TIMING IN CHILD DEVELOPMENT

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Abstract

This study investigated the metronome and musical timing of 585 four- to eleven-year-olds in Effingham, Illinois. A computer system measured *metronome timing* by counting the number of milliseconds that responses differed from a steady beat not embedded in music. Raters measured *musical timing* from videotaped responses to the steady beat embedded in instrumental music. Both measures were internally consistent. They were correlated .5 with each other, suggesting that they measure different aspects of timing. Metronome timing was correlated up to .3 with achievement scores and placements in special educational programs, more strongly than was musical timing. Girls had significantly better musical timing, but not metronome timing, than boys. Both measures were correlated .4 to .5 with age and had statistically significant correlations up to .3 with handedness, attentiveness, coordination, dance and instrumental classes, and socioeconomic background.

TIMING IN CHILD DEVELOPMENT

A child's timing — ability to feel and express steady beat — is fundamental to both movement and music, affecting sports skills and musical performance, as well as speech-flow and performance of timed motor tasks. In addition, children's timing has been found to be positively related to children's overall school achievement, as well as mathematics and reading achievement (Weikart, Schweinhart, & Larner, 1987); self-control; and gross-motor skills (Kiger, 1994; Mitchell, 1994; Peterlin, 1991; Weikart et al., 1987). Many children enter elementary school lacking the ability to identify and express a steady beat. One study revealed that fewer than 10% of kindergarten children could independently feel and express the steady beat of recorded music (Wright & Schweinhart, 1994). Fewer than 15% of first graders tested had this ability (Mitchell, 1994). Fewer than 50% of the children in grades 4 through 6 could walk to the steady beat of a musical selection (Kiger, 1994).

Timing studies have examined children's personal tempo and its relationships to age, handedness, gender, and school achievement. Children's personal tempo improves with age (Ellis, 1992; Jersild & Bienstock, 1935; Osburn, 1981; Petzold, 1966). There is little evidence that children's personal tempo is related to handedness (Grieshaber, (1987), nor does it appear to be related to gender (Petzold, 1966; Walter, 1983). Children's personal tempo has been found to be correlated with achievement test scores of children in grades 1 and 2 (Weikart et al., 1987); gross-motor skills and reading group levels of children in grades 1, 3, and 5 (Kiger, 1994); and the language and mathematics performance of children in grade 1 (Mitchell, 1994).

The study reported herein was designed to assess the internal characteristics, reliability and concurrent validity of two measures of the timing of children — **metronome timing**, assessed by computer counts of the number of milliseconds that responses differed from a steady beat not embedded in music; and **musical timing**, assessed by ratings of videotaped responses to the steady beat embedded in instrumental music. Of particular interest were the relationships that these measures had with age and measures of school achievement.

Method

In this study, the Interactive Metronome™ measured metronome timing, and the High/Scope Beat Competence Analysis Test measured musical timing. The validity of these two measures was assessed using data from parent questionnaires (with variables such as child's gender, handedness, and age; and family configuration, parental educational status, household income, child's dance and instrument training); teacher questionnaires (with variables such as child's participation in various school-based programs), kindergarten-teacher child achievement reports, and California Achievement Tests for grades 1 through 4. The study participants were 585 children aged 4 through 11 years old in Effingham, Illinois.

The Interactive Metronome™

Synaptec, LLC, of Grand Rapids Michigan, has developed and patented the Interactive Metronome™, a computer program and input devices that quickly and precisely measure a person's metronome timing, that is, ability to match a movement to the steady beat of a metronome. The standard package has two motion-sensing triggers that are plugged into a personal computer's parallel port. One is strapped to a person's hand or foot and signals the computer program when the person claps or pats a hand or steps with a foot. The other is in a floor pad on which a person taps.

The Interactive Metronome™ produces a recurring beep which can be set at any tempo, that is, number of beats per minute. When using the metronome, the objective is to move the triggered hand or foot at the same tempo as that of the metronome, patting or tapping at the exact moment of the beep. The attached trigger signals the metronome program immediately, and the program registers the time between the metronome beep and the person's action, to the nearest millisecond. A person's timing score is the difference in milliseconds between the moment of the beep and the moment of the person's tap. The computer program averages these scores across the many tapping events involved. In the current study, a child's timing score was the average time in milliseconds between each of the 34 metronome beeps and the child's response to each by tapping the triggered hand or foot. A high timing score indicates a larger average number of milliseconds between the metronome beeps and a child's movements, hence, less accurate timing. The lower the timing score, the better the timing.

In this study, children completed seven movements paced by the metronome beeps—patting knees with both hands, clapping hands together, patting knees with alternating hands (triggered hand on each beep), patting knee with preferred hand, patting knee with nonpreferred hand, toe-tapping pad with alternating feet (triggered foot on each beep), and walking in place (triggered foot on each beep). These movements were modified from the High/Scope Beat Competence Analysis Test (Weikart, 1987) for use with the Interactive Metronome™. Children received a score for each of the seven items, the score representing their average timing over 34 beeps per item.

The High/Scope Beat Competence Analysis Test

A version of the High/Scope Beat Competence Analysis Test (Weikart, 1987), using the seven movements listed above, was used in this study to assess beat competence by observing an individual's performance of a series of seven movements to the steady beat of music. Although two pieces of recorded instrumental music of different tempos are generally used, only one piece of recorded instrumental music was used in this study, to allow time for the child's participation in the other assessment activities.

In this study, children performed the same seven movements used to assess metronome timing to the steady beat of a recorded musical selection. Of course, they did not have to use the several motion-sensing triggers. Their performance was videotaped and subsequently scored by eight trained raters. A rater gave each child a score of 1 through 5 on each of these items, the score representing the rater's assessment of each child's ability to identify and match the steady beat over a series of 36 beats. Raters characterized children's musical timing as follows:

1. Accurate and consistent, all but 0 to 3 beats matched
2. Fairly accurate and consistent; 24 beats matched
3. Sometimes accurate and consistent; 16 beats matched
4. Steady and even, but off the beat; 8 to 12 beats matched, 4 at a time
5. Uneven and off the beat; no beats matched

Several studies using the High/Scope Beat Competence Analysis Test provide evidence of the instrument's psychometric properties. Weikart et al. (1987) found the instrument to have alpha coefficients of internal consistency ranging from .70 to .79. The concurrent validity of the instrument was shown by its statistically significant, positive correlations with the Test of Gross-Motor Ability (Kiger, 1994) and school achievement (Kiger, 1994; Weikart et al., 1987).

Study Participants

This study was conducted in Effingham, Illinois, a city of about 12,500 people (Greater Effingham Chamber of Commerce and Industry, 1997). Children in preschool through grade four at three elementary schools and the early learning center of the Effingham school district participated in this study. Of the 609 children who returned signed permission forms, 605 were tested, 585 produced usable data on metronome timing, and 523 produced usable data on musical timing.

The percentages of children in the sample diminished steadily by grade, with 26% of the sample in preschool and 10% in grade 4. The children ranged from 4 years old up to 11 years old. Of the 585 children in the sample, 571 (98%) were Caucasian, 6 (1%) were Hispanic, 4 (1%) were Black, and 4 (1%) were Asian. Of 576 children for whom parents or guardians reported family configuration, 477 (83%) were in two-parent homes, including 30 (5%) living with either a stepfather or stepmother; 89 (15%) lived with their mother only, 6 (1%) lived with their father only, and 4 (1%) lived with other relatives. Of 1,056 parents and guardians reporting, 920 (87%) had at least a high school diploma — 525 (50%) had only a high school diploma, 170 (16%) had an associate's degree, 152 (14%) had a bachelor's degree, and 73 (7%) had a graduate degree. For the 537 families reporting, the median household income was $30,000 - $39,999. Of the 576 children, 85 (15%) received free lunches (available to those with annual incomes up to 130% of the federal poverty guidelines — $17,329 for a family of three in FY 1998).

Of the 585 children with parental reports, 77 (13%) had dance training and 45 (8%) had instrumental music training. These classes were almost certainly extracurricular, because the Effingham school district did not offer dance or

instrumental music classes until fifth grade. Various school-based programs were available to children in grades 1 through 4. Of the 312 children in these grades, the following numbers and percentages were or had been in such classes: 33 (11%) in gifted and talented classes; 43 (7%) in the district's Title 1 Reading Recovery program; 36 (12%) in speech and language programs; 15 (5%) in classes for children with learning disabilities; 5(2%) in classes for children with educable mental handicaps. One child was treated for trainable mental handicap, two were visually impaired, one was hearing impaired, and one was behavior disabled.

Results

This section examines the internal structure and reliability of metronome and musical timing and their relationship to each other. Next it looks at their correlations with children's various characteristics, with special attention to age and school achievement.

Metronome and Musical Timing

Table 1 lists children's average scores on each item. Of the children tested, the metronome timing assessment and qualitative information were complete for 585 children — 316 boys and 269 girls. The table presents the items in order of their increasing difficulty. This order differs from the originally hypothesized order in two ways: (a) patting knees with alternating hands was easier than patting a knee with either the preferred or the nonpreferred hand; and (b) of the two locomotor items, tapping toe and stepping back was easier than walking in place. Children's timing scores were the sums of their scores from the seven items divided by the number of items completed. The 7-item metronome timing scale had a very respectable internal consistency, with an alpha coefficient of .889.

Table 1: Metronome Timing Items

Item	*n*	Mean	SD	Minimum	Maximum
2. Patting knees with both hands	585	145.7	98.8	17.0	514.4
3. Clapping hands together	585	153.9	107.8	21.0	517.0
4. Patting knees with alternating hands	585	161.4	97.5	24.4	396.4
5. Patting knee with preferred hand	585	166.8	108.0	18.0	501.9
6. Patting knee with nonpreferred hand	585	170.0	108.3	17.0	527.6
7. Toe-tapping pad with alternating feet	569	197.1	106.5	33.1	500.3
8. Walking in place	585	202.3	101.5	25.9	457.4
Metronome timing (mean of the 7 items)	585	171.2	80.7		

***Note*. A metronome timing score is the student's mean number of milliseconds off the beat of the Interactive Metronome™; thus, the lower the score, the better the timing.**

Although 569 children participated in the assessment of musical timing, 22 did not complete the testing procedure, and descriptive information was incomplete for another 24. Thus, the information and assessment was complete for 523 children, 279 boys and 244 girls. Table 2 presents counts and percentages of each rating and the mean ratings for each item. The item means vary between 3.14 and 3.79. Noting that equal percentages of ratings across five levels would

place 20% of ratings at each level, it appears that children tended to be at the extremes, either fully accurate and consistent or uneven and off the beat, matching no beats. The percentages at these two extremes together varied from 61% to 70%, exceeding their allotted 40% by 21% to 30%.

Table 2: Musical Timing Items

Item	Rating						
	1	2	3	4	5	Mean	SD
1. Patting knees with both hands	119	64	58	85	197	3.34	1.61
	23%	12%	11%	16%	38%		
2. Clapping hands together	139	51	54	55	224	3.33	1.70
	27%	10%	10%	11%	43%		
3. Patting knees with alternating hands	133	63	57	70	200	3.27	1.65
	25%	12%	11%	13%	38%		
4. Patting knee with preferred hand	126	49	65	70	213	3.37	1.64
	24%	9%	12%	13%	41%		
5. Patting knee with nonpreferred hand	135	48	63	68	209	3.32	1.66
	26%	9%	12%	13%	40%		
6. Toe-tapping pad with alternating feet	154	46	69	81	173	3.14	1.65
	29%	9%	13%	16%	33%		
7. Walking in place	91	37	42	74	279	3.79	1.56
	17%	7%	8%	14%	53%		
Musical timing	73	80	89	135	146	3.37	1.33
	11%	12%	14%	21%	22%		

***Note*. *N* = 523. Rating 1 (1.00 to 1.49) = Accurate and consistent; 2 (1.50 to 2.49) = Fairly accurate and consistent; 3 (2.50 to 3.49) = Sometimes accurate and consistent; 4 (3.50 to 4.49) = Even but off the beat; 5 (4.50 to 5.00) = Uneven and off the beat. Thus, the lower the score, the better the timing.**

The musical timing ratings had a different order of difficulty from the metronome timing scores. The items listed 1-7 in Tables 1 and 2 are arranged in order of their difficulty in metronome timing, from easiest to most difficult. Their difficulty ranking for musical timing was 6-3-5-2-1-4-7. Only walking in place was found to have the same level of difficulty (most difficult) by both measures. Perhaps raters compensated for the varying degrees of inherent difficulty

in assigning their ratings, because as presented below, they did reliably distinguish children with varying levels of musical timing. The internal consistency of the seven items was quite high, with an alpha coefficient of .915.

The correlations between metronome timing and musical timing suggest distinct but related abilities. The correlations between the same items measured both ways ranged from .243 to .399, and the correlation between the two total scores was .498 (n = 523, p < .001). While both metronome timing and musical timing had strong internal consistency, indicating the integrity of the constructs that they each measured, they clearly measured different aspects of timing.

Concurrent Validity of the Timing Measures

As shown in Table 3, both metronome timing and musical timing had statistically significant correlations in the expected direction with most of the variables examined for this purpose. Exceptions to this generalization are that metronome timing was not significantly correlated with gender, repeating a grade, or being treated for learning disability; and musical timing was not significantly correlated with reading or mathematics achievement or with placement in any of the compensatory or special education programs (Title I reading, speech and language, repeating a grade, learning disability, or mentally handicapped). Metronome timing had correlations of .3 or greater with physical coordination/motor skill, ability to attend over a period of time, age, and rated kindergarten achievement. Musical timing had correlations of .3 or greater with age. These discrepancies do not challenge the validity of either measure, but rather help define the difference between them.

Table 3: Correlations of Timing Measures with Validity Variables

	Metronome Timing			Musical Timing	
Variable	*N*	*R*		*N*	*R*
Gender (1 = male, 2 = female)	585	.060		523	.155[d]
Handedness (1 = right, 2 = left)	585	.146[d]		523	.182[c]
Physical coordination/motor skill	427	.303[d]		398	.241[a]
Pays attention during class	427	.244[d]		398	.195[a]
Ability to attend over a period of time	427	.330[d]		398	.244[d]
Dance classes	585	.122[c]		523	.184[d]
Instrumental music	585	.187[d]		523	.237[d]
Household income	537	.243[d]		478	.249[d]
Parents' highest level of schooling	575	.166[d]		513	.228[d]
Age	585	.491[d]		523	.426[d]
Grade	585	.498[d]		523	.426[d]
CAT total achievement, grades 1 - 4	303	.264[d]		279	.137[a]
CAT reading, grades 1 - 4	304	.231[d]		280	.125
CAT language, grades 1 - 4	304	.225[c]		280	.156[b]
CAT mathematics, grades 1 - 4	303	.273[d]		279	.107
Rated kindergarten achievement	112	.335[c]		109	.212[a]
Gifted & talented program	427	.150[c]		398	.243[d]

Title I reading program	427	-.150[c]		398	-.066
Speech & language program	427	-.119[a]		398	-.059
Repeated a grade	585	-.068		523	-.030
Learning disability program	427	-.091		398	-.081
Mentally handicapped program	427	-.132[b]		398	-.040

***Note*. The signs of correlation coefficients with metronome timing and with musical timing are reversed to reflect the fact that, on both measures, lower scores indicate better timing.**

[a] $p < .05$ [b] $p < .01$ [c] $p < .005$ [d] $p < .001$

The directions of timing findings for gender and handedness are interesting. Girls had better musical timing than boys, but no better metronome timing, suggesting that girls have greater ability to identify the beat of a musical selection than boys, but cannot track beeps better. Left-handers had better metronome and musical timing than right-handers, perhaps because left-handers are required to use their nonpreferred right hand more often than right-handers are required to use their nonpreferred left hand. In support of this explanation, while left-handers scored significantly better than right-handers on all 7 metronome timing items and all 7 musical timing items, patting knee with nonpreferred hand had the largest difference for metronome timing and only .04 of a point less than the largest difference for musical timing.

Children's Timing and Age

As Table 4 shows, older children had better metronome and musical timing than younger children. The metronome timing means ranked in order by age, except that 6-year-olds had better timing than 7-year-olds. The musical timing means ranked in order by age without exception. Post-hoc Bonferroni analyses indicated two metronome timing plateaus — the metronome timing of children aged 4 to 7 was significantly different from the metronome timing of children aged 8 to 10. A similar but more complex pattern was found for musical timing — each age mean was not significantly different from adjacent years, but was significantly different from any age more than one year above or below it.

Table 4: Metronome and Musical Timing by Age

	Metronome Timing[b]				Musical Timing[c]		
Age	*n*	*Mean*	*SD*		*n*	*Mean*	*SD*
4	83	234.6	46.0		65	4.41	0.76
5	95	221.2	54.6		81	3.91	1.07
6	117	161.8	72.5		110	3.47	1.22
7	97	168.6	83.3		93	3.31	1.34
8	73	142.7	76.1		69	2.76	1.51
9	61	118.4	79.7		52	2.68	1.32
10	59	115.1	70.2		53	2.63	1.33

***Note*. The year of age includes all children from that birthday to the day before the next one; for example, "4" includes children from 4.00 to 4.99. For both metronome timing and musical timing, the lower the score, the**

better the timing.

[a]*F* (6, 578) = 34.13, *p* < .001, two-tailed. Bonferroni post hoc analyses indicated that the metronome timing of children aged 4 to 7 was significantly different from the metronome timing of children aged 8 to 10 (*p* < .05).

[b]F = (6, 516) = 19.98, *p* < .001, two-tailed. Bonferroni post hoc analyses indicated that each age mean was not significantly different (*p* < .05) f rom adjacent years, but was significantly different from any age more than one year above or below it, for example, 4-year-olds had worse timing than 6- to 10-year-olds; 6-year-olds had better timing than 4-year-olds but worse timing than 8- to 10-year-olds.

Children's Timing and School Achievement

As shown in Table 5, children's metronome and musical timing were significantly related to their percentiles on the California Achievement Test. The relationship between metronome timing and these test scores was the stronger of the two, with consistently better means with increasing achievement test scores; children at or above the 80th percentile in achievement had significantly better metronome timing than children up to the 59th percentile. Although the overall relationship between musical timing and these test scores was also statistically significant, musical timing scores for children up to the 89th percentile varied only .05 of a point across categories, and none of the differences between categories were statistically significant.

Table 5: Metronome and Musical Timing by Children's School Achievement

	Metronome Timing[a]				Musical Timing[b]		
Percentile Category	*n*	*Mean*	*SD*		*n*	*Mean*	*SD*
Up to 59th	79	170.7	81.9		73	3.16	1.31
60th to 79th	69	140.5	81.0		58	3.09	1.31
80th to 89th	53	131.8	69.5		49	3.13	1.31
90th to 99th	102	116.9	73.9		99	2.60	1.36

***Note*. California Achieveme nt Test total score percentiles for grades 1 - 4. For both metronome timing and musical timing, the lower the score, the better the timing.**

[a]*F* (3, 299) = 7.42, *r* = .264, *p* < .001; Bonferroni post hoc analyses found that children scoring at or above the 80th percentile in achievement had significantly better metronome timing than children up to the 59th percentile in achievement (*p* < .05).

[b]*F* (3, 275) = 3.34, *r* = .137, *p* < .05; Bonferroni post hoc analyses found no significant differences (at *p* < .05) in the musical timing of children differing in their achievement percentiles.

Discussion

This study's results present the reliability and concurrent validity of metronome timing and musical timing. Both measures were internally consistent and related in reasonable ways to the variables used to assess their concurrent validity. Is one better than the other or should they be used together? An analysis of their partial and multiple correlations revealed no clear-cut empirical advantage to using one or the other or even both together.

While both measures of timing had the same seven items, metronome timing used a computer and input devices to measure responses to unembedded beeps, while musical timing had observers measure responses to beats embedded in instrumental music. Metronome timing requires available equipment and competent operators, while musical timing requires trained observers. Equipment error is mechanical or electrical, while observer error comes largely from their subjective judgments - two very different types of error. If girls really did have better timing than boys, for example, the musical timing measure was more sensitive to this difference than was the metronome timing measure. On the other hand, if girls really did not have better timing than boys, observers' subjective bias towards girls influenced the musical timing scores.

This study has established that children's timing can be measured with reliability and concurrent validity. Its reliability was established by its high internal consistency, whether assessed as metronome timing or as musical timing. The .5 correlation between the two measurement techniques suggests that timing is a multifaceted construct. By both measures, timing had statistically significant correlations of .43 to .49 with age and .15 to .33 with handedness, physical coordination/motor skill, paying attention during class and ability to attend over a period of time; participation in dance classes, instrumental music classes, and gifted and talented classes; and household incomes and parents' highest level of schooling. In addition, one or the other measure of children's timing was significantly correlated about .15 with gender and remedial education classes and as high as .34 with measures of school achievement.

The generalizability of this study is limited by the constituency of its sample, of whom 98% were Caucasian, 87% had parents with a high school diploma, and 83% lived in two-parent families. Similar research should be carried out with diverse ethnic groups, children whose parents did not complete high school, and children of single parents. This study was correlational. It could suggest, but not establish, causal relationships. It was not designed to say whether improving children's timing will definitely improve their reading achievement or other aspects of school achievement. However, the substantial relationships found between children's metronome timing and their school achievement and the relationships found between both metronome and musical timing and children's ability to pay attention are consistent with these possibilities. One fruitful area for further research is a training study in which children experience a program to improve their timing. Not only their timing but also their ability to pay attention and their school achievement could be assessed before and after this program. Then, after verifying the improvement in children's timing, the study would be in a position to see if improvements in timing led to improvements in ability to pay attention, reading achievement, and other aspects of school achievement. Such High/Scope studies are currently under way in Effingham, Illinois, and Dayton, Ohio.

It is worth noting that in this study, metronome and/or musical timing were more strongly correlated than household income and parents' highest level of schooling with children's ability to pay attention. Schools that want children who pay attention can do little to affect their household income or parents' schooling. They can, however, offer training programs in timing. Although the significant correlations between timing and ability to pay attention do not guarantee that improved timing leads to improved ability to pay attention, it is highly plausible that it does. Similarly, children's metronome timing was statistically significantly correlated with their participation in special and compensatory classes. These are high-cost programs, much higher in cost than programs that train teachers to provide children with activities to improve their timing. If improving children's timing could reduce their need for special or compensatory classes, it is plausible that such teacher training (e.g., Weikart, 1995, 1998) could eventually pay for itself in this way.

Children's timing is important in its own right. It is important because it is a key factor in sports, music, and dance, in speech and general life functioning. Movement educators have also detected signs of a relationship between improvements in children's timing and improvements in their reading. If further research confirms such a relationship, the perceived educational importance of timing programs will increase, and we will have obtained one more tool in our efforts to achieve our national goal of having all young children complete third grade with the ability to read.

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