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Everyday Parameters for Episode-to-Episode Dynamics in the Daily Music of Infancy

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Abstract

Experience-dependent change pervades early human development. Though trajectories of developmental change have been well charted in many domains, the episode-to-episode schedules of experiences on which they are hypothesized to depend have not. Here, we took up this issue in a domain known to be governed in part by early experiences: music. Using a corpus of longform audio recordings, we parameterized the daily schedules of music encountered by 35 infants ages 6–12 months. We discovered that everyday music episodes, as well as the interstices between episodes, typically persisted less than a minute, with most daily schedules also including some very extended episodes and interstices. We also discovered that infants encountered music episodes in a bursty rhythm, rather than a periodic or random rhythm, over the day. These findings join a suite of recent discoveries from everyday vision, motor, and language that expand our imaginations beyond artificial learning schedules and enable theorists to model the history-dependence of developmental process in ways that respect everyday sensory histories. Future theories about how infants build knowledge across multiple episodes can now be parameterized using these insights from infants' everyday lives.

Keywords: Input; Dynamics; Spacing; Burstiness; Music; LENA

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1. Introduction

As learners encounter their world over time, they experience a given activity for some duration, then engage with other people, places, and things, and then move on to another activity that may be reminiscent of past episodes. These temporal rhythms of life can be described by quantifying how long activities persist, the duration of interstices between activities of like kind, and an overall temporal rhythm that is the combination of episode-to-episode clustering and spacing. These parameters offer the “when” in addition to the “what” of encountered episodes.

Ample evidence suggests that “when” matters for “what” is learned from episodes in multiple domains throughout life (Carvalho & Goldstone, 2015; Cepeda, Vul, Rohrer, Wixted, & Pashler, 2008; Schwab & Lew-Williams, 2016; Vlach, Sandhofer, & Kornell, 2008; Yu & Smith, 2012; Yu, Suanda, & Smith, 2019; see also Ebbinghaus, 1913; Hintzman, 1984; Rovee-Collier, 1995; Thiessen & Pavlik, 2013). Yet, despite strong evidence for synergy between the “what” and the “when” of learning, we know very little about parameters of the temporal schedules available to shape learning in real life. Without the everyday “when,” insights about the everyday “what” like frequency distributions of seen objects and heard voices (Clerkin, Hart, Rehg, Yu, & Smith, 2017; Fausey, Jayaraman, & Smith, 2016; Mendoza & Fausey, 2021a) will be of limited value to theories of experience-dependent learning because attention, encoding, retrieval, and integration happen over time. Luckily, extended continuous sampling of everyday environments—capturing schedules in which activities happen, stop happening, then happen again—can now begin to address longstanding calls to incorporate everyday dynamics into theories of learning (Thelen & Smith, 1994). Here, we address this issue in one early and foundational experience-dependent domain: music.

1.1. Toward dynamics theories of musical enculturation

Infants become preferentially sensitive to the musical rhythm and scale structures that they experience in their first postnatal year of life (Hannon & Trainor, 2007; Trainor & Unrau, 2012) and so theories of musical enculturation are theories of experience-dependent learning. Recent evidence has begun to detail what this experience is. Caregivers report that infants encounter live and recorded music (Custodero & Johnson-Green, 2003). Long-form audio recordings of infants’ soundscapes at home have confirmed these reports (Costa-Giomi & Benetti, 2017; Mendoza & Fausey, 2021a) and have also discovered some additional properties of infants’ everyday music. For example, a recent investigation found that infants encounter multiple tunes and voices per day distributed nonuniformly such that some musical identities are much more available than others (Mendoza & Fausey, 2021a). Everyday music episodes thus present opportunities for infants to encounter various pitches, chord sequences, musical rhythms, lyrics, and more. These quantifications emphasize the “what” but leave open many questions about the “when” of infants’ soundscapes. For example, do infants encounter their daily music in a single continuous episode? Or, do infants have opportunities to benefit from temporal proximity as well as temporal distance as they encounter multiple music episodes throughout a day? Discovering the temporal parameters for daily schedules of music in infancy is a next essential step in building theories of musical enculturation grounded in infants' learning opportunities over time.

1.2. Everyday dynamics in infancy

One emerging priority in the science of experience-dependent change is to model the learning opportunities that arise across activity contexts as young learners cumulatively sample the world (Montag, Jones, & Smith, 2018). Music is one activity among many in everyday infancy (Trehub & Degé, 2016) that together may provide overlapping opportunities to build skills. For example, infants encounter words in musical as well as other linguistic episodes, they practice coordinating with social partners during musical and nonmusical episodes, and more. Musical episodes themselves package linguistic, motoric, visual, and social experiences and thus engage multiple complex processes (Pearce & Rohrmeier, 2012; Trainor & Hannon, 2013). The dynamics of musical episodes, therefore, potentially impact how young learners build a wide range of skills. Thus, insights about the episode-to-episode dynamics of this common activity in human infancy will inform theories of musical enculturation and broader theories of building knowledge alike.

1.3. Episode duration

Scott Joplin's *Treemonisha* opera is almost an hour and a half long, the complete album of Andreya Triana's *Giants* takes roughly 46 min from start to finish, and *Country Lass,* a song featured in studies of early musical memory, lasts for about 30 s. Unlike for concertgoers, audiophiles, and lab infants, everyday encounters with music need not respect composed starts and stops (Hawes, 1974). Thus, a first question about temporal schedules of everyday music is the duration of its episodes. Prior results about some kinds of everyday music suggest that many of these episodes may be brief (Mendoza & Fausey, 2021a).

Episode duration is important for theories of experience-dependent learning in part because duration both shapes and reflects attention. For example, brief music episodes that punctuate the everyday hubbub may capture infants' attention, providing a boost to encoding the encountered music's pitches and rhythms (Nakata & Trehub, 2004). In contrast, more extended music episodes may function in concert with related behaviors from responsive social partners to promote sustained attention and learning (Nakata & Trehub, 2004; Yu & Smith, 2016; Yu et al., 2019) and provide opportunities to detect multiple levels of musical structure (Margulis, 2014). Further, encountered episode durations may provide clues about operative mechanisms for learning. An hour of daily music that is distributed across many brief episodes could create frequent opportunities to retrieve prior episodes and this practice could stabilize memories for encountered musical structures (Rovee-Collier, 1999). In contrast, more continuous extended episodes could engage mechanisms that integrate over persistently available input (Hasson, Chen, & Honey, 2015; James, Jones, Smith, & Swain, 2014; Margulis, 2014). Interestingly, recent evidence about everyday sensory histories in several domains suggests that early experiences are a mix of many brief and few extended episodes that together could helpfully engage multiple learning mechanisms (Jayaraman & Smith, 2019; Lee, Cole, Golenia, & Adolph, 2018; Suarez-Rivera, Smith, & Yu, 2019).

1.4. Interstice duration

Any temporal schedule includes episodes and the periods in between those episodes. We refer to these periods as interstices. They provide opportunities for learners to connect prior and subsequent episodes across distinct interstice durations. Toward one extreme, interstices may exceed 24 h if learners do not encounter multiple music episodes per day (e.g., Monday 8 AM to Tuesday 9 AM). Toward another extreme, brief 1-s interstices could separate multiple music episodes throughout a day. Evidence suggests interstice durations shorter than daily (Custodero & Johnson-Green, 2003; Mendoza & Fausey, 2021a) but plausible durations within a day are currently unknown.

Interstice duration is important for theories of experience-dependent learning because interstices create opportunities to forget and then later retrieve encountered input. Extended interstices increase retrieval challenges, sometimes acting as “desirable difficulties” that support learning (Bjork, 1994; Vlach, 2019). For example, young children often show better memory and generalization for words and objects if they encounter them in schedules with extended rather than brief interstices (Childers & Tomasello, 2002; Vlach et al., 2008). Intriguingly, brief interstices between newly encountered episodes may potentiate memories that are tolerant to increasingly extended interstices (Rovee-Collier, 1995). The impact of interstice duration on learning depends on many other aspects of sensory histories including but not limited to prior history of interstice durations (Rovee-Collier, 1995), delays until needing to retrieve encountered input (Cepeda et al., 2008; Vlach, Ankowski, & Sandhofer, 2012), and the learner’s developmental age (Benitez, Zettersten, & Wojcik, 2020), with many open questions about young learners (Vlach, 2019). Interstices involving sleep may engage additional mechanisms (Gómez & Edgin, 2015; Hupbach, Gómez, Bootzin, & Nadel, 2009).

Laboratory studies of early music learning typically implement schedules with interstice durations on the order of seconds and infants learn pitch and musical rhythmic patterns in these studies (Trehub & Degé, 2016). Other evidence also suggests the relevance of longer-term mechanisms for early music learning, such as infants remembering various aspects of a tune played daily when tested days to weeks later (see Saffran, 2003; Trainor & Hannon, 2013, for review). Recent evidence from longform sampling of everyday language suggests the presence of at least some everyday interstices on the order of minutes to hours (Cristia et al., 2021; Tamis-LeMonda, Kuchirko, Luo, Escobar, & Bornstein, 2017). Everyday opportunities to integrate across multiple episodes may be a mix of briefer and extended periods without music, creating multiple routes to retrieval practice over multiple timescales in everyday learning.

1.5. Temporal rhythm

Episodes and interstices do not exist in isolation; together they structure an overall temporal rhythm. An everyday mix of both brief and extended episodes and interstices may give rise to a clustered temporal rhythm. Quantifying temporal rhythm per se provides clues about mechanisms relevant for building knowledge across multiple episodes in everyday life.

Burstiness (B) is a measure of overall temporal rhythm that is an efficient summary of both temporal proximity and distance across multiple episodes (Barabási, 2005; Goh & Barabási, 2008; Kim & Jo, 2016). Burstiness quantifies how episode onsets arise over time, thus highlighting opportunities for switching into the target activity. Broadly, temporal rhythms can be periodic, random, or bursty. Periodic rhythms in which episodes begin "on the hour, every hour" are characterized by identical inter-onset intervals throughout the day (e.g., 1 h between each episode onset). Random rhythms are characterized by a distribution of inter-onset intervals whose mean and standard deviation are similar. Bursty rhythms, in which some episodes are clustered in close temporal proximity with extended lulls between other episodes, are characterized by a distribution of highly heterogeneous inter-onset intervals whose standard deviation exceeds its mean. Interestingly, many human activities show bursty temporal rhythms (Abney, Dale, Louwerse, & Kello, 2018; Karsai, Jo, & Kaski, 2018).

Temporal rhythm is important for theories of experience-dependent learning because it suggests the nature of opportunities to integrate information from related episodes. Periodic rhythms could suggest a role for prediction, as learners come to anticipate regularly occurring input. Random rhythms might instead engage more local attention and learning mechanisms. Bursty rhythms could provide opportunities for learners to build knowledge by harnessing shorter-term (Schwab & Lew-Williams, 2016; Trehub & Degé, 2016) as well as longer-term (Ilari & Polka, 2006; Vlach, 2019) integration. Like other insights about sensory histories sampled outside the laboratory (Smith, Jayaraman, Clerkin, & Yu, 2018), longform sampling of everyday experiences may reveal an overall temporal rhythm comprised of multiple, distinct learning opportunities each more commonly tested in isolation in current laboratory-based protocols.

1.6. Everyday parameters

Theorists make discoveries about the everyday experiences that are available to drive developmental change by sampling instead of scripting experiences (de Barbaro & Fausey, 2022). Quantifying theory-relevant properties of sampled experiences sharpens our understanding about how infants build knowledge across episodes in part by revealing the extent to which parameter-values-as-implemented-in-the-lab match the everyday opportunities that infants really face (see also Hasson, Nastase, & Goldstein, 2020; Nastase, Goldstein, & Hasson, 2020). Sampling everyday life for extended periods of time, in particular, has the potential to dramatically update our insights about these opportunities by revealing structure at timescales traditionally outside of empiricists' toolkits (i.e., one cannot smoosh a 2-h interstice into a 15-min study). Thus, we advance theories of musical enculturation by quantifying everyday dynamics, with implications for infants' opportunities and challenges to build knowledge across multiple episodes.

We parameterize the daily temporal schedules of everyday music in infancy by quantifying episode durations, interstice durations, and temporal rhythms in the Mendoza Music Corpus (Mendoza & Fausey, 2018; 2021a). This corpus consists of 35 longform audio recordings sampled from the at-home everyday lives of infants ages 6- to 12-months-old. This developmental period is sampled in order to make discoveries about the experiences available to drive soundscape-specific enculturation that emerges around the end of the first postnatal year (Hannon & Trainor, 2007). Importantly, this corpus sampled raw audio, in families' homes

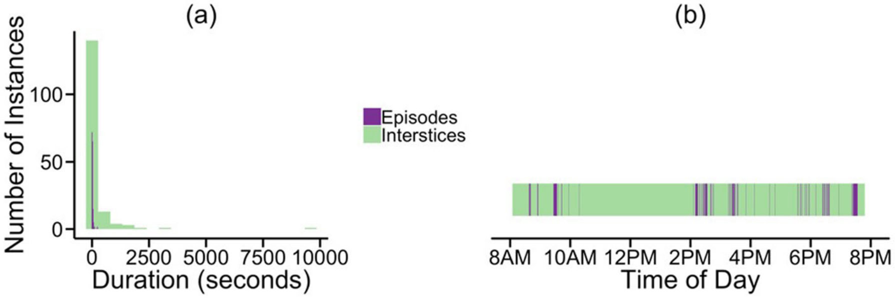

Fig. 1. One day-in-the-life of an infant encountering music episodes. Three thousand nine hundred and forty-one musical seconds distributed across 164 episodes. (a) Histogram of this day's episode (purple) and interstice (green) durations, which are mostly brief together with some extended durations of each. (b) Music episodes and interstices distributed in an overall clustered daily temporal schedule.

without researchers present, and continuously through a full day in order to minimize artificial perturbations of everyday sensory input due to caregiver self-report or excess conscious monitoring. This corpus provides a unique opportunity to discover everyday parameters for the durations of music episodes, the durations of interstices in between episodes, and the overall temporal clustering of music episodes throughout a day (see Fig. 1 for one illustrative day-in-the-life).

2. Method

2.1. Ethics and open science

We analyze the corpus presented in Mendoza and Fausey (2021a). Thus, we repeat key information here. The University of Oregon (USA) approved this research protocol. Caregivers provided informed consent for their family's participation. Most caregivers consented to share their recordings with the research community and these .wav files are available on HomeBank (Fausey & Mendoza, 2018a). Study materials, behavioral coding manuals, numerical data, and analysis code are available on Open Science Framework (Mendoza & Fausey, 2020; henceforth "OSF").

2.2. Participants, materials, and procedure

One audio recording from each of 35 infants (sex assigned at birth: 20 females and 15 males) between the ages of 6 and 12 months ($M = 38.78$ weeks, $SD = 6.66$ weeks) was annotated and analyzed. Infants wore the digital language processor from the Language Environment Analysis system (Ford et al., 2008) for up to 16 h of audio at home. Caregivers were not told about music as an analytic target (see Mendoza & Fausey, 2021a, for additional details).

Approximately 467 h of the everyday sounds of infancy were captured (*Median* = 13.13 h per recording; *Interquartile range [IQR]* = 4.32 h per recording). Musical sounds were

Table 1
Descriptive summaries of music episodes, interstices between episodes, and inter-onset intervals across episodes in the corpus ($N = 4798$ episodes; $N = 4763$ interstices and inter-onset intervals)

	Median duration (s)	Interquartile range duration (s)	Range duration (s)	Proportion shorter than 1 min	Proportion longer than 5 min
Episodes	13	21	2–827	0.88	0.01
Interstices	17	76	1–42,566	0.71	0.12
Inter-onset intervals	48	115.5	3–42,627	0.56	0.13

operationalized as live or recorded singing, instrument playing, and pitched, rhythmic, repetitive patterns that were vocally or instrumentally produced (OSF). Music episodes were operationalized as the uninterrupted, continuous presence of music. Annotators identified music episodes by listening continuously to each recording and upon hearing a musical sound marked the onset of an episode. Annotators marked the offset of an episode when the source of the music stopped producing musical sounds or the musical sounds became too faint or too obscured to be perceived. Thus, everyday music episodes presented infants with opportunities to potentially learn about many musical pitches, musical rhythms, and more. As reported by Mendoza and Fausey (2021a), two independent annotators identified music in each recording and the number of seconds identified as music per each minute of each recording was highly correlated (*Median* $r = .93$, *IQR* $r = .11$). Therefore, one annotation per recording was randomly selected for analysis. Each recording is represented as a timeseries of seconds, some of which are music episodes (*Median* = 3311 music seconds per recording; *IQR* = 3858.50 music seconds per recording).

3. Results

3.1. Everyday parameters: Overview

We present new discoveries about the daily temporal dynamics of music in infants' everyday lives during the second half of their first postnatal year, based on 35 longform audio recordings sampled from this developmental period. We first report the durations of music episodes and the durations of interstices between episodes. We then show that episodes are not distributed randomly or periodically throughout a day, but rather in a bursty rhythm.

3.2. Everyday music episodes are (mostly) shorter than a minute

Fig. 2a shows the durations of everyday music episodes. The distribution of all music episodes in the corpus is nonuniform, with 0.88 of episodes shorter than 1 min and a long tail of episode durations extending to a maximum of 827 s. The median duration of an everyday music episode is 13 s (for additional descriptive statistics, see Table 1). The nonuniform distribution of music episode durations also characterizes music episodes within each daily recording (OSF). We invite readers to listen to everyday music episodes on HomeBank

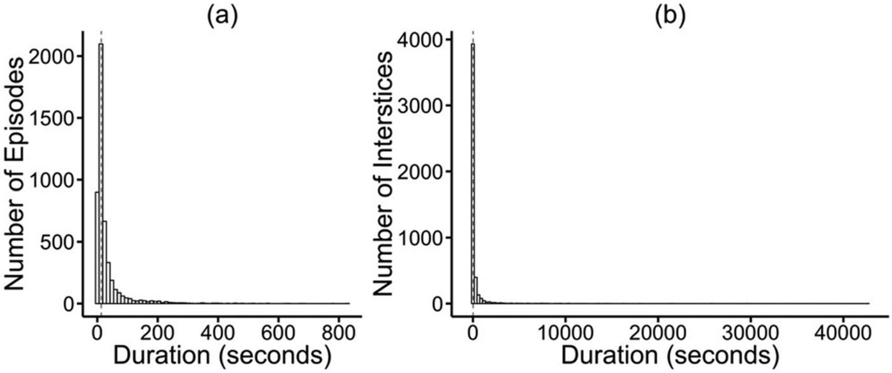

Fig. 2. Durations of everyday music episodes and interstices between music episodes. Histograms of the durations of all (a) music episodes ($N = 4798$) and (b) interstices between music episodes ($N = 4763$) in the corpus. Dashed lines are each distribution's median duration.

(Mendoza & Fausey, 2018; illustrative brief [Clip 629], median [Clip 1027], and extended [Clip 179] episodes).

3.3. *Everyday interstices between music episodes are (mostly) shorter than a minute*

Fig. 2b shows the durations of everyday interstices between music episodes. The distribution of all interstices in the corpus is nonuniform, with 0.71 of interstices shorter than 1 min and a long tail of interstice durations extending to a maximum of 42,566 s. The median duration of an everyday interstice between music episodes is 17 s (Table 1). The nonuniform distribution of interstice durations also characterizes individual daily temporal schedules (OSF). We invite readers to listen to an example of four music episodes interleaved with three interstices on HomeBank (Fausey & Mendoza, 2018b; file G448_001102, 00:54:26 to 00:56:31).

Though the acoustic details of interstices are not the main empirical contribution here (see Discussion), we quantified the proportion of interstice seconds that were silence (0.44), nonmusical sounds (0.51), or due to the recorder being turned off during the day (0.05). Thus, infants encountered everyday music episodes interleaved with a combination of silence and other nonmusical sounds.

Notably, every recording in this corpus had at least one interstice between music episodes at the hourly timescale. As illustrated in Fig. 3b, these extended lulls within a day suggest an overall clustered schedule of everyday music episodes. Such daily clustering can be quantified using the burstiness parameter.

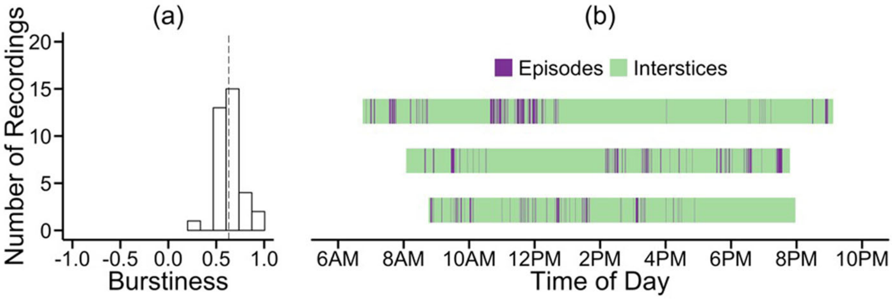

Fig. 3. Bursty rhythms of music episodes over a day. (a) Histogram of the burstiness parameter from each recording in this corpus ($N = 35$). Dashed line depicts median burstiness. (b) Three illustrative daily schedules (top: B = 0.67, middle: B = 0.63, bottom: B = 0.59; episodes in purple and interstices in green).

3.4. *Everyday music episodes are distributed as bursty throughout a day*

Burstiness is a measure that quantifies deviations from randomly organized episodes using the distribution of inter-onset intervals in an overall temporal rhythm. Burstiness considers the onset of each episode, ignoring duration per se, in order to classify temporal rhythms as random, periodic, or bursty (Goh & Barabási, 2008; Kim & Jo, 2016). Random rhythms are characterized by a distribution in which the mean and standard deviation of inter-onset intervals are equal (Burstiness B is closer to 0). Periodic rhythms are characterized by a distribution in which the standard deviation of inter-onset intervals is 0 (Burstiness B closer to –1). Bursty rhythms are characterized by a distribution in which the standard deviation exceeds the mean of the inter-onset intervals (Burstiness B closer to 1).

Formally, we computed burstiness using the following equation that represents the total number of onsets in a schedule in addition to its inter-onset intervals (Kim & Jo, 2016). n represents the total number of onsets and r represents σ/μ of the inter-onset intervals:

$$Burstiness\ (B) = \frac{\sqrt{n-1}r - \sqrt{n-1}}{\left(\sqrt{n+1}-2\right) r + \sqrt{n-1}}$$

Fig. 3a shows that the overall temporal rhythm of everyday music episodes is bursty, with a median Burstiness $B = 0.63$. Fig. 3b shows three illustrative daily schedules with Burstiness B close to this observed median (see OSF for all daily schedules). Interpreted categorically, these daily temporal rhythms are clearly bursty. Interpreted continuously, these temporal rhythms are similar to or exceed the degree of burstiness observed in other human activities (Abney et al., 2018; Altmann, Pierrehumbert, & Motter, 2009; Goh & Barabási, 2008).

3.5. *Supplemental analyses*

A suite of analyses addressed supplemental questions. Briefly, these analyses revealed (1) no correlations of any reported parameters with infants' age, and (2) everyday music episode durations, interstice durations, and daily temporal schedules differ from artificial perturbations of everyday music in which the same total amount of music is distributed randomly throughout a day (OSF).

4. Discussion

Longform audio recordings of infants' everyday lives revealed that the daily temporal schedule of music in infancy includes many brief music episodes and interstices, together with some extended durations of each. This clustered daily schedule suggests that the mechanisms responsible for musical enculturation may exploit opportunities to integrate encountered musical pitches and musical rhythms at multiple timescales. Everyday music episode duration, interstice duration, and overall temporal rhythm parameters can now guide manipulation and modeling efforts designed to advance theories of musical enculturation—and potentially other experience-dependent learning processes that are also distributed over time—that respect the nature of everyday learning opportunities.

4.1. Everyday parameters

Encountering musical episodes over time yields sensitivities to culture-specific pitch and rhythmic patterns (Hannon & Trainor, 2007; see also Gerry, Faux, & Trainor, 2010). Related experience-dependent sensitivities in multiple domains are known to arise from distributional learning mechanisms that operate over multiple episodes (Saffran & Kirkham, 2018; Smith & Yu, 2008). Theorists typically (though not exclusively; see Introduction) test hypotheses about how infants build musical knowledge by instantiating brief episode and interstice durations. Overall temporal rhythms are often undefined (as when music plays continuously, e.g., Saffran, Johnson, Aslin, & Newport, 1999), periodic (e.g., Trehub, Bull, & Thorpe, 1984), or unknown (as in infant-controlled habituation protocols, e.g., Costa-Giomi & Davila, 2014). Though sensible from the perspective of the original hypotheses tested, such theorist-designed schedules diverge from the everyday schedules available to shape infants' musical enculturation over their first year of life.

Indeed, the practice of implementing trial-to-trial schedules at short timescales in order to test mechanistic hypotheses dominates many areas of research and is increasingly recognized as a barrier to insights about mechanisms that operate for everyday learners. Prompts for greater fidelity to properties of everyday time include favoring continuous time instead of "trial" units (Huk, Bonnen, & He, 2018), instantiating slower rates of switching between instances (Duncan & Schlichting, 2018), investigating extended timescale dynamics (Creel, 2019; Halpern & Bartlett, 2010; Naselaris, Allen, & Kay, 2021; Spencer, Perone, & Buss, 2011; Vlach, 2019), and connecting multiple scales of integrating information over time (Hasson et al., 2015; Thelen & Smith, 1994). Sampling extended timescales of everyday life is a foundational step en route to better aligning empirical protocols with everyday temporal realities in part because it affords discoveries about multiple timescales (Mendoza & Fausey, 2021b; Ritwika et al., 2020). The everyday parameters discovered here propel theorists toward testing hypotheses in which learners encounter many opportunities to integrate musical episodes over seconds mixed with some opportunities to integrate over hours.

4.2. Building knowledge across multiple episodes

Encountering a musical episode may prompt retrieval of prior episodes due to feature overlap in singers, tunes, pitches, and/or musical rhythms (Love, Medin, & Gureckis, 2004; Mack, Love, & Preston, 2018; Thiessen & Pavlik, 2013). The hippocampus may play a critical role in this process, including in infants (Ellis et al., 2021; Zeithamova, Dominick, & Preston, 2012; see also Ramsaran, Schlichting, & Frankland, 2019). One illustrative mechanism for building knowledge is thus iterative reactivation. Interestingly, iterative reactivation is partially governed by temporal dynamics. For example, blocked episodes promote strong initial encoding, subsequent reactivation, and integration (Schlichting, Mumford, & Preston, 2015). Novelty-driven differentiation arises for dissimilar episodes that occur within seconds of each other, along with integration of episodes separated by restful states during a day (Duncan & Schlichting, 2018). Over time, the push and pull of integration and differentiation may shape infants' emerging sensitivities to both specific (Cirelli & Trehub, 2018; Creel, 2012) and general (Hannon & Trainor, 2007) musical content. The current results enable testing new hypotheses about iterative reactivation by suggesting everyday parameters for episode-to-episode dynamics.

Theorists could harness technology like Lookit (Scott & Schulz, 2017) or mobile applications (Franchak, 2019) to present musical episodes to infants at scheduled moments during their everyday lives. Or, caregivers could implement schedules at home by activating musical recordings embedded in toys (Mehr, Song, & Spelke, 2016). New hypotheses can also be tested via computational modeling. Interestingly, training regimes that respect the heterogeneity of infants' everyday experiences outperform status quo regimes in several domains, including soccer-playing robots' goals when trained on infants' variable motor paths (Ossmy et al., 2018) and convolutional neural nets' object recognition when trained on toddlers' variable egocentric views (Bambach, Crandall, Smith, & Yu, 2016). The variability in timescales across which infants encounter everyday musical episodes may similarly optimize learning by creating varied pressures on attention, encoding, retrieval, and/or integration. We look forward to discoveries in which models that are sensitive to sequence, order, and/or real time (Carvalho & Goldstone, 2022; Honey, Newman, & Schapiro, 2017; Howard & Kahana, 2002; Mozer & Lindsey, 2017; Smith et al., 2018; Thiessen & Pavlik, 2013) learn from input with parameters inspired by infants' everyday dynamics.

4.3. Toward more expansive everyday parameters

The parameters reported here arose in one sample from a particular place, time, and community. Evidence from multiple domains suggests that opportunities to integrate episodes across multiple timescales will generally characterize infants' everyday dynamics, but this deserves empirical inquiry for everyday music. Encouragingly, related efforts are underway (Benetti & Costa-Giomi, 2019; Yan et al., 2021). Importantly, many details of musical episodes—like their pitches and rhythms—must be specified in order to understand how they matter for infants' learning, memory, and musical enculturation trajectories. These details can be annotated together with details of nonmusical episodes like linguistic exchanges and naps in order to advance theories of experience-dependent change that respect the rich nature of infants' everyday soundscapes (Warlaumont, Sobowale, & Fausey, 2022). We encourage theorists to collectively make progress by annotating the shared everyday recordings (Mendoza & Fausey, 2018; 2021a; 2021b).

Overall, quantitative parameters reported across initial investigations of everyday infancy are broadly consistent with nonuniform temporal and feature distributions. Nonuniform temporal distributions arise for many behaviors, including music as well as other kinds of everyday audio like language (Abney, Warlaumont, Oller, Wallot, & Kello, 2016; 2018; Cristia et al., 2021; Tamis-LeMonda et al., 2017) and crying (de Barbaro et al., 2021). Additionally, nonuniform feature distributions arise not only for musical tunes and voices (Mendoza & Fausey, 2021a) but also for linguistic and visual object distributions (see Introduction). Future research in which multiple modalities are sampled in the same way at the same timescales will help to populate a more fully specified everyday parameter space. Nonuniformity can be a signal of a complex system with many interacting components (Warlaumont et al., 2022). Accumulating evidence sampled from everyday infancy motivates theorists to more closely approximate such nonuniformity when testing hypotheses about how experiences matter for building skills within these complex systems over time.

5. Conclusion

Infants encounter everyday music across a mix of brief and extended episodes, interspersed among a mix of brief and extended interstices, in a clustered daily schedule. These findings join recent discoveries from many domains of everyday infancy that expand our imaginations beyond artificial parameters (Adolph, 2020; Bulgarelli & Bergelson, 2020; Casillas, Brown, & Levinson, 2020; Custode & Tamis-LeMonda, 2020; Herzberg, Fletcher, Schatz, Adolph, & Tamis-LeMonda, 2021; Jayaraman, Fausey, & Smith, 2015; Lee et al., 2018; Mendoza & Fausey, 2021a; Weisleder & Fernald, 2013) and enable theorists to model the history-dependence of developmental process (Smith, Byrge, & Sporns, 2020) in ways that respect everyday sensory histories. Theories about how infants build knowledge across episodes—musical pitch and rhythmic patterns as in musical enculturation, but also linguistic, motor, and emotion regulation skills that are bundled with multimodal musical activities (Trainor & Hannon, 2013)—can now be parameterized using insights from infants' everyday lives.

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