Article

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Auditory Temporal Processing in Dancers

Erika Skoe[1], Erica V. Scarpati[1], and Allison McVeety[2]

Abstract

While many studies have examined the auditory abilities of musicians, this study uniquely asks whether dance training, a similar yet understudied type of early-life training, also benefits auditory abilities. We focused this investigation on temporal resolution, given the importance of subtle temporal cues in synchronizing movement. We found that, compared to untrained controls, novice adult dancers who have trained continuously since childhood had enhanced temporal resolution, measured with a gap detection task. In an analysis involving current and former dancers, total years of training was a significant predictor of temporal resolution thresholds. The association between dance experience and improved auditory skills has implications for current theories of experience-dependent auditory plasticity and the design of sound-based educational and rehabilitation activities.

Keywords

temporal resolution, gap detection, auditory expertise, dance

Introduction

Numerous studies have reported enhanced abilities in musicians compared to controls across a variety of perceptual tasks, including pitch discrimination and

[1]Department of Speech, Language, and Hearing Sciences, University of Connecticut, Storrs, Connecticut, United States
[2]The New York Otolaryngology Group, New York, United States

Corresponding Author:
Erika V. Skoe, Department of Speech, Language, and Hearing Sciences, University of Connecticut, 2 Alethia Dr., U-1085, Storrs, Connecticut 06129, United States.
Email: erika.skoe@uconn.edu

temporal processing (e.g., Micheyl et al., 2006; Strait et al., 2010). Current theories propose that musical training acts as a type of cross-training that strengthens auditory function through multiple avenues: (a) by engaging neural circuits relating to emotion and reward; (b) by demanding perceptual precision and focus; (c) by coordinating auditory, motor, and visual systems within and across individuals; and (d) by countless hours of repeated sensorimotor actions and structured practice (Herholz et al., 2011; Kraus & Chandrasekaran, 2010; Patel, 2011). Dance training has many comparable features to musical training. In addition to both being ancient yet popular artistic expressions of emotion, expert dancers, like musicians, often start training at a young age and engage in lifelong intensive regimented practice that involves skill repetition. Another feature at the core of both music and dance is timing. Musicians and dancers must both learn to time their actions to music, synchronize their movements in time across individuals in an ensemble and make subtle temporal refinements to their motor movements for aesthetic effect. For theories of auditory plasticity, dance provides an interesting counterpoint to musical training; while both share many features, the primary focus of dance training is not the auditory domain.

Despite the many studies on musicians and the parallels between music and dance, little is known of the auditory abilities of dancers outside of a few recent studies (da Silva et al., 2015; Joseph et al., 2019; Nehring et al., 2015; Pisharody et al., 2016). Historically the focus has been on the sensorimotor and artistic abilities of dancers, with more recent attention directed toward the neural correlates of dance training, both as an independent art form and in comparison to music (reviewed in Karpati et al., 2015). Most relevant to the current investigation is work showing that both dancers and musicians had increased cortical thickness in the superior temporal brain region, compared to controls; this is an area devoted to auditory processing (Karpati et al., 2017). In addition to this overlapping neural profile for musicians and dancers, cortical thickness was found to correlate with performance on a whole-body dance videogame, implicating a neurobiological connection between dance and auditory function (Karpati et al., 2017).

Dance, like music, is also well-recognized as a therapeutic tool across multiple health care domains (Clements-Cortes & Bartel, 2018; Serlin, 2010). With respect to the auditory system, rehabilitation programs have already started to adopt elements of music making into their design (e.g., Whitton et al., 2014), and a case has also been made for incorporating music activities in the treatment and management of listening difficulties in children with an auditory processing disorder and related conditions (Chermak, 2010; Kraus & Chandrasekaran, 2010). Music lessons may, however, not be of interest or be accessible to all children and all families. Alternative therapies such as dance may, therefore, offer an alternative path for families to consider (Phillips, 2002); although there is currently no empirical evidence on which to base this clinical recommendation.

One critical difference between dance and music is that sound is an integral but not necessary element of dance (Jola et al., 2014). Dance is commonly practiced and performed without an accompanying soundtrack, with movements anchored to internal, imagined rhythms of "beats" or "counts". At the early stages of learning a dance routine, beats are often counted aloud or visually marked, like an orchestra conductor visually marking time. But as the routine is mastered, these external counts can become internalized. However, while dance does not require an external soundtrack, the act of dancing is not silent. Dancers movements and breath patterns create sounds used by a dancer to regulate motor action and synchronize group dynamics via auditory-motor feedback (e.g., the sound of their feet hitting the floor) and auditory-visual feedback (e.g., the sound of their movements in sync with the visual movement of their dance partners). While dance is not a completely silent act, if it were to be viewed by an audience without any accompanying auditory signal (e.g., played as a video on mute), it would still be classified as dance (Karpati et al., 2015). By contrast, music, except in its most Avant-guard forms, would not be classified as music if the audience did not hear any sound. Even so, sound is quite important for a lot of dance training. Thus, dance training may potentially benefit auditory temporal processing through rhythmic movement, exposure to music through dance, or the combination of auditory-motor synchronization while dancing.

This background motivates the current preliminary study in which we used a behavioral paradigm to examine rapid temporal processing abilities of novice dancers who began training early in life (<7 years old) and untrained controls. To minimize variability in participants' dance training history, we restrited participant recruitment to females with Western dance training. We evaluated rapid auditory temporal resolution using an adaptive gap detection task, in which the listener detects a brief millisecond-level temporal interruption within a sound. We focused on gap detection for several reasons. First, the ability to detect subtle temporal cues is of common importance to both dance and music. Second, musicians have been reported to have better temporal resolution across multiple studies (Grassi et al., 2017; Kuhnis et al., 2013; Kumar et al., 2016; Mishra et al., 2014; Zendel & Alain, 2012). And finally, because gap detection ability has been widely studied across the lifespan in connection to auditory functions and behaviors, including language, this allows for a broader discussion of the potential implications of training-related enhancements to temporal resolution (Peiffer et al., 2004; Musiek et al., 2005; Snell & Frisina, 2000; Trehub & Henderson, 1996). Building from the observation that dance meets many of the conditions considered necessary to drive auditory plasticity in musicians, we predicted that novice dancers, who have trained continuously from a young age and practice weekly, would have better temporal resolution thresholds compared to untrained controls. To draw stronger parallels to the musician literature, we limited our cohort to dancers with early life training

(<=7 years old), given known differences between early and late trained musicians across auditory and motor tasks (Penhune, 2011). We selected age 7 because this age cutoff showed the strongest associations between age-onset and auditory-motor entrainment in musicians (Bailey & Penhune, 2013).

As with other specialized populations (e.g., musicians and bilinguals), dance is not a strictly categorical variable (Luk & Bialystok, 2013; Skoe et al., 2019). Thus, to fully understand the influence of dance on perceptual and motor function, it should be studied as a multidimensional experience. This framework for conceptualizing experience guided our approach to recruitment and analysis. In addition to making a group comparison between controls and current dancers, we also recruited former dancers with a range of experience, allowing for an examination of how gap detection thresholds vary with respect to two experiential variables, age onset of training and total years of training. We note that these are just two variables that could be considered when studying dance, and so we designed our study to minimize the confounds of other experiential variables such as training style. We hypothesized that if group-level differences between dancers and controls are due to dance-related experience-dependent plasticity of the auditory system, and not solely the result of demographic, inborn, and/or experiential differences unrelated to dance, that temporal resolution ability should scale to match gradients in the dance experience, similar to what has been observed in musicians (e.g., Pantev et al., 1998; Parbery-Clark et al., 2009; Ruggles et al., 2014). This led us to predict a relationship between temporal resolution thresholds and two variables associated with dance training experience: age onset and years of training.

Method

University students served as a sample of convenience for this preliminary study. Participants included native English-speaking female adults (ages 18–21), all full-time college students at the University of Connecticut with no history of otologic disorders (self-report), and with audiometric thresholds below 20 dB HL as confirmed by a clinical audiogram (octave frequencies from 500–8,000 Hz). All participants provided written informed consent to engage in the procedures, and the research protocol was approved by the University of Connecticut Internal Review Board. All participants were compensated $10/hour. Participants completed a survey developed by the authors about their dance training that included questions about (a) the age at which dance training began; (b) the participant's total years of training; (c) the styles of dance in which participants had been trained; (d) their main style of dance; (e) where they had received their training (dance studio/academy, university/college program, self-taught, recreation or community dance group, and/or other); (f) current total training/practice hours per week; and (g) self-rated dance skill (beginner, intermediate, advanced, professional). The survey did not ask former dancers directly about how much time had elapsed since they last trained in dance, but this information could be inferred from their age and their responses to the first two questions (a and b). The survey (Appendix A) included a mixture of open-ended and multiple-choice questions. As part of a general intake survey, participants were also asked to report their total years of musical training (instrumental or voice).

From the responses to the dance history survey, participants were categorized as Untrained Controls ($n = 10$, 19–21 years old, $M = 19.70$ years old), Active Dancers ($n = 16$, 18–21 years old, $M = 19.50$ years old), or Former Dancers ($n = 9$, 18–21 years old, $M = 19.44$ years old). Participants categorized as Controls reported no formal dance training. The Active Dancers, by definition, were actively training at the time of study enrollment, with the level of engagement ranging from 4–15 hours per week as part of a dance team/ensemble. The University of Connecticut does not offer a degree in dance but it does support several dance teams who practice and compete regularly. All the Active Dancers had trained at a dance studio/academy at some point in their training, with most rating themselves as advanced-level dancers. They began dance training in preschool (between ages 2–5) and had an average of $\sim$16 years of training ($M = 15.97$ years) (Table 1). For all but one of the Active Dancers, training was continuous from the time they first started training to the time of enrollment. This dancer with non-continuous training was treated as an outlier with respect to the training profile of the other current dancers and was excluded from the group comparisons to the Control group but was included in the correlation analysis (see below).

By definition, none of the Former Dancers were currently training at the time of study enrollment (Table 2). Compared to the Active Dancers with continuous training, participants with past dance experience were more diverse with respect to their age onset of training (ages 2–7), total years of training (2–19 years), and their self-reported range of dance abilities (from beginner to professional level). Two of the Former Dancers had stopped training in the last year, while others stopped in childhood, with a range of <1 year to 15 years since they last trained. Most of the participants classified as Former Dancers had been trained in multiple Western dance styles, with ballet being the most common style.

Gap Detection Procedure

For the Gap Detection Procedure, testing occurred in a quiet room under insert earphones (ER-2, Etymotic Research, Inc.) using the Psychoacoustics Toolbox Staircase module (Soranzo & Grassi, 2014). The software was run through the MATLAB programming environment on a desktop computer with the sound outputted binaurally to an external sound card (M-Audio M-Track). Stimuli were calibrated to be 70 dBA using a Bruel and Kjar 2250-Light-G4 sound level meter with a 2-cc coupler. An adaptive, two-alternative forced-choice staircase

Table 1. Training History for Current Dancers.

Age onset	Years (* = discontinuous training)	Current hours	Level	Styles (* = main type)	Primary training location(s)
2	16	4	Advanced	Acro, Ballet, Contemporary/Modern, Jazz*, Pom, hip-hop/street, Tap, Other (Swing)	Dance studio/Academy
2	16	4 to 6	Advanced	Ballet, Contemporary/Modern*, Jazz, Lyrical, Tap	Dance studio/Academy
2	17	4 to 6	Advanced	Acro, Ballet, Contemporary/Modern, Hip hop/Street, Jazz*, Lyrical, Pointe, Tap, Theatre	Dance studio/Academy, University/College Program
3	15	4	Advanced	Ballet, Contemporary/Modern, Jazz*, Lyrical, Pom, Tap, Other (Kickline*)	Dance studio/Academy
3	15	4	Intermediate	Acro, Contemporary/Modern*, Hip hop/Street, Jazz, Lyrical, Tap, Other (Kickline)	Dance studio/Academy
3	16	4	Advanced	Ballet*, Jazz, Pom, Pointe, Theatre	Dance studio/Academy
3	16	4	Advanced	Ballet, Contemporary/Modern, Jazz*, Lyrical, Pointe, Tap, Theatre*, Acro, Hip hop/Street	Dance studio/Academy
3	16	5	Advanced	Jazz, Ballet*, Contemporary/Modern, Lyrical, Pointe	Dance studio/Academy
3	17	4	Intermediate	Ballet, Hip hop/Street, Jazz, Pointe, Pom, Tap, Other (Kickline*)	Dance studio/Academy, university/college program, high school program

(continued)

Table 1. Continued.

Age onset	Years (* = discontinuous training)	Current hours	Level	Styles (* = main type)	Primary training location(s)
3	17	4	Advanced	Ballet, Contemporary/Modern, Hip hop/Street, Jazz, Lyrical, Pointe, Tap, Other (Kickline*)	Dance studio/Academy
3	18	4	Advanced	Acro, Ballet, Contemporary/Modern, Jazz, Lyrical, Tap, Other (Kickline*)	Dance studio/ Academy, University/college program
3	18	4	Advanced	Jazz*, Tap, Ballet, Pom, Lyrical, Pointe, Theatre, hip-hop/street	Dance studio/Academy
3	18	15	Advanced	Jazz*, Tap, Ballet, Contemporary/ Modern*, Pom, Lyrical, Pointe, Hip hop/Street, Ballroom	Dance studio/ Academy, University/College program
4	16	4 to 6	Advanced	Ballet*, Contemporary/Modern, Jazz, Lyrical, Pointe, Theatre	Dance studio/Academy
5	9*	2	Advanced	Ballet, Contemporary/Modern, hip-hop/street, Jazz, Lyrical, Pom, Theatre, Other (Kickline*)	Dance studio/ Academy, University/College program
5	14	4	Advanced	Ballet, Contemporary/Modern, hip-hop/street, Jazz*, Lyrical, Pointe, Tap, Theatre	Dance studio/Academy

Table 2. Training History for the Former Dancer Group.

Age onset	Years	Years since	Level	Styles (* = main type)	Primary training location
2	19	<1	Professional	Acro, Ballet, Contemporary/ Modern*, Jazz, Lyrical, Pom, Hip-Hop/Street, Tap	Dance studio/Academy
3	17	<1	Advanced	Ballet*, Hop/Street Jazz, Pointe, Hip-Hop/Street	Dance studio/Academy
3	2	15	Beginner	Ballet*, Tap	Dance studio/Academy
3	10	6	Beginner	Ballet, Contemporary/ Modern, Hip-Hop/ Street*, Jazz, Lyrical, Tap	Dance studio/Academy
4	14	2	Intermediate	Ballet*, Tap, Theater	Dance studio/Academy
4	5	9	Intermediate	Jazz*, Ballet	Recreational/ Community Dance group
6	2	13	Beginner	Hip-Hop/Street*	Dance studio/Academy
7	10	2	Intermediate	Ballet*, Jazz, Pointe	Dance studio/Academy
7	3	8	Beginner	Ballet*	Dance studio/Academy

procedure was used to determine the gap duration threshold. Within each trial, the participant was played two intervals of a 750-ms broadband noise, one of which contained a short gap in its temporal center. The participant selected the interval containing the gap using the "1" or "2" keys on the keyboard, and feedback (correct or incorrect) was given after each trial. The gap duration varied by a factor of two for the first two reversals followed by a factor of $\sqrt{2}$ for the final six reversals, with the first trial having a gap duration of 60 millisecods. The duration decreased after three correct trials and it increased after one incorrect trial.

Each participant completed three blocks of the test. For each block, the threshold was calculated based on the final six reversals. All participants were naïve to the task, and so, before the first block, they were given a practice round of 10 trials. Each block took approximately 5–10 minutes to complete and required the participant to remain attentive throughout. It was common for performance to decline in the third block, potentially due to attentional fatigue for some participants (main effect of block: $F(2, 68) = 3.108$, $p = 0.05$, Eta Squared = 0.084; Block *1* $M = 2.47$ milliseconds; Block 2 $M = 2.43$ ms; block 3 $M = 2.67$ ms). This decline prompted us to exclude the final block and take the average threshold of the first two blocks as the primary dependent variable in the statistical analysis of the gap detection threshold (GDT).

Statistical Analysis

We performed a group-level analysis comparing GDTs between the group of Untrained Controls ($n = 10$) and the group of Current Dancers with continuous training ($n = 15$). To test for a group difference, we applied an unequal variances test (Welch's test) in order to account for the data variances for GDTs being different for the two groups. Given the unequal sample sizes, the Welch's test was also used when comparing the groups with respect to age, hearing thresholds, and musical training. Former dancers were not included in this group-wise comparison because the heterogeneity of dance experience precludes treating them as a single homogenous group (see above). To study how GDT related to different dimensions of dance experience, we correlated GDTs with Total Years of Dance Training and Age Onset of Dance Training, in a dataset that included all participants with dance experience ($n = 25$) but not the controls. We used a nonparametric measure of rank correlation (Spearman correlation).

Results

There were no significant differences between the Controls and Active Dancers with continuous training in age ($t(22.85) = 0.83$, $p = 0.41$), bilateral audiometric averages ($t(21.90) = -0.34$, $p = 0.93$) or total years of musical training ($t(19.39) = -0.83$, $p = 0.42$). Both groups had ~5 years of musical training on average, with a range from 0-10 years for the Controls and 0–13 years for the Active Dancers. For the Active Continuous Dancer group, the mean GDT was 2.21 milliseconds (range 1.59–2.61 ms, $\sigma = 0.27$) and the Control group mean was 2.64 milliseconds (range 1.77–3.55 millisecondss, $\sigma = 0.60$). This represented a statistically significant group difference ($t(11.56) = 2.14$, $p = 0.05$) (Figure 1).

Next, we examined the correlations between GDT and different dimensions of dance training, in a group that included current and former dancers but not the controls ($n = 25$). Here we found that more training was predictive of better temporal resolution (Total Years: rho $= -0.45$, $p = 0.023$). The correlation with Age Onset of training showed a comparatively weaker correlation (Age Onset: rho= 0.35, $p = 0.09$) (Figure 1). The correlation between GDT and Years of Musical Training was not statistically significant (rho $= 0.03$, $p = 0.91$).

Discussion

Much can be learned about perceptual plasticity from studying auditory experts and populations who have undergone rigorous auditory and/or auditory-motor training (Chartrand et al., 2008). Musicians are by far the most well-studied auditory experts but the expertise of other less populous groups has been recognized, though not as extensively studied (e.g., phoneticians, bird watchers,

Figure 1. A. Group mean gap detection threshold for Controls (black) and Active Dancers with continuous training (white bar). Errors bars represent +1 standard error of the mean. *=<0.05. B. Scatter plot for years of dance training and gap detection threshold for Former Dancers (gray circles) and Active Dancers (white circles). C. Scatter plot for age onset of dance training and gap detection threshold for Former Dancers (gray circles) and Active Dancers (white circles).

sound engineers, Morse code operators). In the current investigation, we extended this line of research to novice dancers, a population not colloquially considered sound experts but one with long-term experience interacting with sound in ways paralleling musicians. We found that novice dancers who have trained continuously from an early age had better auditory thresholds compared to untrained controls using a test of gap detection. Among current and former dancers, we found that temporal resolution thresholds correlated with the total years of training. Collectively, this suggests that dance training, like musical training, may hone auditory skills. Our findings, in combination with studies of musicians and other experts, help to elucidate the set of environmental conditions and experiential factors critical to driving auditory plasticity. However, it is not possible to tease apart whether he potential effect of dance training on auditory processing observed here is mainly due to dancers' exposure to and interactions with music while dancing, as opposed to rhythmic movement without music.

This study was motivated by the commonalities between music and dance training. The literature on musicians, therefore, offers a rich source for guiding how the current findings are interpreted and the direction that future studies of dancers could take. For example, in the musician literature, questions have been raised as to whether "advantages" on auditory tasks are due to real differences in sensory discrimination abilities or better procedural learning of auditory tasks. Supporting the latter possibility, Micheyl et al. (2006) reported that when non-musicians are given more exposure to a pitch discrimination task (beyond the typical duration of most studies), their performance improved to the level of musicians (i.e., the musician advantage disappears). The same could hold for dancers: that is, our findings may reflect differences between dancers and controls in their ability to pick up new auditory tasks but not an inherent baseline difference in temporal acuity. Another debate in the musician literature is the scope of "advantages," with questions such as whether music learning transfers to skills not directly trained by music such as speech perception and domain-general executive function. These same questions are germane to dance, and should be explored in future investigations using an expanded test battery that goes beyond gap detection to include other measures of temporal resolution and temporal processing (e.g., temporal sequencing), as well as other dimensions of auditory processing (e.g., pitch perception and speech perception), in order to test whether findings here are specific to temporal resolution or carry over to other auditory processes. A limitation of using gap detection to measure temporal resolution is that intensity resolution confounds performance, and thus lower gap detection thresholds in dancers might be the result of better temporal resolution and/or intensity resolution (Shailer & Moore, 1985), further underscoring the value of an expanded test battery.

Study Limitations and Directions for Future Research

In this preliminary work, we examined dance from a fairly limited view by focusing on young adult women trained in Western styles of dance training where most of the training occurred in a formal setting such as a dance studio or academy. This focus, and the relatively small sample, impose several limitations on the study. First, by focusing on Western dance, findings may not be representative of other styles of dance, such as traditional dances of Africa, that utilize more complex rhythmic timing structures than, for example, ballet, the type of training common to most of the dancers in this study. Second, we recruited an all-female sample because early-life dance training is more common among girls than boys in the United States for reasons most likely tied to gender stereotypes and female-oriented dance studios. Although sex differences and gender differences have not been widely reported for gap detection thresholds, sexual dimorphism is evident in peripheral and central auditory development (McFadden, 1998). This dimorphism could potentially extend to processes related to gap detection and should be investigated more directly in the future. A third limitation is that dance is not the only possible influencing variable. In our target population, multiple socio-economic variables may factor into the decision to enroll and pay for dance lessons that could influence sensory and cognitive development. As a related point, parents who are in a position to support their child's dance lesson may support their child in other ways that could also benefit their child's sensory and cognitive abilities later in life. Connected to this third point, is the fact that we did not exclude participants with musical training. But, only a small number of participants with dance training ($n = 3$) self-reported as current musicians (of which two were vocalists), and, among those with dance training, the average amount of musical training was modest ($\sim$5 years). Collectively, this could explain why a relationship between gap detection thresholds and years of musical training was not observed in this study, but an effect of musicianship has been observed in datasets with more extensive levels of musical training (e.g., Grassi et al., 2017; Mishra et al., 2014).

Another limitation is that our focus on young adults narrowed the variability of auditory processing observed in the sample. For all participants, gap detection thresholds were below four milliseconds, with an overall mean of 2.44 milliseconds. This is in line with the group mean reported by Hoover et al., who tested young adults on a similar adaptive paradigm (Hoover et al., 2015). Hoover et al. (2015) compared gap detection thresholds between a clinical test of temporal resolution called Gaps in Noise (GIN) (Musiek et al., 2005) and an adaptive psychophysical variant. In young adults who completed both tasks, thresholds correlated across tests, but the estimated threshold was, on average, lower for the adaptive procedure compared to GIN (2.99 ms compared to 4.53 ms) (Hoover et al., 2015). The mean threshold for GIN, while higher than the adaptive paradigm, was consistent with the mean GIN threshold for young adults (4.9 ms) reported by Musiek et al. (2005). In clinical settings, thresholds > 7 milliseconds on the GIN are typically considered an indication of a central auditory disorder (Musiek et al., 2005). We extrapolate from these previous studies that gap detection thresholds were clinically normal for all our study participants and that the small group difference (<1 ms) between Controls and Current Dancers with continuous training is unlikely to be clinically meaningful. However, studies comparing experts to healthy controls, have rarely shown large, clinically differences between groups on auditory processing tasks (Boebinger et al., 2015; Strait et al., 2010; Zendel & Alain, 2012), suggesting perhaps that what differentiates normal from expert processing is more subtle than what differentiates normal from impaired processing. An older population is likely to have yielded more inter-individual differences and potentially stronger, clinically significant, effects would emerge. However, the advantage of taking a narrower focus in this preliminary study was that we could control for other confounding variables that were likely to emerge in a sample encompassing broader age and dance styles.

We note that this was not the first study to examine gap detection abilities in dancers, although it was the first to focus specifically on early-trained dancers and to examine dance experience as a gradient (e.g., years of training, age onset). This previous work, did not give clear and consistent findings. Studies of Classical Indian dancers reported no group difference relative to controls on gap detection tasks (Pisharody et al., 2016; Sanju & Tayal, 2018), although one study did show superior performance for dancers on another index of temporal resolution, the temporal modulation transfer function (Pisharody et al., 2016). In a study of ballet dancers, a dance style more comparable to the current work, participants were tested on the GIN, but findings were difficult to interpret due to inconsistencies in the reported group differences (da Silva et al., 2015). For the GIN, each trial consists of 6-second samples of noise that contains gaps that vary in duration between 2–20 milliseconds. On this test, the participant/patient presses a button each time they hear a gap, with the number of gaps ranging from zero to three per segment (Musiek et al., 2005; Paulovicks, 2008). da Silva et al. found that the Ballet dancer group was statistically better at identifying the location of gaps (i.e., had higher hit rates), although, dubiously, the calculated threshold was not different between the two groups (da Silva et al., 2015). A limitation of all of this previous work was that detailed dance histories were not provided in these reports and the analysis was strictly categorical. In combination with the limitations of our study, this suggests that more carefully designed research on larger samples is needed.

Conclusion

In summary, the results from this brief report suggest that early dance experience, like music experience, may influence auditory processing in an experience-dependent fashion. We see dance as fertile ground for continued scientific exploration of topics relating to auditory abilities, including the connection between experience, auditory function, non-auditory behaviors, and sensitive periods in auditory development. While some degree of shared overlap has been predicted between dancers and musicians for auditory behaviors and neurobiological structures and functions (Karpati et al., 2017), dance training is a unique form of training that potentially has its own perceptual and neurobiological signature, distinct from music. For example, the cardiovascular and physical demands of dance may exert their own unique benefits on auditory abilities compared to musicians or other more sedentary performers (Hull & Kerschen, 2010; Krizman et al., 2020; Ozturk et al., 2007).

Appendix A

Dance Training Questionnaire

1. At what age did you first start training as a dancer? ______________________
2. How long (in years) have you been training as a dancer? __________________
3. In what types of dancing have you been trained? Check all that apply.
   a. Jazz
   b. Tap
   c. Ballet
   d. Contemporary/Modern
   e. Pointe

f. Theater
g. Hip Hop/Street
h. Ballroom (identify type)
i. Other (Please list_______________)
4. What is your main style of dance/training? _________________________
5. Where you were primarily trained?
a. Dance studio or academy
b. University/College program
c. Self-taught
d. Recreational or community dance group
e. Other (Please specify:______________)
6. How many hours a week does your training currently consist of? __________
7. How often do you currently perform? __________________________
a. Compete? __________________________
b. Choreograph? __________________________
8. As a dancer, how would you rate your skill level?
a. Beginner
b. Intermediate
c. Advanced
d. Professional

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ORCID iD

Erika Skoe https://orcid.org/0000-0001-7500-5197

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Author Biographies

Erika Skoe: received her PhD from Northwestern University in 2012 and is currently an Associate Professor at the University of Connecticut. She studies inter-individual differences in perception and cognition in listeners with diverse auditory experiences and abilities, with a focus on the underlying biological processes.

Erica Scarpati: received her doctoral degree in Audiology from the University of Connecticut in 2021. She is now a practicing clinical audiologist who specializes in the pediatric population. Her research interests include the study of auditory processing abilities in diverse populations. She is dedicated to applying her knowledge regarding this research to the field of audiology to better help her patients with auditory impairments.

Allison McVeety: received her doctoral degree in Audiology from the University of Connecticut in 2018. Since then, she has been a practicing clinical audiologist at a high-volume ENT practice in Manhattan, New York where she specializes in diagnostics. She has spent most of her life as a dancer, and through this research she has been able to combine her two loves: dancing and audiology.