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# Theoretical Perspectives on Singing Accuracy: An Introduction to the Special Issue on Singing Accuracy (Part 1)

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Over the years, particularly in the past few years, diverse theoretical approaches have been proposed to account for singing ability and its individual differences. A particularly important point of concern has been on pitch production, given that it is in pitch production or pitch matching that the most profound deficiencies seem to appear (e.g., Dalla Bella, Giguere, & Peretz, 2007). The focus of these theories has varied with respect to their context, often serving to provide a backdrop for a particular hypothesis being tested in a given experimental paper. For instance Hutchins and Peretz (2012) emphasize the role of timbre matching in poor-pitch singing, whereas Pfordresher and Mantell (2014) emphasize predictions of an internal model framework for sensorimotor translation.

The papers reported in this special issue originated in a symposium held in Seattle on October 17-19, 2013, concerning the measurement of singing accuracy (with a special focus on pitch). One goal of the symposium in Seattle, which led to this special issue, was to synthesize the theoretical approaches from recent research. During our meeting, participants proposed specific new theoretical developments; these appear in the articles that follow this introduction. However, we also discussed how to integrate these ideas into a broader theoretical framework that ultimately may offer a more powerful paradigm for understanding singing accuracy.[1] In this introductory paper, we present the product of these discussions. The papers that follow elaborate on issues and subsets of those issues within this model.

The model presented here (which will be presented in three different ways to represent different foci) is in some respects limited but in other respects broad. It is limited in that we focus explicitly on pitch production and on auditory-motor connections that relate to pitch (which may be based on internally or externally generated auditory models). For now, we set aside the potentially important role of proprioceptive feedback (Mürbe, Friedemann, Hofmann, & Sundberg, 2002; Welch, 1985). The model is also limited to singing, and does not involve pitch control in other tasks like speaking (cf. Peretz & Coltheart, 2003). On the other hand, the model is broad in that it can potentially apply to a variety of singing-related tasks. The model can relate to the production of single pitches or of melodic sequences. Likewise, it encompasses both singing from memory and singing based on matching, such as via imitation or chorused singing.

A particular focus of the meeting was to bring together scholars whose primary focus is in cognitive science, along with scholars whose primary focus is in music education. Based on the different theoretical paradigms and practical problems germane to each area, these two clusters converged on distinct theoretical perspectives. Whereas those representing cognitive science focused primarily on *structural and functional mechanisms in singing*, those representing music education focused primarily on the nature of the *developmental trajectories* exhibited across years of involvement in singing. Though these perspectives are ultimately related, as functional mechanisms are shaped by a developmental trajectory, we present them separately here

[1] We here refer to 'accuracy' using the broader colloquial sense of the term, which encompasses both accuracy and precision in the technical senses of the term (cf. Dalla Bella, this volume; Pfordresher, Brown, Meier, Belyk, & Liotti, 2010).

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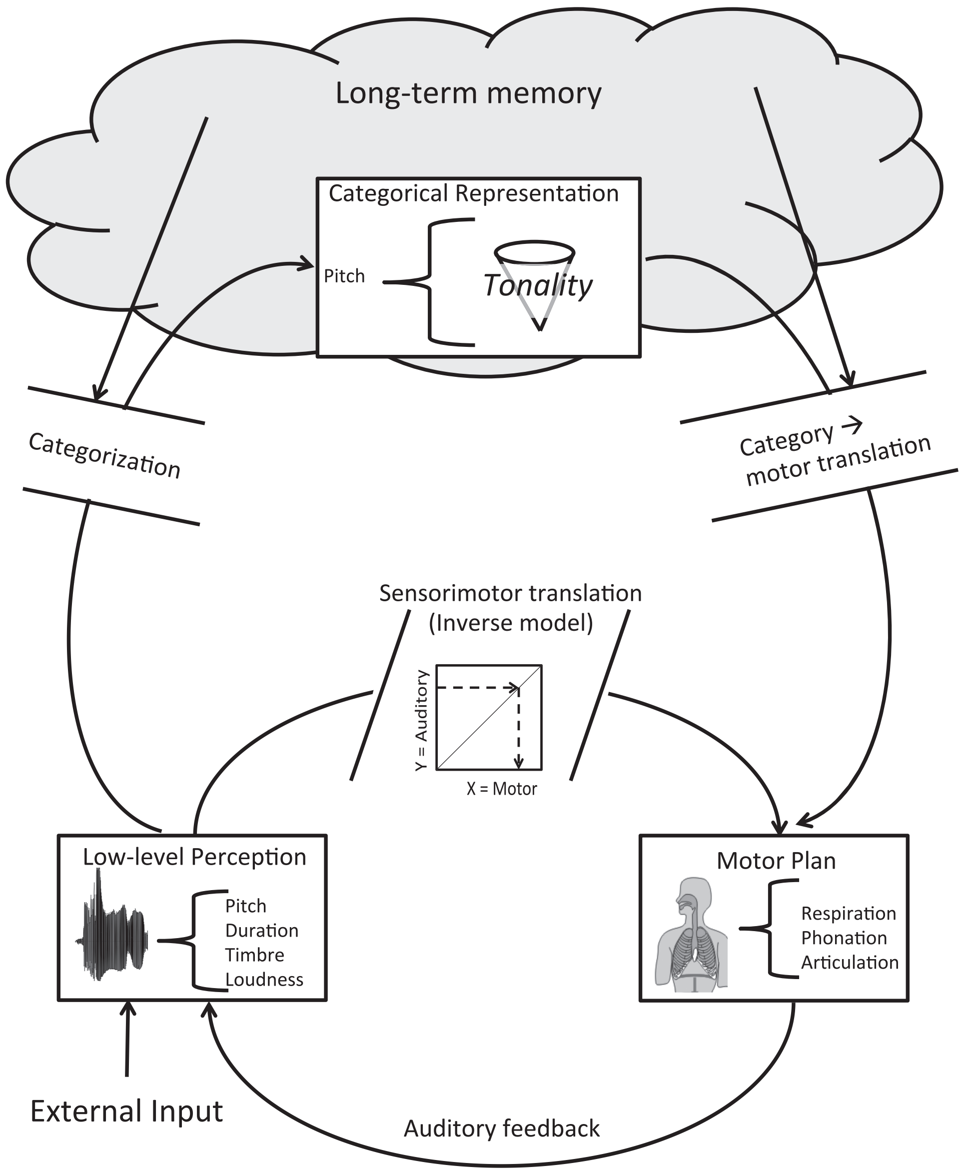


**FIGURE 1.** Proposed functional architecture underlying singing accuracy.

both for the purpose of clarity and as a concession to the differences across these groups.

STRUCTURAL AND FUNCTIONAL MECHANISMS IN SINGING

Figure 1 illustrates the basic components that arose from discussions of papers that follow (by participants Dalla Bella, Hutchins, Loui, and Pfordresher).

The model below illustrates functional components that are involved in singing and reflects some dominant theoretical views in the current literature. The basic design of this framework is as follows. Rectangles highlight functional representations of content. Representations are framed as a code (on the right side of the bracket) for some physical or perceptual event (on the left side of the bracket). For instance, the motor plan is considered to be a representation of muscle movements (illustrated by the human torso) as a set of motor commands for respiration, phonation, and articulation. Arrows show connections between representations for singing; for the sake of simplicity we show only feed-forward connections although feedback connections also exist. The open parallelograms that disrupt the arrows indicate conversion/mapping functions that are necessary to translate one representation to another. Based on the assumptions of this framework, the process of singing relies on a series of transformations between representations. As such, poor-pitch singing may result from a deficit within the basic representations themselves, or from deficient connections between these representations.

A great deal of recent attention has focused on the role of the *sensorimotor loop*, shown in the lower half of Figure 1 (cf. Berkowska & Dalla Bella, 2009; Dalla Bella, Berkowska, & Sowiński, 2011; see also Dalla Bella in the present volume). This basic structure relates low-level perceptual representations of pitch content to the coordination of muscles responsible for pitch production (with primary importance typically being allocated to muscles responsible for phonation). Some recent data suggest that a considerable number of poor-pitch singers may suffer from an inability to appropriately translate perceptual representations into motor plans (e.g., Hutchins & Peretz, 2012; Pfordresher & Brown, 2007), accompanied in some cases by difficulty in controlling the vocal motor system (Dalla Bella et al., 2007; Hutchins & Peretz, 2012; Pfordresher, Brown, Meier, Belyk, & Liotti, 2010). By contrast, although deficient pitch perception can also contribute to poor-pitch singing, there is increasing evidence that perceptual deficits are not a sine qua non for poor pitch singing (e.g., Ayotte, Peretz, & Hyde, 2002; Dalla Bella, Giguere, & Peretz, 2009). The article by Pfordresher and colleagues in the present volume elaborates on the kind of transformational deficit that might exist in poor singing. Note that the sensorimotor loop in the present model relates only to the control of pitch moment-by-moment in real time during pitch production, and does not address the role of hierarchical pitch control that may relate to planning and monitoring of pitch intervals and higher-level tonal structures.

Completion of the sensorimotor loop in Figure 1 involves using the output of motor planning – a sung pitch – as auditory feedback that is then processed as low level pitch. The degree to which auditory feedback can be used to control motor planning is addressed in the present volume by Loui. Her paper discusses how the dorsal and ventral branches of fronto-temporal white matter pathways, including the arcuate fasciculus, help singers use categorical information and auditory feedback to guide motor planning, and how deficiencies in this neural mechanism may lead to poor-pitch singing. The importance of feedback in singing has been recognized for some time, and was also given considerable attention in an earlier groundbreaking schema theory of singing (Welch, 1985), which laid the groundwork for the framework in Figure 1. In addition to auditory feedback, low-level perception may also incorporate external input during tasks that involve imitation of a model or chorused singing with others. More information on possible neural underpinnings of the functions illustrated in Figure 1 is shown in Figure 2.

Above the sensorimotor loop the framework in Figure 1 shows connections to a categorical representation of pitches and their combinations, along with translations from low-level perception to this representation, as well as translation from these categorical representations to the motor plan. The categorical representation involves the incorporation of musical schemata that shape low-level perception. The contribution of such schemata to the perception of musical pitch has been known for some time; an example of such encoding shown in Figure 1 is the conical representation of tonal stability proposed by Krumhansl (1979). In the present volume, Hutchins considers how this type of representation can play a role in singing, along with the use of low-level perception from the sensorimotor loop (cf. Hutchins & Moreno, 2013).

Figure 1 also represents the role of long-term memory in singing (though memory in its various forms may contribute to singing in ways not shown in Figure 1). Categorical representations are thought to be stored in memory as a result of long-term knowledge acquisition; as such, the box denoting categorical representations is located in the memory "cloud." Furthermore, long-term memory helps to guide conversion to and from categorical representations. For singing based simply on long-term memory and not from imitation, production may rely solely on the arrow from memory to the translation function from the categorical representation to the motor plan.

A shortcoming of cognitive models like the one shown in Figures 1 and 2 is that they can imply a static architecture. Such an interpretation is of course contrary to the spirit of this special issue, which focuses instead on individual differences and development. In this spirit, it is worth pointing out that individuals can differ with respect to how successfully different model components function, as well as the strength and specificity of connections between components. It is also worth pointing out that activity within components of the model, and connections between these components, varies dynamically. Nevertheless, as the model presented thus far does not specify the nature of the developmental progression in singing, this is a matter we turn to next.

## DEVELOPMENTAL TRAJECTORIES IN SINGING ACCURACY

Figure 3 represents ideas about how training influences development, as discussed during the symposium and in related literature from music education (participants Demorest, Rutkowski, and Welch). Two factors are highlighted. One is the fact that vocal range increases with development. This progression has been documented in

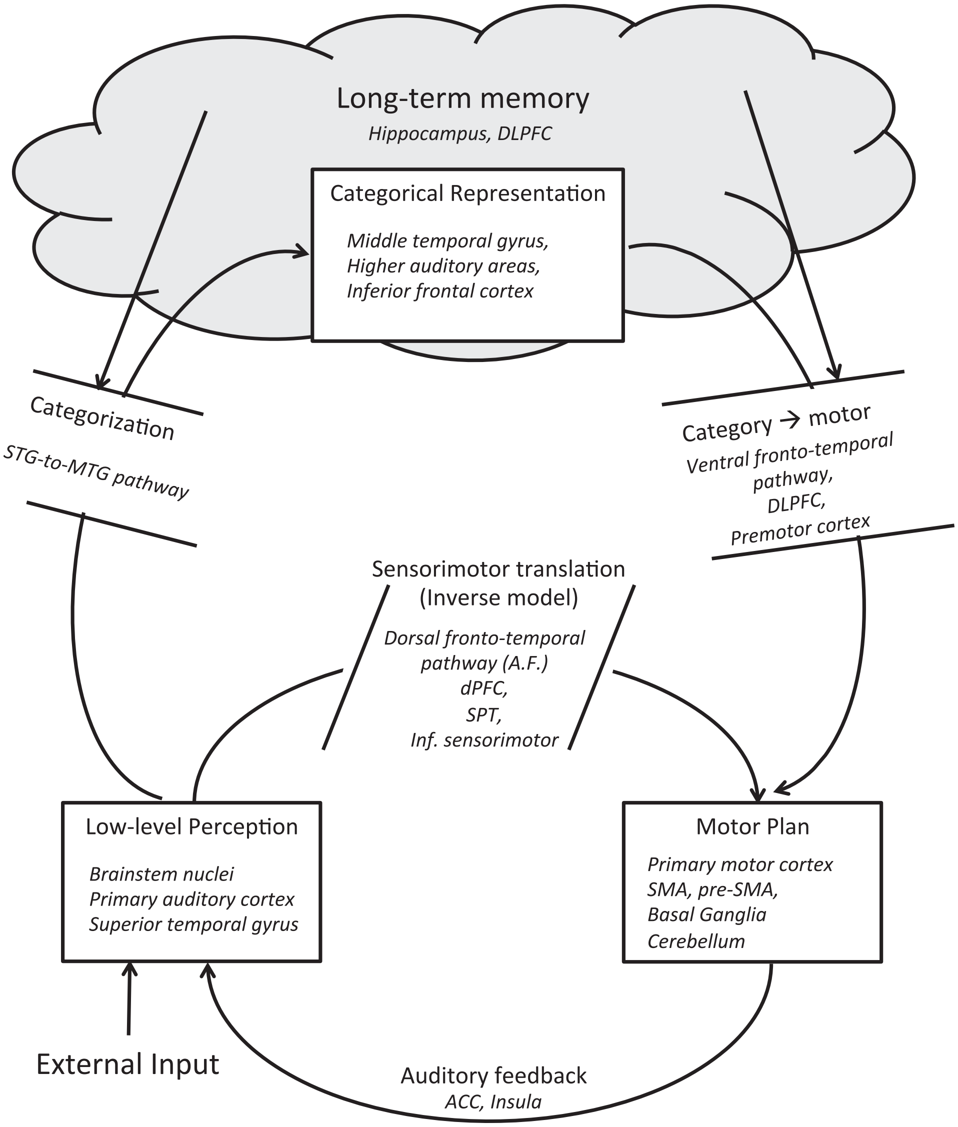


**FIGURE 2.** Proposed neural substrates underlying the architecture illustrated in Figure 1.

several past papers by Welch (e.g., Welch, 1979, 2006). Importantly, on average vocal range increases with age, along with vocal accuracy (although it is important to note that large individual differences exist at all ages).

Figure 3 represents the developmental trajectory that is generally found. The left side of Figure 3 illustrates the correlation between increases in vocal range and qualitative changes to singing accuracy. Four qualitative benchmarks are highlighted that map onto aspects of musical structure typically reproduced accurately. Although these benchmarks give the appearance of discrete stages, they should be construed more loosely as "phases" of development that an individual may move between flexibly at different times and possibly across different tasks. These are somewhat related to the hierarchical organization of melodies. At an early phase, when the singer exhibits a constrained vocal range, singing takes on a monotone-like quality. With development, singers reproduce pitch with increasing accuracy as vocal range widens and various vocal registers become comfortable. Note that vocal range (the horizontal axis) is related to accuracy in a correlational sense, and that for an individual the relationship may not be linear in the average sense that is shown in Figure 3.

Whereas Figures 1 and 2 offer a mechanistic account of singing, Figure 3 is more descriptive. Two papers in the

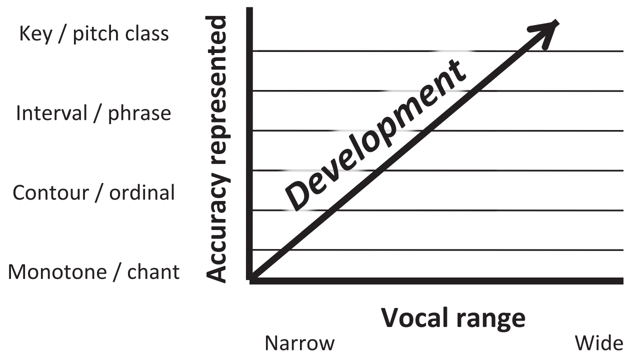


FIGURE 3. Proposed developmental trajectory relating singing accuracy to vocal range.

present volume offer suggestions as to the kinds of underlying mechanisms that lead to the trajectory shown in Figure 3. The present paper by Rutkowski proposes that the use of vocal register can function as a catalyst for vocal development. Specifically, she proposes that the physical exertion involved in shifting from the more comfortable speaking range to a higher pitch range associated with singing can help to spur on changes to vocal range and changes to associated accuracy. The present paper by Demorest documents changes to pitch accuracy during a year of kindergarten and beyond. An important point of this paper is that the developmental progression shown in Figure 3 is primarily determined by experience in singing, rather than simply occurring as a byproduct of development over time.

Taken together, the present papers shed light on the different perspectives that were presented at the Seattle International Symposium on Research in Singing. By documenting the functional mechanisms, neural underpinnings, and developmental trajectory of singing and its multiple components, our goal is to converge towards a multidisciplinary model of singing that can generate empirical predictions of individual differences and development of this fundamental musical ability. Each paper included here underwent a full review process, including comments by symposium participants and outside reviewers.

## Author Note

After the first two authors, the author order of this paper was determined alphabetically.

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