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ASSESSMENT

Measuring Rhythmic Ability: Validation of a Digital Rhythmic Ability Evaluation Tool (DRAET)

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Abstract

This study aimed (a) to create a digital rhythmic ability evaluation tool (DRAET) that could record, compare, and appraise coordinated motions of subjects' body parts, using accelerometer sensors with various music rhythms, and (b) to certify and validate the DRAET, compared with an accepted rhythmic ability evaluation methodology (i.e., the High/Scope Beat Competence Analysis Test, H/SBCAT). After the DRAET was constructed, 120 individuals (6 to 15 years old) were tested while engaging in seven tasks, toward synchronization with 36 beats at a rhythm of 2/4. Rhythmic performance was simultaneously estimated digitally by the DRAET and H/SBCAT. Correlation analysis via Pearson's r, Cronbach's α, and kappa coefficients revealed a significant relationship between digital recordings and judges' evaluations through observation in practical tests, certifying its validity and reliability. Results provide preliminary support for the validity and reliability of the DRAET and suggest that it can be used as a tool for measuring rhythmic ability.

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The evaluation of rhythmic ability is an essential feature of human motion, as it enhances teaching approaches in both physical education and music-movement education that aims for smooth, kinetic, emotional development with rhythm. Gallahue (1996) emphasizes that when a motion is performed with rhythm, children tend to better create basic motional elements while improving their abilities. Considering this, creating and implementing reliable methodological tools (in terms of accuracy in digital recording, as well as evaluating the multifaceted aspects of rhythm and human motion) is important for researchers in many sectors of education (Chamberlain, 2003; Kuhlman & Schweinhart, 1999).

A survey based on the studies of musical education noted an absence in the evaluation of rhythmic synchronization of complex motions between individual body parts (Ben-Pazi, Gross-Tsur, Bergman, & Schalev, 2003; Chen, Penhune, & Zattore, 2008; Corriveau & Goswami, 2009; Grahn & Brett, 2007; Repp & Penel, 2004; Snyder & Krumhansl, 2001). This renders these works unfit for application in music-movement education and generally in physical education, where such complex motions are usually required. For example, to evaluate rhythmic ability, some tools assess the difference of the rhythmic correspondence to visual and auditory stimuli by applying a computer as an auxiliary tool, in which the user is called to press the space button or to click the left button of their mouse, according to visual samples on the screen (or the audio samples on the speakers). A common feature of these methods is the study of rhythmical and fine motion of a specific body part (e.g., finger motion), while ignoring other body parts and rhythmic coordination among them.

Moreover, in other studies examining rhythmic ability by tests that contain a wide variety of motions suited to physical education, lack of accuracy has been noticed by studies that collect data through visual observation. Specifically, one method often applied by those that study the influence of music and motional intervention programs in physical education is the High/Scope Beat Competence Analysis Test (H/SBCAT), which is offered in several variations with a common feature (i.e., the judges' evaluation through visual observation). An earlier version called Rhythmic Competency Analysis Test (RCAT) proposed by Weikart (1982) was applied as a rhythmic evaluation test by High (1994), who studied the effectiveness of rhythmic education methods in the development of rhythmic correspondence in preschool children.

Zachopoulou, Derri, Chatzopoulos, and Ellinoudis (2003) assessed the rhythmic ability of children aged 4 to 6 in an updated version of the H/SBCAT (Weikart, Schweinhart, & Larner, 1987); subjects were asked to implement seven discrete motional tasks (clapping hands, preferred hand tapping, nonpreferred hand tapping, bilateral hands tapping, parallel hands tapping, bilateral foot movement, and walking) according to the beat pattern with a metronome at 100 bpm. Two judges and visual observers determined whether the motions were synchronized to the beat. Other researchers applied other variations of the H/SBCAT to preschool and young children (Agdiniotis et al., 2009; Derri, Tsapakidou, Zachopoulou, & Gini, 2001; Pollatou, Karadimou, & Gerodimos, 2005; Pollatou et al., 2012; Kuhlman & Schweinhart, 1999) and secondary school children (Pollatou, Liapa, Diggelidis, & Zachopoulou, 2005).

Weikart et al. (1987) provided evidence on the validity and internal consistency (αs between .70 and .79) of the H/SBCAT. The test has also shown a strong positive correlation with gross-motor ability (Kiger, 1994) and school achievement (Kiger, 1994; Weikart et al., 1987). Kuhlman and Schweinhart (1999) studied a group of children aged 4 to 11 for metronome timing, with a computer and input devices to measure response to unimpeded beeps; musical timing was measured with responses to beats embedded in instrumental music, as a variation of the H/SBCAT (Weikart et al., 1987), and a strong correlation was found between tests.

Its reliability was established via high internal consistency, whether assessed with a metronome or musical timing. Venetsanou, Donti, and Koutsouba (2014) measured the rhythmic ability of 70 preschool children, using "jumps on the rhythm" (or the Democritus-Psychomotor Assessment Tool for Preschool Children (Kambas & Venetsanou, 2014). The participants were tested in four tasks with a duration of 10 s each, with the music having a 4/4 rhythmic pattern with 100 bpm tempo. The evaluation criteria included timing, as well as rhythm and exercise duration throughout the visual observation. In another study, Phillips-Silver and Trainor (2005) evaluated infants for associated timing to the rhythm of bouncing their knees, examining the hypothesis that movement influences auditory encoding of rhythm patterns in infants. Their findings provided evidence that musical rhythm perception is significantly affected by the experience of body movement. The described methods present some limitations, however, such as the evaluation through visual observation instead of computer-assisted digital recording; in addition, the tasks were restricted to single motions instead of free motions and only with the rhythmic pattern of 2/4.

The need for more precise and specific evaluations of rhythmic ability led researchers to propose several new methods that digitally record the motional data, without the need for visual observation. Rose (2016) studied the ability of 119 preschool children to synchronize a rhythm in three tempos (80 bpm slow, 100 bpm moderate, and 120 bpm fast) by tapping their hands simultaneously and their feet bilaterally on a pair of Musical Instrument Digital Interface (MIDI) controllers (DrumKat 3.8) connected to a computer for digital analysis. Similarly, Fotiadou et al. (2006) studied the rhythmic ability of deaf children, by recording the 4/4 beat pattern of a metronome, along with motions and steps on a floorboard; then they compared the deviation (in milliseconds) of the steps of deaf children to the metronome beat, which yielded a score through which they could calculate this deviation as a quantitative measurement. Aschersleben and Prinz (1995) calculated the time interval between a tapping finger and a foot on a sensor with a rhythmical sound sample. Similarly, Fraisse (1995) studied synchronization between hand and foot motions with a sound stimulus.

A couple of studies about multimedia technology used some tracking platforms to deal with the credibility of dance performances. Essid et al. (2012) and Gowing et al. (2011) assessed dance performance with a platform based on the Kinect skeleton tracking system and the Wireless Inertial Measurement Units (WIMU). Individual choreography was watched via screen, with measurement tools analyzing joint position and tracked footsteps through accelerometer sensors of the Kinect and WIMU; the synchronization of motion steps with demonstrated choreography was used by the researchers to calculate the corresponding deviation as a measurable score.

A common feature of motional abilities and evaluation methods is the use of an accelerometer sensor, which can digitally record motion in space and time and its attributes (intensity, speed, etc.; Naghshineh, Ameri, & Zereshki, 2009). Several research studies used a widely known computer game platform (i.e., the Nintendo

Wii) to evaluate the rhythm and recording of motion; this included the accelerometer sensor and the wireless communication of the Bluetooth protocol, which can be done with the remote controller. De Bruyn, Leman, and Moelants (2008) examined children at age 9 for the rhythmical motion of their hands while they listened to specific musical tracks. They wanted to compare the children's performance as individuals and as a group of classmates. They recorded mean values of the Wii accelerometer on a graph, to compare individual and group performance. Phillips-Silver et al. (2011) used the Wii remote to study the performance of 33 adults in bouncing their knees and tapping their hands, versus the performance of a person with no sense of rhythm, but with the aim of studying the issue of amusia. The performance evaluation compared the accelerometer graphs.

The Nintendo Wii has been used as a research tool for motion recording. Sheridan (2010) studied a group of children clapping their hands and observed that the action could be traced on a graph, in which the acceleration (in [x, y, z]) shows sharp and sudden changes. Shih, Wang, and Wang (2014) used the Nintendo Wiimote to study the behavior of two hyperactive children in class. The tilt of the sensor was monitored via Bluetooth while attached to the child's leg, such that the monitoring system caused the Wiimote to vibrate each time the child stood up.

The construction of a tool that can digitally evaluate the performance of rhythmic motions coordinated to different rhythms would be a challenge in various scientific fields (e.g., physical education, music education, dance, and special education). The efficiency of several intervention programs on children's rhythmic education could be tested, allowing for the identification and classification of conceptual problems, as well as a person's rhythmic performance. It is essential for dance and physical education to use technology (Dania, Hatziharistos, Koutsouba, & Tyrovola, 2011), with the aim to create a measurement tool that could evaluate rhythmic ability and the efficiency of an athlete's technique in training and help detect new talents.

This study aimed to create a digital rhythmic ability evaluation tool (DRAET) that can record, compare, and appraise precisely coordinated motions of subjects' body parts, using a set of accelerometer sensors with various music rhythms. The study also aimed to certify and validate DRAET, in comparison with an accepted rhythmic ability evaluation methodology (i.e., the H/SBCAT; Weikart et al., 1987). Furthermore, the DRAET can evaluate motions in space using a set of simple or complex rhythmical patterns with accompanying beats or even music, and it can be applied in the individual's own environment or in the presence of other people (e.g., classmates), which can reduce the stress caused by a strict evaluation in a research lab.

Method

Technical Overview of the Measurement Tool (DRAET)

An innovative method that can evaluate rhythmic ability using computer-assisted recording and analysis techniques through a set of accelerometer sensors was developed. For the data acquisition, a device of a widely known gaming console was used (i.e., the remote control of the Nintendo Wii). This device was chosen for its compact size, which allows it to be attached to any body part, with a belt or some tape, and because it can easily communicate with a computer through its wireless Bluetooth interface, which allowed the researchers to evaluate subjects' rhythmic ability in a defined area within a range of 5 to 100 m^2.

For the measurement of an individual's rhythmic ability, a set of accelerometer sensors records the changes in the acceleration on the attached body part as a waveform such as the one in Figure 1. The steepest changes in the waveform correspond to the moments where a motion starts or ends. When a foot takes a step, the moment it touches the ground it suddenly stops moving. The waveform recorded by the accelerometer sensor will have a peak at this moment. For this reason, the method focuses on such motions, which are represented in the waveform as the points of local maxima (or minima). Depending on the trajectory of the motion and the orientation of the attached device, sometimes the important information is located at the local maxima of the waveform and other times at the local minima. If the device, for example, is attached vertically on a body part, the motions may be contained in the local maxima, and if the device is attached horizontally, the motions may be contained in the local minima. Additionally, motions that are performed on the z-axis (up-down) are recorded by the accelerometer sensor separately from the motions on the x-axis (left-right) and the y-axis (front-back).

Depending on the case, the method may focus on motions at a single direction—while the other directions are ignored—or a combination of many directions may be used.

Rhythmic ability was evaluated via a comparison of the moments of local maxima (which represent the steps or motions) with the beat of the music at the moment of the recording. For the extraction of the beats of the music, a sound processing tool was used (Audacity, 2017). Figure 1 illustrates the beats as vertical lines below the waveform (note that the x-axis of the waveform is the time expressed in seconds). For the numerical evaluation of the correspondence of the recorded steps and the beats, a numerical analysis tool (Mathworks, 2017) computed the deviation of the steps to the beats with a tolerance expressed in milliseconds. Depending on the attributes of the test sample (e.g., age) and the aim of the research, a threshold (in milliseconds) is defined, where a step is in rhythm when the time interval between the step and the corresponding beat is within the given threshold. This condition allows for some remarks and conclusions regarding the rhythmic ability of an individual to be made. These conclusions are expressed as absolute numbers (e.g., number of synchronized or unsynchronized steps or motions), as a percentage (e.g., ratio of unsynchronized steps to the total number of steps), or even as a time deviation (e.g., the sum error of the steps and the corresponding beats, expressed in milliseconds). These calculations allow the development of a digitally accurate evaluation criterion of rhythmic ability.

For the implementation of the DRAET, the open-source Wiimote Lib (Microsoft, 2013) was used for the communication between the sensor and the computer via Bluetooth. The user interface was implemented in the Visual Basic programming environment (Microsoft, 2011). Figure 1 illustrates a waveform that consists of 37 steps. Twenty-nine of the steps are identified as synchronized and eight steps out of limits. Additionally, two steps have been falsely assigned to the same beat, which caused another beat to remain orphan. The steps are illustrated in various shapes and colors (green circle for steps within limits, red square for steps out of limits, green filling for single steps, red filling for double steps). The error per step and the total error are also illustrated in Figure 1 (expressed in milliseconds), which allows for visual observation for the evaluation of an individual's rhythmic ability.

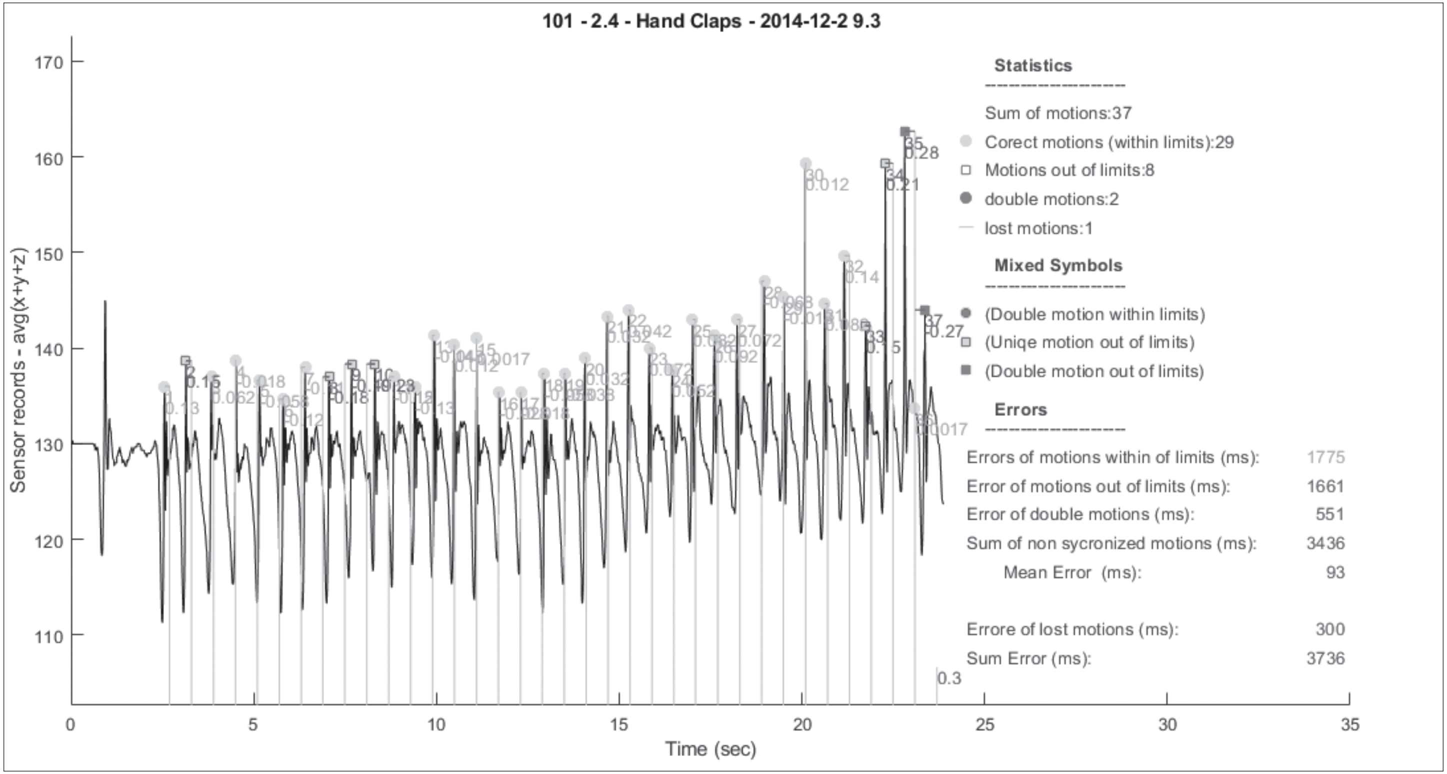

Figure 1. Measurement of rhythmic ability is achieved with the recording of the motions in various body parts using accelerometer sensors.

High/Scope Beat Competence Analysis Test (H/SBCAT)

The validity and reliability of the DRAET can be determined through a comparison of its scores with those provided by other valid and reliable rhythmic ability evaluation methods. The most appropriate method to serve as a criterion is the H/SBCAT, which uses a wide range of motions (clapping, tapping, walking, etc.) in the context of music-movement education and physical education. The approach of recording and evaluating the rhythmic ability with the H/SBCAT variation proposed by Weikart et al. (1987), as well as other researchers (Derri et al., 2001; Zachopoulou et al., 2003), includes visual observation of the synchronized motions (in a total of 36 motions) according to a rhythmical sound by judges who perform the evaluation.

Although the DRAET can evaluate motions in space using a set of simple or complex rhythmical patterns with accompanying beats or even music, the subjects were tested exclusively with the rhythmical pattern of 2/4 with beats and no music. This was decided so that the test conditions performed by the other studies were not modified (Derri et al., 2001; Zachopoulou et al., 2003). Moreover, Pollatou, Hatzitaki, and Karadimou (2003), who studied the rhythmic synchronization on 30 adult female students (M_{age} = 20.1 years old), concluded that the subjects performed higher scores with beats than with music.

Sample and Procedure

The sample consisted of 120 individuals (60 boys, 60 girls) aged 6 to 15 years old (M = 10.53, SD = 2.719). All of them were schoolchildren of primary and secondary education levels, who were chosen through convenience sampling so that the researchers could test the effectiveness of the DRAET in a large range of school ages. Each participant underwent the series of seven motional tests described in the H/SBCAT (Weikart et al., 1987) and tried to synchronize with the 2/4 beat pattern at 100 bpm for 36 beats. The motional tests included clapping, preferred hand tapping, nonpreferred hand tapping, bilateral hands tapping, parallel hands tapping, bilateral foot movement, and walking. During the tests, the accelerometer sensor of the DRAET was attached on the corresponding body part, for digitally recording their motions. At the same time, one visual observer acted as a judge to evaluate the participant. Two more judges evaluated the test through visual observation, not at the same time, but using a video recording of the test instead. All three judges were experts, as they were specialized in rhythmic gymnastics judgment. The evaluation score was computed as the number of synchronized motions (in a total of 36) as observed by the judges, as well as with the digital recording of the DRAET. The threshold in which a motion was considered to be within limits was defined as 150 ms, as a result of adjustments provided in collaboration with the judges, given the young age of the subjects, which included very young children. The participants were properly informed about the context of the test and were allowed attempts without being recorded. Then, in the beginning of the test, a set of four warning sounds accompanied the verbal instruction of the examiner, "one, two, three, go," to start synchronizing their motions with the rhythmical pattern of 2/4 in 100 bpm.

Statistical Analysis

For the statistical analysis of the results, SPSS 22.0 was used. A number of descriptive statistics were calculated such as means and standard deviation, as well as Pearson's r correlation analysis, which verified the construct and criterion validity. The internal consistency of the variables was verified through Cronbach's α, while the index kappa was calculated through crosstabulation analysis between the results provided by the DRAET and the H/SBCAT judges. The level of significance was set to .05.

Results

Table 1 summarizes the means and standard deviations of the scores obtained by the DRAET and the judges.

Construct Validity

An analysis of correlation among the results of the DRAET for all seven trials demonstrated a strong correlation among them, between the number of synchronized motions and between the values of error (in milliseconds), as summarized in Table 2.

Tale 1

Means and Standard Deviations for the Evaluation Results for the DRAET and the Three Judges

	DRAET				Judge 1		Judge 2		Judge 3		Judges *M*	
DRAET	***M***	***SD***	***M* (ms)**	***SD* (ms)**	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Clapping	34.72	3.07	1558.64	1042.81	34.81	3.01	34.51	2.90	34.63	3.33	34.64	3.06
Preferred hand tapping	35.06	3.03	1313.66	966.07	35.22	2.37	34.88	2.64	35.10	3.06	35.08	2.62
Nonpreferred hand tapping	34.67	3.69	1453.17	1102.63	34.98	2.87	34.54	2.94	34.78	3.45	34.77	3.05
Bilateral hands tapping	34.53	3.24	1775.38	1370.01	34.85	2.80	34.35	2.84	34.73	2.86	34.79	2.79
Parallel hands tapping	35.11	2.62	1283.64	1016.80	35.20	2.55	34.98	2.53	35.02	2.77	35.08	2.63
Bilateral foot movement	32.97	4.701	2317.33	1644.35	33.37	4.43	33.08	4.52	33.10	4.24	33.38	4.06
Walking	32.19	5.70	2273.91	1725.98	32.96	5.12	32.85	4.80	32.55	5.02	32.84	4.89

Table 2

Correlations Between Number of Synchronized Motions by DRAET and the Values of Error in Milliseconds

		Clapping		Preferred hand tapping		Nonpreferred hand tapping		Bilateral hands tapping		Parallel hands tapping		Bilateral foot movement		Walking	
Pearson correlation (r)		**Beat sync**	**ms**	**Beat sync**	**ms**	**Beat sync**	**ms**	**Beat sync**	**ms**	**Beat sync**	**ms**	**Beat sync**	**ms**	**Beat sync**	**ms**
Clapping	Sync.			.58**		.53**		.38**		.42**		.25**		.53**	
	ms				.59**		.57**		.48**		.49**		.49**		.46**
Preferred hand tapping	Sync.	.58**				.29**		.33**		.40**		.28**		.52**	
	ms		.59**				.54**		.53**		.65**		.48**		.57**
Nonpreferred hand tapping	Sync.	.53**		.29**				.51**		.63**		.41**		.45**	
	ms		.57**		.54**				.66**		.65**		.70**		.56**
Bilateral hands tapping	Sync.	.38**		.33**		.51**				.62**		.53**		.53**	
	ms		.48**		.53**		.66**				.75**		.60**		.58**
Parallel hands tapping	Sync.	.42**		.40**		.64**		.62**				.54**		.50**	
	ms		.49**		.65**		.65**		.75**				.59**		.53**
Bilateral foot movement	Sync.	.25**		.28**		.41**		.53**		.54**				.49**	
	ms		.49**		.48**		.70**		.60**		.59**				.59**
Walking	Sync.	.53**		.52**		.45**		.53**		.50**		.49**			
	ms		.46**		.57**		.56**		.58**		.53**		.59**		

**$p < .01$, two-tailed.

Criterion Validity

The criterion validity concerns the criteria that render the choice of the H/SBCAT (Weikart, 1987) for certifying the reliability and validity of the results provided by the DRAET. The H/SBCAT tool developed by Weikart et al. (1987) has been proven as a valid and reliable tool for measuring and evaluating rhythmic ability. Based on some literature (Kuhlman & Schweinhart, 1999), it can serve as an adequate criterion for measuring the validity of the newly developed DRAET.

The correlation analysis according to Pearson's *r* between the scores of each test of the DRAET and each judge, as well as the mean of the judges, indicated a strong correlation in all cases, as summarized in Table 3. An examination of the kappa factor shows a moderate agreement among the DRAET results and the judges nearly on all trials, with some exceptions concerning the second judge, as shown in Table 3, which adds one more element of criterion validity. The element of subjectivity in the evaluation of the judges through visual observation, combined with the digital and accurate results of the DRAET, justifies this moderate agreement of the results, which, however, is constant on all trials, without irregular variations in the kappa value. Additionally, the examination of the mean values in Table 1 indicates that the results provided by the DRAET are consistent with the observations of the three judges in all seven trials.

Internal Consistency of the DRAET

The internal consistency of the results provided by the DRAET among the seven evaluation tests was tested with Cronbach's α coefficient and supported the internal consistency of the tool concerning the variables of synchronized motions (α = 84) and total error in milliseconds (α = .89), as shown in Table 4. Moreover, the calculation of the coefficient α with the absence of each variable indicates that the coefficient α does not increase, a fact that certifies the additional individual internal consistency of the results in each trial.

Table 3

Mean Value and Correlations Between the DRAET and the Judges of H/SBCAT

	DRAET	Judge1			Judge2			Judge3			Judges *M*		
DRAET	***M***	***M***	***r***	**Kappa**	***M***	***r***	**Kappa**	***M***	***r***	**Kappa**	***M***	***r***	**Kappa**
Clapping	34.72	34.81	.95**	.42**	34.42	.93**	.30*	34.63	.96**	.50**	34.64	.95**	.40**
Preferred hand tapping	35.06	35.22	.97**	.45**	34.85	.92**	.34*	35.10	.95**	.47**	35.08	.98**	.47**
Non-Preferred hand tapping	34.67	34.98	.98**	.42**	34.50	.91**	.27*	34.78	.97**	.47**	34.77	.97**	.42**
Bilateral hands tapping	34.53	34.85	.94**	.45**	34.51	.93**	.26*	34.73	.93**	.46**	34.79	.93**	.43**
Parallel hands tapping	35.11	35.20	.96**	.42**	35.00	.95**	.42**	35.02	.94**	.40**	35.08	.960*	.41**
Bilateral foot movement	32.97	33.37	.97**	.42**	33.02	.89**	.28*	33.10	.93**	.41**	33.38	.93**	.38*
Walking	32.19	32.96	.95**	.42**	32.92	.95**	.36*	32.55	.95**	.38*	32.84	.96**	.34*

Note. Kappa is considered as 20–40 fair agreement*, 40–60 moderate agreement**, 60–80 good agreement***, and 80–100 very good agreement****.

*$p < .05$. **$p < .001$.

Table 4
Internal Consistency of the DRAET Results

Reliability statistics in beat synchronization and ms error	Cronbach's α with absence of the specific variable	
Cronbach's α in beat synchronization: .838 Cronbach's α ms error: .891	Beat synchronization < .838	ms error < .891
Clapping	.82**	.88**
Preferred hand tapping	.83**	.88**
Nonpreferred hand tapping	.81**	.87**
Bilateral hands tapping	.81**	.87**
Parallel hands tapping	.81**	.87**
Bilateral foot movement	.83**	.88**
Walking	.81**	.88**

Note. The coefficient Cronbach's α < .83 in sync and α < .88 in error (ms) certifies the internal consistency of each trial.

$^{**}p < .001$.

Discussion

This study aimed to create a digital rhythmic ability evaluation tool (DRAET) that can record, compare, and appraise precisely coordinated motions of subjects' body parts, using a set of accelerometer sensors with various music rhythms. The study also wanted to certify and validate the DRAET, in comparison with an accepted rhythmic ability evaluation methodology (i.e., the H/SBCAT).

The results of the analyses indicate that the DRAET is an evaluation tool of rhythmic ability that can measure the motional synchronization of a subject's body parts with a rhythmic pattern or music with significant accuracy, due to digital recording. The DRAET tracks the synchronized motions similarly to the H/SBCAT, but can calculate the total error in milliseconds of all motions (synchronized or not), providing a more accurate rhythmic ability evaluation tool. The validity of the DRAET results have been corroborated by statistical analyses and comparison of the results to other methods, thereby confirming the research assumptions. The strong correlation ($p < .001$) among seven trials (evaluated digitally) between the number of synchronized motions and between the values of error (in milliseconds) provided elements of construct validity. It can be substantiated that the DRAET examined the same variable in all tests (i.e., rhythmic ability) as judges did via observation for the H/SBCAT.

Few tools can synchronize body parts with a motion in open space, or rhythmical patterns (simple or complex) in free motion conditions, which created a limitation of this study. For a comparison of the DRAET's results to other evaluation methods, the H/SBCAT (Weikart et al., 1987) was used, as it includes trials such as clapping, tapping, and walking, which are suitable for activities in music-movement education and physical education. This allowed for simultaneous application of the DRAET and H/SBCAT for simultaneous digital examination and visual observation. Moreover, the H/SBCAT is considered a valid method, according to Weikart et al. (1987) and Kuhlman and Schweinhart (1999). Thus, it was a good choice for comparison to the DRAET's effectiveness and provided a significant element of criterion validity.

The DRAET uses the H/SBCAT as a comparison tool, and the strong correlation between judges' results and digital recording provides validation of the DRAET as a rhythmic ability evaluation tool. The stable values of the kappa factor and analysis of the mean results of all trials gauge the results between judges and the DRAET's digital recording. The similarity of these evaluation methods was confirmed, which established the capability of the DRAET to judge rhythmic ability parameters. These facts lead to the ascertainment that those measuring rhythmic ability need to avoid the subjectivity of the H/SBCAT, with which observers evaluate rhythmic ability, and trust the objectivity of the DRAET, which provides digital accuracy. Moreover, the assessment of Cronbach's α coefficient among the digital recording of synchronized motions and among the total error recording in milliseconds for all trials indicates significant internal consistency of the DRAET ($\alpha > .80$), thus corroborating strong homogeneity.

Conclusion

The DRAET is a valid and reliable digital tool capable of recording and evaluating the parameters of rhythmic ability of the human body and its body parts. The tool shows significant correlation to the valid H/SBCAT. As a digital tool, it offers increased accuracy, using additional criteria for the evaluation of rhythmic ability. Unlike other methods, it can be applied with various rhythmic patterns (simple or complex) and offers freedom of motions in open space, which makes it suitable for applications in the fields of physical education, music-movement education, dance, and sports. In future research, the DRAET could be applied as an evaluation method in education, in the form of intervention programs in music-movement education, with various motions and various rhythmic patterns or music. With some adjustments, it could also be used as an evaluation tool in dance or sports, providing new capabilities in analysis of technical performance. The DRAET could also be used as an evaluation tool in special education, providing essential feedback to a possible connection of rhythmic ability and various learning difficulties and to the effect of music-movement education programs in special education.

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