Maternal singing modulates infant arousal

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TALI SHENFIELD, SANDRA E. TREHUB
AND TAKAYUKI NAKATA
UNIVERSITY OF TORONTO

ABSTRACT We examined the effect of maternal singing on the arousal levels of healthy, non-distressed infants. Mothers sang to their 6-month-old infants for 10 minutes, after which they continued interacting for another 10 minutes. To estimate infant arousal, we gathered saliva samples from infants immediately before the mothers began singing and 20 minutes later. Laboratory analyses of the saliva samples revealed that salivary cortisol levels converged from baseline to post-test periods. Specifically, infants with lower baseline levels exhibited modest cortisol increases in response to maternal singing; those with higher baseline levels exhibited modest reductions. This convergence of arousal levels was confirmed by reduced variability in cortisol values from baseline to post-test. These findings are consistent with the view that maternal singing modulates the arousal of prelinguistic infants.

KEYWORDS: *cortisol, infants, mothers, songs*

Mothers across cultures commonly sing to infants in the course of caregiving (Trehub and Schellenberg, 1995; Trehub and Trainor, 1998). For this purpose, they use a distinct musical repertoire, which includes lullabies (Trehub et al., 1993a; Unyk et al., 1992), play songs (Rock et al., 1999; Trehub et al., 1993b; Trehub, Unyk et al., 1997), and songs adapted from the adult repertoire (Trehub, Hill et al., 1997). Their manner of singing is also distinctive, being marked by higher than usual pitch, slower than usual tempo, and acoustic indicators of heightened emotionality (Trainor et al., 1997; Trehub et al., 1993b; Trehub, Unyk et al., 1997). Not surprisingly, mothers make age-appropriate adjustments in performing style. When singing to infants, for example, they use a higher pitch level and articulate the lyrics less clearly than when singing to preschoolers (Bergeson and Trehub, 1999).

Mothers' performance adjustments are well suited to the preferences of young listeners. Newborns and older infants listen more attentively to singing in the infant-directed style than to other styles of singing (Masataka, 1999; Trainor, 1996) just as they listen more attentively to infant-directed speech than to adult-directed speech (e.g. Cooper and Aslin, 1990; Fernald, 1985; Werker et al., 1994). In the case of speech, it is not infant-directedness in itself, but rather positive affect that accounts for infants' preference (Singh et al., 2002). For example, Singh et al. (2002) found that infants are more attentive to adult-directed speech with positive emotional tone than to infant-directed speech with neutral emotional tone. What is critical for infants, then, is the emotive quality of speech – positive affect, in particular. Infants are also attracted to emotive gestures in other modalities, for example, positive facial expressions (Kuchuk et al., 1986) and affectionate messages in sign language (Masataka, 1996, 1998). It is likely, then, that infants' attraction to infant-directed singing stems from its positive emotive qualities.

Infants' responsiveness to the maternal style of singing may account for its extensive use in child care contexts across cultures (Trehub and Schellenberg, 1995; Trehub and Trainor, 1998). It is notable that Masataka's (1999) and Trainor's (1996) demonstrations of preferential responding to infant-directed singing were achieved with relatively impoverished stimuli – audio recordings by unfamiliar singers (the mothers of other infants). When Nakata and Trehub (2000, 2001) exposed infants to richer materials, specifically, to audio-visual recordings of speech and singing featuring their own mother, they found considerably greater attention to these audio-visual displays than to the audio materials of previous research on speech or singing (Cooper and Aslin, 1990; Fernald, 1985; Masataka, 1999; Trainor, 1996). Of special interest, however, was infants' enhanced attention to the singing episodes relative to the speech episodes. For one thing, infants looked longer at their mother's on-screen image during her singing episodes. Moreover, reductions in body movement, which reflect the intensity of infant engagement (Bacher and Robertson, 2001), were especially pronounced during the singing episodes (Trehub and Nakata, 2002).

Overt attentional responses are often accompanied by measurable autonomic changes. For example, infant attention to visual and auditory stimuli is accompanied by decreases in heart rate (Byrne and Miller, 1988; Byrne and Smith-Martel, 1987). Moreover, heightened infant attention is associated with reductions in heart rate variability (Byrne and Smith-Martel, 1987). One would expect similar links between other overt behaviours and autonomic measures.

There are suggestions that the effects of maternal singing on arousal may be more important than its effects on overt behaviour (Trehub, 2001). To date, however, there is no empirical demonstration of the consequences of maternal singing on infant arousal. Nevertheless, the practice of singing lullabies to induce sleep – an obvious reduction in arousal – is unlikely to have

persisted across cultures and historical periods if it were ineffectual. In recent years it has become clear that music has salutary effects on prematurely born infants, whose arousal levels are often dangerously high. Music stabilizes their heart rate (Lorch et al., 1994) and oxygen saturation levels (Cassidy and Standley, 1995; Standley and Moore, 1995), and it reduces their need for sedation (Standley, 2001). However, we know little about the impact of music – maternal singing, in particular – on physiological indices of arousal in healthy, non-distressed infants. Progress in this respect has been impeded by the challenges of measuring arousal in healthy, non-distressed infants.

Salivary cortisol is a potentially suitable measure for infants because of its non-invasiveness and its reliability in indexing autonomic arousal (e.g. Kirschbaum and Hellhammer, 1994). Cortisol is a steroid hormone that is released by the adrenocortical system into the bloodstream. Because traces of the hormone pass into saliva, it is possible to estimate concentrations in the blood from salivary levels. The relative ease of collecting saliva samples accounts for the increasing use of salivary cortisol as a measure of arousal in adults and children. Stress-inducing stimuli lead to a robust surge in cortisol concentrations (Ben-Aryeh et al., 1985; Gunnar et al., 1989; Stansbury and Gunnar, 1994). By contrast, pleasurable and relaxing stimuli reduce cortisol levels that were previously elevated (Field et al., 1996; Gunnar et al., 1992; Kurihara et al., 1996).

For the most part, cortisol measures have been used to index arousal changes linked to the induction or reduction of stress. There are indications, however, that the adrenocortical system may be sensitive to subtle changes of state, even in the context of moderate arousal levels (Hertsgaard et al., 1992). Because maternal singing succeeds in capturing infant attention, it is likely to induce changes in arousal. In principle, maternal singing could arouse a sleepy or lethargic infant, on the one hand, and calm an active or fussy infant on the other. In other words, its effect on infants may not be uniform. If singing heightens attention, it could lead to reduced variability in cortisol levels across infants, just as heightened attention reduces heart rate variability (Byrne and Smith-Martel, 1987).

Salivary cortisol measures present particular challenges with infant participants. For one thing, cortisol secretion follows a circadian rhythm, with concentrations of the hormone surging in early morning and decreasing gradually throughout the day (Kirschbaum and Hellhammer, 1994). Unfortunately, the rate of decrease is not constant, nor has it been described systematically. Cortisol responses are thought to show adult-like circadian rhythms by 5–6 months of age (Lewis and Thomas, 1990; Spangler, 1991), but it is unclear whether the rate of decrease in infants mirrors that of adults. Practical problems arise from the appearance of cortisol changes in saliva some 15 minutes after the changes appear in blood samples. In other words, changes in salivary cortisol are temporally displaced from the stress-inducing or stress-reducing events. Finally, problems can arise from food residues in

saliva – proteins, in particular – and teething (e.g. blood residue), which can mask or distort salivary cortisol levels.

Our goal, in the present investigation, was to identify changes in salivary cortisol levels in 6-month-old infants as a consequence of maternal singing. Our focus was on live maternal performances rather than the audio recordings (Masataka, 1999; Trainor, 1996) or audio-visual recordings (Nakata and Trehub, 2000, 2001) that have been used in previous research. The choice of age level was influenced by several factors, including relatively mature adrenocortical activity by 6 months of age (Lewis and Thomas, 1990; Spangler, 1991), the ubiquity of maternal singing to this age group (Trehub, Unyk et al., 1997), and 6-month-olds' responsiveness to the maternal style of singing (Nakata and Trehub, 2000; Trainor, 1996). Mothers sang to their infants for a 10-minute period. Saliva samples were taken from infants immediately before singing and 20 minutes later (i.e. 10 minutes after mothers stopped singing). The samples were frozen and subsequently assayed to determine concentrations of salivary cortisol. Because the infant participants had normal (i.e. relatively low) initial levels of cortisol, we did not anticipate the cortisol reductions that typically occur when infants have high initial stress levels (e.g. Field et al., 1996; Gunnar et al., 1992). Instead, we expected our group of infant listeners to show a reduced range of cortisol levels (relative to their initial levels) in response to maternal singing.

Method

PARTICIPANTS

Infant participants had to meet the following inclusion criteria:

a. full-term birth;
b. 5–7 months of age;
c. good health;
d. no family history of hearing impairment;
e. no food or milk consumption in the hour before testing; and
f. no fussing or crying during maternal singing (confirmed by video recordings of the test sessions).

The sample of participants consisted of 34 middle-class mothers (M = 32 years) and their infants (17 boys, 17 girls; M = 6 months, 3 days).

APPARATUS

Testing was conducted in a quiet room on campus. Mothers were seated facing their infant, who was in a low chair (BabyTime™, with wheels removed) that provided freedom of movement for arms and legs. A Sony CCD–TR500 video camera captured a frontal view of the infant. Saliva samples were obtained by means of salivette kits (Sarstedt Canada Inc., St Laurent, Quebec), which included a syringe, an insert tube, and cotton roll. The

standard 2.5 cm cotton roll was replaced by a 15.2 cm sterile cotton dental roll (Richmond Dental) for safety concerns. The salivettes were frozen at –20°C for subsequent assay. On the day of the assay, the salivettes were thawed and centrifuged for 15 minutes, 1000 g at 4°C. As a result, the saliva passed through the hole in the bottom of the insert tube and into the syringe. Salivary cortisol levels were estimated with solid-phase radio-immunoassays (Coat-a-Count, Diagnostic Products Corp., Los Angeles, CA). Samples were assayed in duplicate, and discrepant duplicates were re-assayed.

PROCEDURE

Test sessions were scheduled between 9:30 and 11:30 am because morning cortisol levels are known to be less sensitive to environmental factors than are afternoon levels (Walker et al., 1978). Mothers were asked to restrict food and fluid intake of their infants for the hour preceding the scheduled appointment. They were also asked to avoid singing and music listening on the morning of the test.

Within 10 minutes of their arrival at the laboratory, baseline saliva samples were collected from the infants. The mother swabbed her infant's mouth with the large cotton roll, allowing the infant to chew on it. The saliva-saturated portion of the roll was clipped, placed in the insert tube of the salivette, and capped. After mother and infant were seated comfortably facing one another, the mother was asked to sing or hum as she usually did at home, continuing in that way until the experimenter indicated that 10 minutes had elapsed. Mothers were assured that the quality of their singing was not of interest. They were also asked to refrain from touching their infant during this 10-minute period. The experimenter then left the room and returned 10 minutes later. Following the 10-minute singing episode, the mother interacted with the experimenter for a further 10 minutes. At that point, 20 minutes from the onset of singing, the mother took a second saliva sample from her infant.

Results

Participants were excluded from the final data set because of insufficient saliva for laboratory analysis ($n = 9$) or because initial cortisol levels deviated by more than two standard deviations from the group mean ($n = 1$). Because there were no sex differences in baseline, post-test, or change scores (difference between baseline and post-test scores), all scores were collapsed over sex for subsequent analyses. Overall, baseline and 20-minute cortisol levels were relatively low ($M = 4.56$ nmol/l, SD = 2.70 and $M = 4.82$ nmol/l, SD = 2.07 respectively), which is consistent with the good health and low stress levels of infant participants. Baseline and 20-minute cortisol levels were highly correlated, $r(23) = .71$, $p < .0001$, which attests to the reliability of the cortisol estimates.

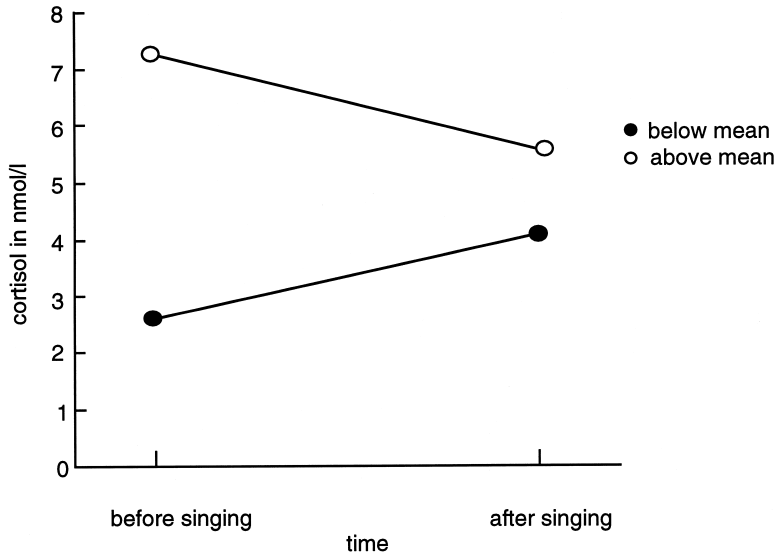

FIGURE 1 *Change in salivary cortisol levels for infants with baseline levels above the mean (n = 15) and below the mean (n = 9).*

A pairwise *t*-test revealed no overall change in infants' cortisol levels from baseline to post-test, $t(23) = .65$, ns. However, inspection of individual profiles of change revealed considerable inter-infant variability (see Figure 1). Specifically, 13 out of 15 infants whose baseline cortisol levels were above the mean showed subsequent decreases in cortisol levels. By contrast, eight of nine infants whose baseline levels were below the mean showed increases in cortisol concentrations. Thus, infant cortisol levels seemed to be converging toward an intermediate level. An *F*-test for two population variances with correlated observations (Kanji, 1993) revealed significant reductions in the variability of cortisol levels from the baseline period to the 20-minute post-test, $Fr(22) = .36$, $p < .05$.

Discussion

The principal purpose of the present investigation was to explore the arousal consequences of maternal singing on healthy, 6-month-old infants. The means of doing so involved salivary cortisol measures, which have had limited use with non-distressed infants. Cortisol levels revealed no change, on average, from baseline to post-test. Instead, there was a significant reduction in the variance of cortisol levels from the baseline period (i.e. before mothers began to sing) to the subsequent period (i.e. after mothers started singing). Specifically, infants whose initial cortisol levels were below the group mean responded to maternal singing with slight cortisol increases. By contrast, those whose initial levels were above the group mean responded with slight

decreases in cortisol levels. This pattern of performance is consistent with a progressive convergence of infant arousal levels toward a common value.

The reduced variance in infant cortisol levels cannot be attributed to regression toward the mean or other measurement artifact. Statistical regression of that nature often results from measurement error when participants are pre-selected on the basis of extreme (i.e. very high or very low) scores (Rogosa, 1995). In such circumstances, subsequent measurements tend to be less extreme than the initial measurements, which results in reduced variance. In the present study, however, we excluded all individuals with extreme cortisol levels. Moreover, baseline and post-test levels were highly correlated, which is inconsistent with the presence of greater measurement error in the baseline period than at post-test. Reductions in variance could also occur when cortisol concentrations approach their minimum values. As noted, however, infants did not show a uniform reduction in cortisol levels. Instead, slight reductions were evident in some instances and slight elevations in others. This bi-directional pattern of change is difficult to explain in terms of circadian cortisol rhythms in infancy, which involve progressive decreases in cortisol levels from their high early morning concentrations (Lewis and Ramsay, 1995; Lewis and Thomas, 1990; Price et al., 1983; Spangler, 1991). Because there is little basis for attributing the findings to measurement error or to circadian rhythms, we believe that the observed pattern reflects the effects of maternal singing.

Although the claim for arousal consequences of maternal speech and singing is not new (e.g. Fernald, 1992; Papoušek, 1992; Trehub and Trainor, 1998), it has not received experimental scrutiny. Thus, the present study is unique in submitting the arousal modulation hypothesis to a direct test. Playful maternal singing, the style that characterized most mothers in the present study, may promote arousal levels that are optimal for sustained infant attention or interest. By contrast, soothing forms of maternal singing may reduce arousal levels and, in so doing, induce sleep.

Of particular interest is the possibility that similar styles of singing have divergent consequences, depending on the infant's initial state. That situation could lead to the converging arousal levels observed in the present study, with subtle elevations in arousal for infants with low initial levels and subtle reductions for those infants with higher initial levels. If maternal singing promotes such homeostasis, it would be an invaluable caregiving tool (Trehub, 2001). Perhaps it is not surprising, then, that maternal singing to infants has been documented in every culture and historical period for which information is available (Trehub and Schellenberg, 1995; Trehub and Trainor, 1998).

For some time, it has been clear that salivary cortisol is useful in documenting high stress levels (Gunnar et al., 1992; Hertsgaard et al., 1992) as well as reductions from previously high stress levels (Field et al., 1996). The present findings indicate that salivary cortisol measures can also be used to

document subtle changes in arousal when healthy, non-distressed infants experience performances of maternal singing. The finding of robust within-session correlations also confirms the reliability of salivary cortisol measures in 6-month-old infants. Although the arousal consequences of maternal singing on healthy infants are relatively modest, they are consistent with the dramatic consequences of musical interventions on very-low-birth-weight infants, for whom high stress levels are often life-threatening (Standley, 2001).

A number of important questions remain unanswered. For example, do the cortisol changes result from the attentional consequences of maternal singing or from the mildly positive affect in response to such stimulation? How durable are the effects of maternal singing? Questions such as these can be addressed, in future research, by tracking overt behaviour as well as cortisol levels during extended periods of maternal singing.

The broader significance of singing, and of music in general, remains a matter of debate (Pinker, 1997; Trehub, 2001), unlike speech and language, which have obvious utility. Speaking to non-comprehending infants also has questionable utility when viewed through the narrow lens of its information-bearing elements. When enhancing the prosodic elements of their speech by 'undulant, high-pitched, patterned, repetitive vocalizations' (Dissanayake, 2001: 86), mothers seek and apparently achieve emotional communion with infants (Stern et al., 1985). In so doing, they are thought to lay the foundations for subsequent social functioning (Dissanayake, 2001; Trevarthen and Aitken, 1994). In contrast to maternal speech, which retains a dialogic character, even when the infant partner cannot contribute credible turns (Snow, 1977), maternal singing is essentially a solo performance. Nevertheless, such maternal solos are finely tuned to the infant's mood and apparent ability (Bergeson and Trehub, 1999; Trehub and Trainor, 1998; Trehub, Unyk et al., 1997).

According to Tooby and Cosmides (2001), many seemingly non-utilitarian activities promote fitness-enhancing changes in the brain. They contend that aesthetic motivations such as the appreciation of music may have evolved as a means of fostering the development of adaptations and the brain circuitry required for optimal function. Thus, to the extent that maternal singing succeeds in capturing and maintaining infant attention, it could fine-tune the mechanisms that subserve perceptual or social-emotional skills.

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TALI SHENFIELD obtained a degree in choral direction and music education at the Rimsky Korsakov College of Music in St Petersburg. Subsequently, she taught music in Russia, Israel and Canada. At present, she is completing doctoral studies in psychology at the University of Toronto.

SANDRA E. TREHUB obtained her doctorate in psychology from McGill University and is Professor of Psychology at the University of Toronto.
Address: Sandra E. Trehub, Department of Psychology, University of Toronto at Mississauga, Mississauga, Ontario, Canada, L5L 1C6.
[email: sandra.trehub@utoronto.ca]

TAKAYUKI NAKATA completed doctoral studies in psychology at Texas Christian University and postdoctoral studies at the University of Toronto. Currently, he is Associate Professor, Faculty of Humanities, at Nagasaki Junshin Catholic University in Japan.