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Effect of Difficulty Level and Time-Pressure on the Morning-Evening Differences in Accuracy and Consistency of Throwing Darts Among 9-10 Year-Old Boys

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Abstract: This study investigated the impact of task difficulty level and time-pressure on the morning-evening changes in psychomotor performance and perceived difficulty to it among 9–10 years-old boys. Twelve healthy right-handed boys (age = 9.8 ± 0.5 years, height = 144 ± 6.2 cm and body mass = 32.7 ± 3.4 kg) volunteered to take part in the study. They were asked to throw darts to a target from a short (2m, SD) and long (2.37m, LD) distances, either in free (no time limitation, NC) or time-pressure (TPC) conditions, on nonconsecutive days and in a counter-balanced randomized order. Mean scores, missed darts and variability of scores were recorded and analyzed using a three-way ANOVA with repeated measures. Intra-aural temperature and perceived difficulty were recorded too. The results showed higher performance in the afternoon than the in the morning, with higher mean scores around the time of maximum oral temperature ($p<0.001$). The number of missed darts and variability of scores were lower at 17:00 h in comparison with 07:00 h ($p<0.05$). Perceived difficulty decreased significantly with time-of-day, with greater values at 07:00 h than at 17:00 h ($p<0.05$). Psychomotor performance was better in the afternoon than the morning. It seems that, in the early morning, children are less sensitive to the increased level of difficulty when under time-pressure than when throwing a greater distance from the target.

Keywords: Circadian Rhythm, Difficulty Level, Psychomotor Performance, Perceived Difficulty, Time Pressure

1. Introduction

Children engage in motor activities that lead to a progressive development of motor skills, including running, jumping, kicking and throwing. Other motor activities lead to the acquisition of fine motor skills that involve eye-hand coordination, such as playing a video game or using a computer [1]. Previous work suggests that motor learning depends on the level of challenge of a task, which emerges from interactions between the information-processing capability of the learner, the task demands and the practice conditions [2].

Several studies indicate that many physiological variables related to gross motor performance display a time-of-day effect, such as strength, whole-body flexibility, simple reaction time and short-term power output [3]. Recently, results indicate that the time-of-day affects psychomotor performance [4] dribbling performance but not in soccer shooting accuracy [5]. Data's from studies in relation to children age suggest a significant time-of-day effect on short-term maximal performances, on strength, power, and jump tests in 9 to 11 young boys [6]. Likewise, cognitive performance (i.e. simple and choice reaction times, mental arithmetic and alertness) are time-of-day dependent, with higher outcomes observed around the peak of core [7]. It is well established that children have different information-processing capabilities compared with adults [8]. Those differences appear in cognitive processes such as selective attention [9] and processing information speed, which are increasing through the age [10]. In addition, compared to adults, children use different strategies to process information in tasks that require visual-spatial working memory [11], object recognition memory [12], verbal learning [13], copying spatial patterns [14] or higher-level attention focusing [15]. Task constraints of different performance contexts provide different specific information sources that individuals use in performing and acquiring skills [16].

Likewise, throwing darts at a target is a psychomotor task that comprises components that are commonly found in many everyday activities and sports. Moreover, a dart-throwing protocol has proved to be sufficiently sensitive to evaluate effects of muscle fatigue [17] and perceived difficulty [4]. Task difficulty is defined as a subjective perception, as assessed by the task doers [18]. It can be assessed both before and after performing the task [19]. The complexity of the task is sometimes considered to reflect task difficulty [20]. These authors examined the nature of the complexity of a task (its difficulty) in terms of whether users could recognize the complexity of the task and its effect on success and satisfaction in performing the task. They considered that the complexity of the task was a dynamic entity, and that the assessment system must use tasks with appropriate levels of complexity.

Recent research shows that performance is limited by task difficulty, often in the form of a trade-off between speed and accuracy, and learning consists in breaking through this limit [21]. More recently, study showed a significant effect of difficulty level, with performing a head protective response, on total response time, reaction time and movement time. However, there was no significant response to difficulty of gender-by-task interaction with the same measurement [22].

It is common to see deterioration in the performance of a variety of motor tasks when an actor is under pressure (e.g.), basketball shooting [23]; golf putting [24]; playing piano [25]. Although having the ability to perform skills successfully, many athletes execute in sub-optimal situations that magnify the importance of doing well on a particular occasion [26].

Crucially, performance pressure is often accompanied by deterioration in the performer's ability to execute movements correctly, a phenomenon that has been referred to as «choking under pressure» [27, 28, 29]. It's defined as "the occurrence of worse performance despite striving and incentives for better performance" [30].

Especially, it has been claimed that increased pressure to do well heightens self-focus, resulting in conscious attention to the processes that govern performance [28]. They argued that task performance worry or anxiety consumes working memory resources and this may directly affect performance. However, they noted that anxiety does not always lead to a breakdown in performance and the performer can compensate for increased worry by devoting more resources to maintain task performance (i.e., decreased processing efficiency) such that performance breakdown only occurs if these resources are still insufficient [29, 31].

To the authors' knowledge, no previous studies have investigated the relationships between teaching practices (i.e., manipulation of level of difficulty, time pressure) and perception of difficulty at different times-of-day.

In view of above considerations, the aim of the current study was to investigate the effect of the time-of-day, the level of difficulty and the time pressure effects on the daily variations of psychomotor performance, through accuracy and consistency of dart throwing performance in 10–11 years-old boys.

2. Methods

2.1. Participants

Twelve right-handed children (age = 9.8 ± 0.5 years, body height = 144 ± 6.2cm and body mass = 32.7 ± 3.4 kg; mean ± *SD*), volunteered to participate in this study. They didn't have any experience of throwing darts. All subjects participated in their physical activity classes one to two times per week and they didn't have extra scholar activity. All boys were classified as pre-pubertal (stage 1) by a paediatrician according to Tanner's criteria [32]. Moreover, 9 subjects were classified as "neither type" (score range from 42 to 52) and 3 as "moderately evening type" (score range from 31 to 41), from their responses to the self-assessment questionnaire of Horne & Östberg, which determines morningness-eveningness [33]. The protocol was explained in full and any questions had been answered before written informed consent was obtained from the children's parents, and children (in accordance with ethical procedures of the University). Participants reported no sleep disorder, did not consume caffeine and none of them was taking any medication.

2.2. Procedures

Subjects performed a darts throw-test in two experimental sessions at 07:00 h and 17:00 h separated at least by five days. After each throw bloc (i.e., six darts), the dart scores were recorded, and then the darts were collected for the next throw. The official dartboard was fixed on a wall so that its centre was at eye-level for each subject. Participants threw six darts [34], from two distances in randomised order. The first distance was 2 m [35]; the second was at the regular distance of 2.37m [36]. The two distances were marked by a line on the floor.

To increase the level of difficulty for each distance, two conditions were invested. In the first, normal condition (NC), subjects threw six darts and were instructed always to aim for the bulls-eye [34]. In the second, time-pressure condition (TPC), participants were instructed to complete the bloc throws as quickly and accurately as possible.

After each session, a questionnaire for PD, called DP-15 [37], was completed by the subjects. This scale was composed of 15 points, numbered 1-15, and was anchored at the two extremities by verbal labels - "Extremely easy" and "Extremely difficult".

Before taking part in the main experiment, each participant first completed two familiarization sessions starting at 07:00 h and 17:00 h separated by at least 3 days. These sessions ensured that participants were fully conversant with the experimental conditions and the scoring procedures. Participants arrived 20 min before the start of the tests and lay down and relaxed in the laboratory.

Participants were allowed to warm up six dart throwing randomized trials in each condition, in order to become familiar with the task.

They were permitted to drink water and they were required to relax. Oral temperature was measured in the five last minutes by a digital clinical thermometer (Omron®, Paris, France; accuracy ±0.05°C) inserted sublingually for at least 3 min. Two recordings were taken separated by 2 min; if the difference was greater than 0.28°C, a third measurement was taken [38]. The mean temperature for respective time of day was calculated [39]. The task was to throw the darts to strike as close to the bull eye as possible. The posture and throwing techniques were maintained in the two conditions.

2.3. Score Calculations

Each throw was scored according to its position on the board (0–10). A dart that missed the board or that bounced off was given a score of "0". The target consisted of a series of 10 concentric rings. Participants' dart throwing accuracy and consistency were evaluated by using three scores [40]. The first was the mean score of the six throws. This score could range from 0 (all misses) to 10 (all bulls-eyes); it can be considered a measure of accuracy, a high score indicating high accuracy. The second measurement was the numbers of zeros scored (number of times the target was missed). This score could range from 0 to 6, a low number of zeros indicating high accuracy. The third measure of performance was the coefficients of variation of the score: [SD scores] ⁄ [mean score], a lower coefficient indicating a higher consistency

2.4. Statistical Analyses

All statistical tests were processed using STATISTICA Software (Stat Soft, France). Data were reported as mean ± SD. The Kolmogorov-Smirnov test of normality revealed that data were normally distributed. Once the assumption of normality was confirmed, parametric tests were performed. To examine the associations between temperature and other variables, Pearson correlation analyzes were used. Performance measures and difficulty perception were analyzed using a three-way analysis of variance (ANOVA) [2 (time-of-day) × 2 (level of difficulty) × 2 (throw conditions)]. When appropriate, significant differences between means were assessed using the LSD *post hoc* test. Likewise, oral temperature data were analyzed using the test t-Student. The level of statistical significance was set at $p<0.05$.

3. Results

3.1. Temperature

Concerning oral temperature (table 1), the t-test result ($t = -5.39$, $p<0.05$) showed a significant main effect of time-of-day variable, indicating that oral temperature was significantly higher at 17:00 h (36.75 ± 0.19°C) than at 07:00 h (36.00 ± 0.39°C). Our result shows a significant correlation between temperature and error in the SD for morning session in both NC ($r = -0.88$, $p<0.001$) and TPC ($r = -0.85$, $p<0.001$). Moreover, there is a significant correlation between temperature and means errors in SD at 07:00 h in NC ($r = -0.88$, $p<0.001$). Data's show a significant correlation at 17:00 h between temperature and means errors for LD in both NC ($r = -0.64$; $p<0.05$) and TPC ($r = -0.88$; $p<0.001$).

Table 1. *Correlation between temperature, perception difficulty (PD), time pressure and performances measure.*

	07:00h				17:00h			
	SD		LD		SD		LD	
	NC	TPC	NC	TPC	NC	TPC	NC	TPC
Mean/Error	-0.88***	-0.85***	-0.88***	-0.42	-0.36	-0.44	-0.64*	-0.88***
Mean/PD	-0.1	-0.6*	-0.42	-0.39	0.07	-0.13	-0.15	-0.03
Error/PD	0.19	-0.58*	0.37	0.08	0.49	0.23	-0.04	-0.38
Temperature (C°)/Mean	-0.14	0.14	-0.42	0.08	-0.29	-0.23	0.08	-0.26
Temperature (C°)/Error	0.07	0.03	0.62*	0.03	-0.35	0.6*	-0.07	0.03
Temperature (C°)/PD	-0.14	0.27	-0.13	0.13	-0.08	0.37	0.19	0.52

*;**; *** Significant correlation at $p < 0.05$;$p < 0.01$; $p < 0.001$. (Respectively)

3.2. Difficulty Perception

ANOVA revealed a significant time-of-day effect on DP ($F= 12.15$, $p<0.01$), level of difficulty (SD and LD) ($F= 31.91$, $p<0.001$) and time-pressure ($F= 11.42$, $p<0.01$). However, the interaction time-of-day × level of difficulty × time pressure was not significant ($F = 4.48$, $p>0.05$).

The post hoc analysis revealed that DP decreased significantly between 07:00 h and 17:00 h ($p<0.01$) for NC (6.4 ±1 *vs.* 4.6 ±1.2 and 8.5 ± 2.5 *vs.* 7±2 for SD and LD, respectively) (see Table 1). Moreover, in TPC, DP scores were significantly higher at 07:00 h than at 17:00 h for SD ($p<0.05$) (7.4 ± 2.3 *vs.* 6.5 ± 2.1 respectively) and ($p<0.01$) for LD (10.3 ± 2.1 *vs.* 8 ± 1.9).

For level of difficulty, post hoc analysis revealed diurnal variation (evening < morning) in SD and LD for all conditions. DP has a clear rhythm and the score increases with increasing level of difficulty for the same condition (p<0.01; 8.5 ± 2.5 *vs.* 6.4 ± 1)

Table 2. *Perception of difficulty recorded at 07:00 h and 17:00 h at the two distances (D1 and D2) and during the normal condition (NC) and the time pressure condition (TPC).*

		D1		D2	
		NC	TPC	NC	TPC
DP	07:00 h	6.4 ± 1	7.4 ± 2.3$	8.5 ± 2.5###	10.3 ± 2.1$$###
	17:00 h	4.6 ± 1.2**	6.5 ± 2.1$$$*	7 ± 2###**	8 ± 1.9$##***

*, **, ***: significant difference between 07:00 and 17:00 h at the level of p < 0.05, p < 0.01 and p< 0.001 for the same condition respectively.
#, ##, ###: significant difference between D1and D2 at the level of p < 0.05, p < 0.01 and p< 0.001 the same condition respectively.
$, $$, $$$: significant difference between NC and TPC at the level of p < 0.05, p < 0.01 and p< 0.001 for the same condition respectively.

The score of DP was greater in the morning than in the evening and in the highest level of difficulty (distance 2"D2" than distance 1"D1") (p<0.001; 8.5 ± 2.5 *vs.* 7 ± 2; 8.5 ± 2.5 *vs.* 6.4 ± 1 respectively). Moreover, PD was greater in TPC condition than NC in D1 at 07:00 h (p<0.05; 7.4 ± 2.3 vs. 6.4 ± 1 respectively). The difference is significant (p<0.001; 6.5 ± 2.1 *vs.* 4.6 ± 1.2 respectively) for the same condition in D2. In addition, PD was superior in TPC than NC in D2 both at 07:00 h (p<0.01; 10.3 ± 2.1 *vs.* 8.5 ± 2.5 respectively) and at 17:00 h (p<0.05; 8 ± 1.9 *vs.* 7 ± 2 respectively) (Table 2).

3.3. Performance Measures

Mean scores, the number of zeros scored and the coefficient of variation (CV) of the mean are presented in Table 3. There was a significant time-of-day effect on accuracy (F= 9.38; p<0.05), and level of difficulty effect (F= 6.42; p<0.05). However, time pressure effect (F= 0.02; p>0.05) was not significant. Likewise, time-of-day × level of difficulty × time pressure interaction (F = 0.04; p>0.05) was not significant.

The post hoc analysis revealed that accuracy was significantly greater at 17:00 h than 07:00 h in SD during both NC (p<0.01; 4.06 ± 1.11 *vs.* 3.07 ± 1.45 respectively) and TPC (p<0.01; 3.9 ± 1.12 *vs.* 2.88 ± 1.09 respectively) and in LD during both NC (p<0.05; 3.15 ± 0.91 *vs.* 2.6 ± 1.55 respectively) and TPC (p<0.05; 3.32 ± 0.91 *vs.* 2.68 ± 0.92 respectively). Accuracy was significantly different between D1 and D2 only at 17:00 h during NC (p<0.05; 4.06 ± 1.11 *vs.* 3.15 ± 0.9 respectively). Mean scores correlated at 07:00 h with difficulty perception only for D2 during NC (r = - 0.687; p<0.05) and TPC (r = - 0.687; p<0.05). (Table 1)

There were significant main effects for time-of-day (F= 6.37; p<0.05) andlevel of difficulty (F= 9.28; p<0.05). However, time pressure effect (F= 0.01; p>0.05) was not significant. Likewise, time-of-day × level of difficulty × time pressure interaction (F = 0.63; p>0.05) was not significant. However, time-of-day × time pressure interaction (F = 6.25; p<0.05) was significant. The post hoc analysis revealed that the number of zeros scored decreased significantly throughout the daytime (i.e., only during NC in SD (p<0.01; 1.8 ± 1.3 *vs.* 0.7 ± 0.7 at 07:00 h and 17:00 h respectively) and LD (p<0.01; 2.6 ±1.7 vs. 1.4 ± 1 at 07:00 h and 17:00 h respectively) (Table3). The number of zeros scored correlated only at 07:00 h with perception difficulty in D2 during both NC (r = 0.634; p<0.05) and TPC (r = 0.623; p<0.05). (Table 1)

Table 3. *Performances measures recorded at 07:00 h and 17:00 h at the two distances (D1 and D2) and during the normal condition (NC) and the time pressure condition (TPC).*

		D1		D2	
		NC	TPC	NC	TPC
Mean	07:00 h	3.07 ± 1.45	2.88 ± 1.09	2.6 ± 1.55	2.68 ± 0.92
	17:00 h	4.06 ± 1.11**	3.9 ± 1.12**	3.15 ± 0.91##*	3.32 ± 0.91*
Error	07:00 h	1.8 ± 1.3	1.7 ± 1.2	2.6 ± 1.7	1.9 ± 0.9
	17:00 h	0.7 ± 0.7**	1 ± 1	1.4 ± 1**	1.8 ± 1#
CV	07:00 h	1.03 ± 0.45	0.94 ± 0.31	1.28 ± 0.67	1.04 ± 0.29
	17:00 h	0.65 ± 0.25*	0.75 ± 0.4	0.89 ± 0.35*	0.93 ± 0.31

*, **, ***: significant difference between 07:00 and 17:00 h at the level of p < 0.05, p < 0.01 and p< 0.001 for the same condition respectively.
#, ##, ###: significant difference between D1and D2 at the level of p < 0.05, p < 0.01 and p< 0.001 for the same condition respectively.

There was a significant main effect for time-of-day on CV (F = 5.63; p>0.05). The post hoc analysis showed that consistency was significantly higher at 17:00 h in comparison with 07:00 h for both SD (p<0.05) and LD (p<0.05). However, there was a significant level of difficulty effect on CV (F = 5.81; p<0.05). The post hoc analysis showed that the consistency measured for D2 was higher than the one measured for D1 during NC at both 07:00 h and 17:00 h(p<0.05).

4. Discussion

The aim of the current study was to investigate the effect of the time of day, the level of difficulty and time pressure on the psychomotor performance, through accuracy and consistency dart throwing performance. The main finding was that a diurnal variation existed in the accuracy of both short and long distance. Performance in throwing darts task at a dartboard was better in the late afternoon. This improvement was assessed through accuracy measure (i.e., the mean score and numbers of zeros) and consistency measure (i.e., coefficients of variation of the score (Table 3)). There was a significant effect of time-of-day effect on accuracy. The difference is more marked for the short than the long distance during the two conditions. Accuracy (mean score) was far more pronounced with the long than the short distance throws. Our results match those of Edwards et al, who claim that accuracy is more pronounced for longer than short distances [4]. Both short and long throw distances require muscle contraction and hand eye-coordination, but balance is displaced to the muscle contraction with long distance throws. There is a parallelism between the body temperature and muscle strength [38, 40]. In contrast, previous research shows greater accuracy in the short than in the long in badminton serve [40]. For the greater distance, throws required more force to reach the dart. This agrees with the concept of a trade-off between speed and accuracy [41]. Comparable results have been found in other throwing darts investigations [42], andin studies comparing the speed and accuracy of first and second serves in tennis [43]. Explicitly, when the conditions place a premium on muscle strength, performance increases in parallel with body temperature. In contrast, when the requirement is more for control of movement, then the parallelism with body temperature is lost and difficulty in perception becomes more important. That is, the present results, with boy's subjects, indicate that the throwing improvement accuracy in the evening for long distance is the result of the rising of temperature. This improvement is not observed in children because the quality of strength is not fully developed.

Accuracy improves throughout the day. This improvement between morning and evening was found for the short distance during the two conditions NC and TPC. These types of conditions need control mechanisms rather than muscle strength. It seems that the child, in the early morning, is less sensitive to the increased level of difficulty in using the pressure of time than the increase in distance. In the evening, subjects are more performing in higher level difficulty conditions (LD). Increasing the level of difficulty through raising the distance is compensated by the increased temperature in the evening.

There was a significant effect of time-of-day with numbers of zeros. The value of errors and coefficient of variation were greater with the long-distance than the short-distance throws during the NC and TPC. Similar results have been found [4]. Explanation was oriented to the identical posture and throwing action used for the two lengths of throw. Difference was due not to the recruitment of different muscle groups but rather to the increased activity from the same groups of muscles.

Moreover, and this is the second main finding of the present study, the difficulty perception showed an opposite rhythm to that of oral temperature. PD decreases throughout the waking day (Table 2). That is, PD increases with each level of difficulty of throws. Likewise, these fluctuations in performance can be attributed to structural changes.

In accordance with previous reports these changes can be explained by the difficulty of the task to which the subject is confronted [44, 45]. Several studies showed experimental manipulation (i.e., qualitative or quantitative) affects significantly the psychomotor performance [46], and problems during competitive challenges or training [47].

Moreover, the PD appears as a central determinant for the realisation of optimal performance. In addition, previous studies proved that the concept of DT is commonly introduced in psychological models such as motivation and emotions (Frömer et al. 2012). Consequently, the motivation and the DT have a leading role in the acceptance or rejection of the task [49]. These findings can explain the increase of difficulty in short distance in the afternoon rather than in the morning. Moreover, some authors have emphasized the role of the DT in adapting strategies in the realisation of task [50].

5. Conclusions

In conclusion, the results of the current study indicate that psychomotor performance was better in the evening than in the morning with short and long distance in boys. It seems that children, in the early morning, are less sensitive to the increased level of difficulty in using the pressure of time than the increase in distance. PD decreases throughout the waking day. Boys are more sensitive to the increased level of difficulty in the morning than in the evening.

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