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In the beginning: A brief history of infant music perception

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• **ABSTRACT**

The study of infant music perception began in the 1970s—a time when young infants were considered incapable of holistic processing of auditory sequences. These limitations were reconsidered with the demonstration of infants' configural processing of pitch and timing patterns, which presaged the vibrant field of study that unfolded over subsequent decades. The 1980s revealed the salience of melodic contour for infants as well as adult-like processing of pitch and timing patterns. The 1990s shed new light on intervals and scales, uncovering situations in which infant listeners outperformed their adult counterparts. Scholars in the new millennium have documented a number of factors that influence rhythm perception in infancy, including incidental exposure to music and the experience of movement during music listening. In addition, brain-based measures are shedding light on the musical sensitivities of newborn infants. In sum, the conception of infants vis-à-vis music has changed substantially over the past four decades. Moreover, research in this realm is influencing ongoing debate about the nature and origins of music.

In the beginning: A brief history of infant music perception.

The systematic study of infant music perception began in the 1970s. Before then, some scholars speculated that observations of infants could provide insights into the genesis of music. For example, the renowned musicologist, Curt Sachs (1943), claimed that the babble songs of small children recapitulated the earliest known stages of music. Subsequently, ethnomusicologist Bruno Nettl (1956) described his toddler's invented songs, arguing that they revealed features of "primitive" music such as repetitions of a single phrase, longer note durations at phrase endings, and descending contours.

HIGHLIGHTS OF THE 1970S: MODEST BEGINNINGS

By the 1970s, laboratory-based research with infants was well under way, but research on auditory processing was focused largely on speech perception. The finding of principal interest was that infants perceived stop consonants categorically

(Eimas, Siqueland, Jusczyk, & Vigorito, 1971), just as adults do. Infants also differentiated various consonants and vowels (Trehub, 1973; Trehub & Rabinovitch, 1972), including non-native variants that posed difficulty for adults (Trehub, 1976). The major barrier to the study of music perception in infancy was the prevailing belief that infants were incapable of configural processing of auditory sequences. They were thought to attend to the first sound in a sequence of sounds, rather than engaging in the holistic processing that is characteristic of older listeners. As a result, research on infant audition focused on single syllables or tones.

These presumed limitations were challenged in the late 1970s (Chang & Trehub, 1977a). During a familiarization phase, 5-month-old infants were presented with 15 trials of a 6-tone sequence, with tones selected randomly from the 24 chromatic tones in two octaves. Each infant heard the same pattern across trials, but different infants heard different randomly generated patterns. In a subsequent test phase, half of the infants received an upward or downward transposition (3 semitones) of the familiarization pattern, which maintained the original contour and intervals. For the remaining infants, the original tones were reordered, resulting in alterations of the contour and intervals. To ensure that potential differences in responsiveness between these two groups of infants could not arise from differences in the initial tone, the transposed and reordered versions of a particular pattern began with the same tone.

Using what was then state-of-the art technology (see Figure 1), and the researchers measured heart rate deceleration as an index of infants' attention. Unfortunately, 5-month-olds' cardiac response to the stimuli required approximately 12-13 seconds to unfold and return to baseline, which necessitated long (15-second) inter-trial intervals. Further challenges arose from the need to manually convert the heart-beat tracings on the polygraph to heart rate, specifically, beats per minute for every second of the test session – a process that required several hours for each infant participant.

What emerged was that infants' heart rate response waned or habituated over the course of the familiarization trials, reflecting increasing familiarity with the melody. The most remarkable finding, however, was that infants showed renewed responding to the reordered pattern, with its contrasting melodic contour, but not to the transposed pattern whose contour remained unchanged. The implication is that infants considered the transposed pattern equivalent to the original, just as adults do. This demonstration of perceptual constancy for melodies in the context of transposition provided unequivocal evidence of infants' configural processing of auditory patterns. The evidence was consistent with infants' perception of shape constancy for solid objects (Day & McKenzie, 1973), which involved simultaneously rather than sequentially presented elements.

This seemingly impressive evidence of melodic processing was a blip on the radar at a time when speech perception was a central theme in psychology and music perception was a peripheral concern. Nevertheless, evidence of configural processing in the temporal domain emerged shortly thereafter. Infants succeeded in distinguishing

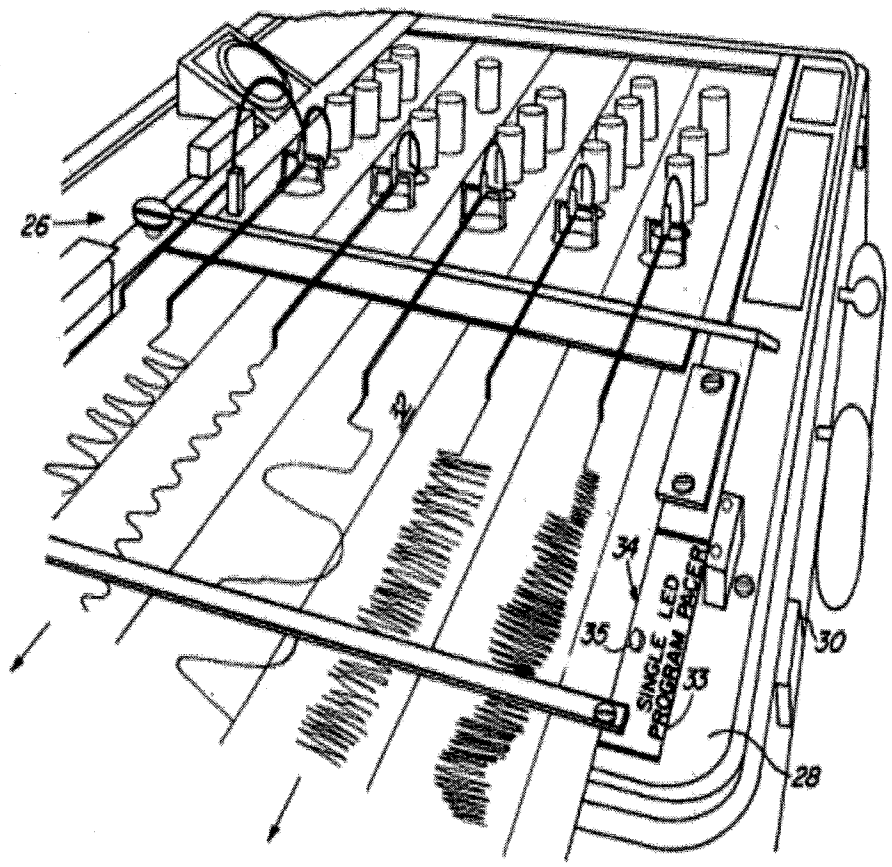

Figure 1.
Image of polygraph used for recording and displaying infant cardiac activity.

one grouping of sounds from a contrasting grouping or rhythm (Chang & Trehub, 1977b; Demany, McKenzie, & Vurpillot, 1977).

Highlights of the 1980s: The great leap forward

Two seminal books, *The Musical Mind* (Sloboda, 1985), and *Music Cognition* (Dowling & Harwood, 1986), helped propel music into the mainstream of cognitive inquiry. Perhaps even more critical for advancing the study of music perception in infancy was the appearance of personal computers in the early 1980s (see Figure 2). Although the primitive devices in question had substantially less memory than current calculators, cell phones, or electronic toys, they could be programmed to control equipment such as tone generators and to tabulate responses. New test procedures were developed to capitalize on these possibilities and circumvent the

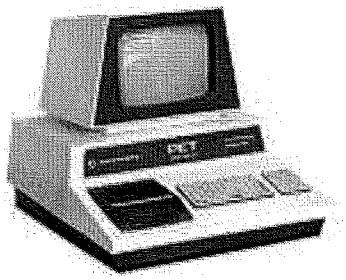

Figure 2.
Early personal computers in laboratory research.

challenges of earlier technology. One procedure that proved fruitful in the early years involved training infants to turn toward the sound source whenever they heard a change in a repeating sound pattern (Trehub, Bull, & Thorpe, 1984).

Pitch processing

Empirical research on music perception in the 1980s was still dominated by studies of musically trained adults (*e.g.*, Butler & Brown, 1984; Edworthy, 1985), but research on naïve listeners, including infants, began to appear with increasing regularity. It became apparent that the pitch contours of musical patterns were highly salient for infants, as were the pitch contours of speech (Fernald, 1991). For example, infants tended to confuse transpositions of a melody with alterations that preserved the contour of the original melody (Trehub *et al.*, 1984), which mirrored earlier findings with adult listeners (Dowling & Fujitani, 1971). Moreover, infants could discriminate contour changes in brief melodies (Trehub, Thorpe, & Morrongiello, 1987) even when the changes were limited to a single tone (Trehub, Thorpe, & Morrongiello, 1985).

At times, infants succeeded in detecting interval changes, and the contexts in which they did so were instructive. When the inter-stimulus intervals were brief and the standard and comparison melodies were presented in the same key, infants were capable of noticing a one-semitone change within a melody (Trehub, Cohen, Thorpe, & Morrongiello, 1986). Correct responses in such cases could have been based on the presence of a novel pitch rather than the altered pitch relations. In further research, the standard and comparison melodies were transposed so that the detection of changes required relative pitch processing. What emerged was that infants' performance depended upon the structure of the melodic context. For example, infants could detect interval changes in the context of diatonic melodies but not in the context of non-diatonic melodies (Cohen, Thorpe, & Trehub, 1987; Trainor & Trehub, 1992, 1993b; Trehub, Thorpe, & Trainor, 1990), which was consistent with the available adult data (Dowling, 1978). Undoubtedly, culture-specific exposure affects interval perception, but the findings from infants raised the possibility that some melodic structures are inherently easier to encode than others.

Temporal processing

New perspectives also emerged on temporal grouping. Not only could infant group tones on the basis of proximity, or patterns of relative duration (Chang & Trehub, 1977b; Demany *et al.*, 1977). They also grouped tones on the basis of their frequency, intensity, or harmonic structure (Thorpe & Trehub, 1989; Thorpe, Trehub, Morrongiello, & Bull, 1988). For example, when infants heard an isochronous (equally timed) six-tone pattern consisting of three identical tones followed by three tones contrasting from the first three in frequency, intensity, or harmonic structure (XXXOOO), they perceived the pattern as two groups of tones separated by a pause (XXX OOO) (Thorpe & Trehub, 1989). Infants were also capable of categorizing tone sequences on the basis of their rhythm, even in the context of changing pitch and tempo (Trehub & Thorpe, 1989). In short, infants' perception of timing, like their perception of pitch patterning, was broadly similar to that of adults.

Highlights of the 1990s: Infants outperforming adults

The 1990s brought clear signs that infant music perception was gaining scholarly credibility. Edited books on music cognition began to include chapters on infant music processing (Deliège & Sloboda, 1996, 1997; McAdams & Bigand, 1993; Tighe & Dowling, 1993), as did edited volumes on child development (Enns, 1990) and comparative perception (Berkley & Stebbins, 1990).

Pitch processing

A surprising finding was infants' detection of some interval changes and tuning changes that adults failed to detect (Trainor & Trehub, 1992; Trehub, Schellenberg, & Kamenetsky, 1999). For example, infants detected tuning changes in the context of invented scales with unequal pitch steps, but adults detected such changes only in the context of familiar scales (Trehub *et al.*, 1999). Infants' ignorance of the conventions of Western music was advantageous in this instance because culture-specific knowledge interfered with adults' processing of atypically structured music.

At times, culture-specific knowledge interfered with the perception of prototypical melodies. In one study, adults readily detected a non-diatonic change in a tonal melody, but they failed to detect a diatonic change that preserved the implied harmony (Trainor & Trehub, 1992). By contrast, 8-month-old infants detected the diatonic and non-diatonic changes equally well, which implies that their performance was not influenced by culture-specific exposure. In fact, implicit knowledge of such conventions is acquired over a relatively protracted period, with sensitivity to key membership being evident by 5 years of age and sensitivity to implied harmony by 7 years of age (Trainor & Trehub, 1994).

Another interesting revelation was that intervals were not equally perceptible or memorable for infants. Some intervals, like the perfect fourth (5 semitones) and perfect

fifth (7 semitones), were encoded more accurately than the 6-semitone interval, or tritone (Schellenberg & Trehub, 1996; Trainor, 1997). Moreover, consonance contributed more to the perceived similarity of harmonic intervals than did interval size, both for infant and adult listeners (Schellenberg & Trainor, 1996). Infants also detected interval changes in melodies more readily when the melodies to be compared were in musically related keys rather than unrelated keys (Trainor & Trehub, 1993a). Not only did infants exhibit processing advantages for consonant melodic and harmonic intervals. They also showed *preferences* for consonant music (Trainor & Heinmiller, 1998; Zentner & Kagan, 1996). Moreover, it became apparent that infants could categorize musical motifs (Mélen & Wachsmann, 2001).

Singing to infants

The study of singing to infants also gained momentum in the 1990s. Parents throughout the world sing in the course of caring for their infants (Trehub & Trainor, 1998), and their singing is marked by higher pitch level (relative to the singer's usual pitch level), slower tempo, and intimate voice quality (Trainor, Clark, Huntley, & Adams, 1997; Trehub, Unyk, & Trainor, 1993a; Trehub *et al.*, 1997). Adults readily distinguish infant-directed from non-infant-directed versions of songs regardless of the musical or cultural background of singer and listener (Trehub, Unyk, & Trainor, 1993b, Trehub *et al.*, 1997). Infants exhibit clear preferences for the infant-directed versions in the newborn period and thereafter (Masataka, 1999; Trainor, 1996).

Although play songs are the songs of choice for most North American and Western European parents, lullabies are ubiquitous elsewhere (Trehub & Trainor, 1998). In most cultures, lullabies are used to maintain infant contentment and induce sleep. Naïve adults readily distinguish foreign lullabies from non-lullabies even when the songs are matched on tempo and culture of origin (Trehub, Unyk, & Trainor, 1993a). Potential cues to the identity of lullabies include their simple pitch structures, repetitiveness, and falling pitch contours (Unyk, Trehub, Trainor, & Schellenberg, 1992).

Highlights of the new millennium

Pitch processing

Infants' short-term memory for music has been evident for some years, but recent evidence has confirmed their long-term memory for music. After 2 weeks of brief daily exposure to Mozart sonatas and a further 2 weeks without hearing the material, infants prefer novel Mozart sonatas to the familiarized sonatas (Saffran, Loman, & Robertson, 2000). Similarly, a single week of exposure to synthesized folk melodies reveals comparable evidence of long-term memory (Trainor, Wu, & Chang, 2004).

Although infants recognize the familiarized melodies in transposition, they do not seem to remember the original pitch level, which implies that infants retain information about relative but not absolute pitch details (Plantinga & Trainor, 2005). Subsequent research with expressively sung lullabies has revealed otherwise. In such circumstances, infants remember absolute aspects of the performance, including its original pitch level (Volkova, Trehub, & Schellenberg, 2006). Perhaps not surprisingly, the nature of the music – its relevance to infants and its expressiveness – influences the information retained.

Just as infants prefer higher- to lower-pitch versions of speech (Fernald, 1991), they were presumed to prefer higher- to lower-pitched versions of the same song by the same singer (Trainor & Zacharias, 1998). What emerged recently, however, was that infants' preferences are context-dependent. They prefer higher-pitched versions of play songs but lower-pitched versions of lullabies (Tsang & Conrad, 2010).

Temporal processing

In the past, research on temporal processing took a back seat to research on pitch processing, but the situation has been changing in recent years. It has become clear that the temporal features of music are critical for infant listeners. For example, the temporal regularity of a melody enhances infants' encoding and retention of its pitch and timing details (Bergeson & Trehub, 2006; Trehub & Hannon, 2009). Moreover, infants categorize rhythmic patterns on the basis of their metrical structure (Hannon & Johnson, 2005).

Remarkably, infants outperform their adult counterparts in some temporal processing contexts, just as they do in some pitch processing contexts. For example, Western 6-month-old infants detect subtle timing changes in of simple or complex metrical patterns, but adults do so only for simple metrical patterns that are characteristic of Western music (Hannon & Trehub, 2005a). By 12 months of age, Western infants detect changes in simple metrical patterns but not in complex metrical patterns (Hannon & Trehub, 2005b), presumably because of their familiarity with the timing regularities in Western music. After limited at-home exposure to foreign music with complex metrical structure (5-10 minutes daily for 2 weeks), 12-month-olds succeed in detecting subtle timing changes in complex metrical patterns, but comparable exposure is ineffectual for Western adults. In short, 6-month-olds perceive foreign metrical patterns more accurately than their adult counterparts, and 12-month-olds learn about foreign metrical patterns more rapidly than adults do.

Although Western 6-month-olds *perceive* simple and complex metrical patterns with equal ease (Hannon & Trehub, 2005a), they *prefer* simple to complex metrical patterns (Soley & Hannon, 2010). Unlike Western music, which is dominated by simple metrical structures, Turkish music has complex as well as simple metrical structures. Interestingly, Turkish infants do not show the simple-metre preference of their Western counterparts, presumably because of their exposure to both metrical

structures (Soley & Hannon, 2010). Rhythmic acculturation in infancy seems to be accelerated by systematic exposure to music, as in a formal parent-infant program (Gerry, Faux, & Trainor, 2010).

Arguably, the most dramatic finding of the decade was the demonstration that movement affected infants' encoding of rhythm (Phillips-Silver & Trainor, 2005). While 7-month-old infants listened to a drumming pattern that was rhythmically ambiguous (*i.e.*, no accented beats), they were bounced on every second beat or on every third beat. Subsequently, they were given a preferential listening test that included the drumming pattern in duple metre (*i.e.*, accents on every second beat) or in triple metre (accents on every third beat). Infants who had been bounced on every second beat listened longer to the pattern in duple metre than in triple metre. Those who had been bounced on every third beat listened longer to the pattern in triple metre. Comparable influences of movement on rhythm perception are evident in adults (Phillips-Silver & Trainor, 2007). Moreover, galvanic stimulation of the vestibular system, which generates the sensation of movement without actual movement, has similar perceptual consequences (Trainor, Gao, Lei, Lethovaara, & Harris, 2009).

Anecdotal reports of infants moving to music are common, but there has been little systematic documentation of this phenomenon. A recent report provides definitive evidence that 6- to 18-month-old infants move rhythmically to music but not to speech (Zentner & Eerola, 2010). Such movement is not synchronized with the music, but the movement is more rapid for faster musical tempi.

Singing to infants continues unabated

The proliferation of musical toys and recorded music in urban households has generated concerns about a decline in parental singing and other interactive musical activities for infants (Baker & Mackinlay, 2006). Evidence from large-scale surveys in North America and the United Kingdom suggests otherwise (Custodero, Britto, & Brooks-Gunn, 2003; Ilari, 2005; Young, 2008). If anything, parent-infant musical activities have been on the rise in recent years, perhaps because of the false but seductive claims that music transforms garden-variety infants into budding geniuses. Even parents who expose their infants to commercial CDs or DVDs (including the infamous *Baby Mozart* ™) are doing so in addition to, not instead of, live singing, which remains the most common musical activity for infants.

Parents generate highly stable performances of each song (*e.g.*, nearly identical pitch level and tempo) from one occasion to another (Bergeson & Trehub, 2002), and they use synchronous, multimodal means of highlighting its temporal structure (Longhi, 2009). Such singing modulates the arousal level of infants (Shenfield, Trehub, & Nakata, 2003), and it is more effective in maintaining infants' attention than is parental speech to infants (Nakata & Trehub, 2004). Mothers talk to infants much more than they sing to them. It is interesting, then, that their infant-directed

speech features individually unique tunes or interval sequences. (Bergeson & Trehub, 2007).

The neural revolution

A description of the current decade would be incomplete without considering the so-called neural revolution, which played a minor role in infant music perception until very recently. Neural responses, which can be recorded during sleep, provide potential access to the music processing capabilities of young infants, including newborns, for whom behavioural responses are often inaccessible or unreliable.

Recordings of event-related potentials in newborns have revealed a number of dramatic findings. When exposed repeatedly to ascending two-tone patterns that vary in absolute pitch and in interval size, newborns show discernible responses to descending intervals (Carral *et al.*, 2005). They also perceive the invariance of pitch across changes in timbre (Háden *et al.*, 2008)—a task that is often difficult for adults. Moreover, newborns detect the invariance of pitch intervals across changes in absolute pitch (Stefanics *et al.*, 2009). Evidence of relative pitch processing in the neonatal period should dispel the oft-repeated claim that absolute pitch processing has priority in infancy and early childhood (Saffran, 2003; Takeuchi & Hulse, 1993). Finally, there are claims that newborns perceive the beat or pulse of an auditory pattern, as reflected in changes in brain activity in response to violations of the beat structure (Winkler, Háden, Ladinig, Sziller, & Honing, 2009).

Coda

Research on infant music perception over the past four decades has changed the conception of infants from passive and ineffectual music listeners to active listeners and adept learners. Infants' ease of processing universal or near-universal aspects of music seems to be complemented by a special-typical motivation for music and a keen sensitivity to the distributional properties of music in their environment (Hannon & Trainor, 2007; Trehub & Hannon, 2006).

Research in this realm has also influenced discussions of the origins of music, for example, the possibility that music in some form preceded language (Mithen, 2005) or that caregivers' melodious vocalizations predated and presaged linguistic communication (Falk, 2009). Early exposure to music in the context of mother-infant interaction may contribute to its life-long role as an emotional regulator and facilitator of social connections (Trehub, Hannon, & Schachner, 2010).

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• En el Principio: Breve historia de la percepción musical infantil.

El estudio de la percepción musical infantil se inició en la década de 1970 - época en que se consideraba que los niños pequeños eran incapaces de un procesamiento holístico de secuencias auditivas. Estas limitaciones fueron reconsideradas con la demostración del proceso configuracional en los infantes, del tono (*pitch*) y patrones temporales, lo cual presagió el advenimiento del dinámico campo de estudio que se desarrollaría durante las décadas posteriores. La década de 1980 puso de manifiesto la relevancia de contorno melódico tanto para los niños como para los adultos en cuanto al procesamiento del tono y los patrones temporales. La década de 1990 arrojó nueva luz sobre intervalos y escalas, descubriendo situaciones en las que los oyentes infantiles superaron a sus homólogos adultos. Los estudiosos en el nuevo milenio han documentado una serie de factores que influyen en la percepción del ritmo en la infancia, incluyendo la exposición incidental a la música y la experiencia del movimiento mientras se escucha música. Además, las observaciones basadas en el cerebro están arrojando luz sobre las sensibilidades musicales de los recién nacidos. En suma, la concepción de las relaciones entre infantes y música ha cambiado sustancialmente en las últimas cuatro décadas. Por otra parte, la investigación en este campo está influyendo en el debate en curso acerca de la naturaleza y los orígenes de la música.

• Al principio: Una breve storia della percezione musicale nell'infanzia

Lo studio della percezione musicale nell'infanzia è cominciato negli anni '70 – un periodo in cui i bambini erano considerati incapaci di percepire olisticamente sequenze acustiche. Questi limiti sono stati riconsiderati sulla base della dimostrazione del processamento configurale da parte dei bambini dei "pattern" tonali e temporali, che ha preceduto il vibrante campo di studi che ne è seguito nelle decadi successive. Gli anni '80 hanno rivelato la salienza del contorno melodico per i bambini cosí come il processamento comparabile a quello adulto dei pattern tonali e temporali. Gli anni '90 hanno fatto luce sugli intervalli e le scale, svelando situazioni in cui gli ascoltatori bambini hanno eseguito i compiti meglio degli adulti. Gli scolari del nuovo millennio hanno documentato un numero di fattori che influenzano la percezione del ritmo nell'infanzia, incluso l'esposizione incidentale alla musica e l'esperienza del movimento durante l'ascolto musicale. Inoltre, misurazioni neurologiche hanno fatto luce sulle sensibilità musicali dei neonati. Per concludere, la concezione della musica nei bambini e neonati è cambiata sostanzialmente nelle ultime quattro decadi. Inoltre, la ricerca in questo campo sta influenzando il dibattito sulla natura e le origini della musica.

• Au commencement : Une histoire brève de la perception musicale infantile

Cette étude de la perception musicale infantile commença dans les années 70, à une époque où les enfants de bas âge étaient tenus comme incapables de

traitement holistique de séquences auditives. Ces limitations ont été remises en cause par la démonstration de l'existence chez l'enfant de traitement configural de motifs de hauteurs et de durées, ce qui ouvra la voie à un nouveau champ d'étude particulièrement dynamique, qui s'est développé au cours des décennies suivantes. Les années 80 ont révélé l'importance des contours mélodiques dans le traitement, par les enfants aussi bien que par les adultes, des motifs de hauteurs et de durées. Durant les années 90, durant lesquelles les notions d'intervalles et d'échelles ont été particulièrement traitées, on a mis en évidence pour certaines tâches des situations de possible supériorité des auditeurs enfants par rapport aux groupes d'adultes. Au cours du nouveau millénaire, ont été documentés un certain nombre de facteurs influençant la perception rythmique chez l'enfant, incluant l'exposition fortuite à la musique et l'expérience du mouvement durant l'écoute musicale. De plus, l'imagerie cérébrale dévoile certaines formes de sensibilité musicale chez les nouveaux-nés. Ainsi durant les quatre dernières décennies, notre conception du rapport entre enfants et musique a sensiblement changé. En outre, les études dans ce domaine influent sur le débat concernant la nature et les origines de la musique.

Die Anfänge: Eine kurze Geschichte der Musikwahrnehmungsforschung bei Kleinkindern

Die Erforschung der Musikwahrnehmung von Kleinkindern begann in den 1970er Jahren – einer Zeit, in der man Kleinkinder für unfähig hielt, Klangfolgen ganzheitlich zu verarbeiten. Mit dem Nachweis, dass Kleinkinder Tonhöhen- und Zeitverläufe tatsächlich konfigural (gestalthaft) verarbeiten können, wurden diese Einschränkungen überdacht. Dieser Nachweis ließ ein lebhaftes Forschungsfeld entstehen, das sich über die folgenden Jahrzehnte ausbreitete. Die Forschung der 1980er Jahre enthüllte die Auffälligkeit der melodischen Konturwahrnehmung bei Kleinkindern sowie die Verarbeitung von Tonhöhen- und Zeitverläufen, die derjenigen von Erwachsenen ähnelt. Die 1990er Jahre brachten neue Erkenntnisse in Bezug auf die Verarbeitung von Intervallen und Tonleitern, indem sogar Situationen identifiziert werden konnten, in denen die kleinkindlichen Hörer die Erwachsenen übertrafen. Wissenschaftler wiesen nach 2000 eine Reihe von Faktoren nach, welche die Rhythmuswahrnehmung im Kleinkindalter beeinflussen. Dabei wurde sowohl das beiläufige Hören als auch die Bewegungserfahrung während des Musikhörens einbezogen. Darüber hinaus brachten neurowissenschaftliche Messverfahren Erkenntnisse über die musikalischen Empfindungen von Säuglingen. Zusammenfassend kann gesagt werden, dass sich die wissenschaftlichen Vorstellungen im Hinblick auf Kleinkinder und Musik in den letzten vierzig Jahren erheblich verändert haben. Darüber hinaus beeinflusst diese Forschung heute die anhaltende Debatte über die Natur und die Herkunft der Musik.