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Singing with yourself: Evidence for an inverse modeling account of poor-pitch singing

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ABSTRACT

Singing is a ubiquitous and culturally significant activity that humans engage in from an early age. Nevertheless, some individuals – termed poor-pitch singers – are unable to match target pitches within a musical semitone while singing. In the experiments reported here, we tested whether poor-pitch singing deficits would be reduced when individuals imitate recordings of themselves as opposed to recordings of other individuals. This prediction was based on the hypothesis that poor-pitch singers have not developed an abstract "inverse model" of the auditory–vocal system and instead must rely on sensorimotor associations that they have experienced directly, which is true for sequences an individual has already produced. In three experiments, participants, both accurate and poor-pitch singers, were better able to imitate sung recordings of themselves than sung recordings of other singers. However, this self-advantage was enhanced for poor-pitch singers. These effects were not a byproduct of self-recognition (Experiment 1), vocal timbre (Experiment 2), or the absolute pitch of target recordings (i.e., the advantage remains when recordings are transposed, Experiment 3). Results support the conceptualization of poor-pitch singing as an imitative deficit resulting from a deficient inverse model of the auditory–vocal system with respect to pitch.

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1. Introduction

Individuals vary in their ability to imitate pitch accurately by singing. Although most individuals are on average accurate when imitating vocal pitch through singing (Dalla Bella, Giguere, & Peretz, 2007; Pfordresher & Brown, 2007; Pfordresher & Mantell, 2009), a minority of individuals (approximately 10–20%, Dalla Bella et al., 2007; Pfordresher & Brown, 2007) sing out-of-tune by more than ±100 cents (1 musical semitone on either side of the target pitch) on average and have been termed 'poor-pitch singers' (Welch, 1979a). Given the ubiquity of singing across cultures and the importance of vocal imitation for language acquisition (Kuhl, 2000; Kuhl & Meltzoff, 1996), such deficits are surprising and intriguing. Moreover, the cognitive bases of poor-pitch singing are still not well understood.

We propose that the problem of poor-pitch singing lies in the fact that vocal imitation, unlike the imitation of manual gestures, cannot rely on the direct observation (visual, kinesthetic or otherwise) of the motor gestures generated by the target. Thus, though singing may be considered a form of vocal imitation, the inability to perceive motor gestures directly causes the task of singing to better resemble what has been termed "emulation" (i.e., reproducing outcomes rather than imitating gestures, cf. Tomasello, 1990). It has been argued that vocal imitation may proceed entirely by error correction in the output (Heyes, 2005). However, recent evidence suggests that most individuals have only a limited capacity for using auditory feedback to improve pitch matching (Hutchins & Peretz, 2012). Thus, we propose an account of poor-pitch singing based on the problem of relating auditory events to kinesthetic motor states.

In the current paper we test the hypothesis that poor-pitch singing arises because these individuals have not formed an abstract *inverse model* of the auditory–vocal system, which allows singers to plan motor gestures based on target perceptual outcome. This framework, described later, leads to the prediction that poor-pitch singing should be reduced when the target exhibits a pitch pattern similar to one's own vocal gestures (for which better-formed associations should exist) as opposed to the vocalizations of others: a *self-imitation benefit*.

1.1. Poor-pitch singing: Background

Recent research has adopted acoustic measurements of production in an attempt to better document what poor pitch singers do while they are singing. As mentioned above, poor-pitch singers are primarily characterized by an overall tendency to distort absolute pitch consistently while singing ("mistuning"). Poor-pitch singers also compress the size of pitch intervals (normal singers exhibit compression to a lesser degree, Dalla Bella, Giguere, & Peretz, 2009; Pfordresher & Brown, 2007). Finally, poor-pitch singers are typically more variable in their production than are accurate singers, suggesting that inaccuracy and imprecision may jointly characterize poor-pitch singers (Pfordresher, Brown, Meier, Belyk, & Liotti, 2010). In contrast to these deficits, poor-pitch singers are often accurate in reproducing melodic contour (the pattern of upwards and downwards pitch changes in a melody, Pfordresher & Brown, 2007).

A variety of core deficits may lead to poor-pitch singing (for reviews see, Berkowska & Dalla Bella, 2009; Pfordresher & Brown, 2007; Pfordresher & Mantell, 2009; Tsang, Friendly, & Trainor, 2012). To date, evidence suggests that poor-pitch singing cannot be accounted for simply by some underlying perceptual deficit (as suggested by the colloquial term "tone deafness", Bradshaw & McHenry, 2005; Dalla Bella et al., 2007; Lévêque, Giovanni, & Schön, 2012; Pfordresher & Brown, 2007), or by problems with motor control (Pfordresher & Brown, 2007; Pfordresher & Mantell, 2009). Nor does an account based on an underlying memory deficit seem likely, particularly given that poor-pitch singing can emerge during matching of single pitches (Hutchins & Peretz, 2012) and poor-pitch singers are capable of performing complex, multi-note melodies even more accurately than simple melodies (Pfordresher & Brown, 2007). Thus, Pfordresher and Brown (2007) suggested that poor-pitch singing is a deficit of sensorimotor-translation in the vocal system—that is, a deficit specific to imitation. Of course, building a theory on negative evidence is not optimal. Thus, the current study represents an