*Original Article (short paper)*

# The effect of matinal active walking on cognitive, fine motor coordination task performances and perceived difficulty in 12-13 young school boys

Elghoul Yousri[1], Fatma Bahri[1], Chaari Nesrine[1], Souissi Nizar[2], Frikha Mohamed[3,4]

*[1]Sfax University, High Institute of Sport and Physical Education, Sfax, Tunisia; [2]Higher Institute of Sport and Physical Education of Ksar Said, Tunisia; [3]King Faisal University, Department of Physical Education, Al Hufūf, KSA; [4]University of Sfax, Research Sfax Unit (EM2S), High Institute of Sport and Physical Education, Sfax, Tunisia*

**Abstract** — **Aim:** The current study examined the relationship between cognitive performances (executive function, selective attention and reaction time), fine motor coordination skills and perceived difficulty after active transport to school. **Method:** Fifteen right-handed children's underwent session, 15-min walking session at 30% (WS1) and 15-min walking session (WS2) at 50% of maximal aerobic speed. Subjects performed tests to evaluate executive function, reaction time and selective attention. After each trial, a questionnaire of perceived difficulty (PD) was completed. **Results:** Average time in TMT part A ($F(2,22) = 4.44$; $p = 0.024$; $\eta^2 = 0.288$) and TMT part B ($F(2,22) = 4.54$; $p = 0.022$; $\eta^2 = 0.292$), and committed errors ($F(2,22) = 7.78$; $p = 0.003$; $\eta^2 = 0.414$) was improved after walking sessions in comparison by CS. The mean scores were significantly higher after walking sessions for both long and short-distance throws ($p < 0.05$). Moreover, a significant negative correlation was found between committed errors (TMT part B) and both dart throwing consistency and accuracy ($r = -0.6$; $r = -0.64$; $p < 0.05$) (respectively). Post-hoc analysis showed that PD was better after walking sessions with low intensity for both short and long throwing distance. However, it seems that walking session with sustained intensity allows speed and accuracy improvement of cognitive processing. **Conclusion:** Thus, active walking to school with low intensity was sufficient to produce positives changes in psychomotor performance and decrease in perceived difficulty scores. By including individual differences in gross motor coordination as well as physical activity level, the exact nature of the link between psychomotor skills and cognitive performance could be more addressed.

**Keywords:** active transport; boys; fine motor coordination; cognitive performances; perceived difficulty.

## Introduction

Physical activity (PA) is important for optimal childhood growth and development; the majority of children in developed countries are insufficiently active[1]. However, recent findings of systematic review confirm that PA is associated with numerous health benefits in school-aged children and youth. Journey between home and school become an important, potential source of PA for children[2,3,4]. Active Transportation (AT) to and/or from school (i.e., walking and biking) is one potential opportunity to be physically active, given that many children can incorporate this behavior into their daily routine[1,2,5]. Recently, Cooper et al.[6] showed that the journey to school of children who used AT, could contribute towards reaching daily PA requirements. Although recently research support thesis that AT is associated with a healthier body composition and higher levels of cardio-respiratory fitness among youth[7].

Generally, the literature shows that executive functions including attention, working memory, problem solving, cognitive flexibility, verbal fluency, decision making, and inhibitory control receive the most benefit from acute exercise[8]. In addition, a previous study concluded that increasing task difficulty or complexity may help to augment the effect of acute exercise on accuracy and speed of processing[9]. Moreover, moderate intensity exercise may be more beneficial to executive function (EF); whereas high-intensity exercise may be beneficial to information processing[8]. In primary school-aged children, author's found positive relation between total volume of light intensity physical activity and executive function (namely: planning performance)[10].

Recent studies suggest specific relationships between aspects of motor coordination and EF[11]. In addition, fine motor skills and EF can be considered as powerful predictors of school readiness and of subsequent academic achievement[12,13]. Thus, a recent hypothesis highlighted that physical activity targeted to increase both physical fitness and motor skills may have the potential to positively affect executive functions and academic performance[14]. Furthermore, the results show a significant correlation between perceived difficulty (PD) and EF in situations which higher levels of difficulty. Higher EF performance approves the ability to manage better the level of task difficulty[15]. Li and Belkin[16] define task difficulty as a subjective perception assessed by task doers. It could be formed in both pre and post-task[17]. Recent research shows that performance is limited by task difficulty, often in the form of a trade-off between speed and accuracy. Learning consists of breaking through this limit[18]. This new information about how to manipulate task difficulty is important when adapting tasks for use with children of different ages[19].

Regarding active transport study, only one reported that active commuting to school and its duration (more than 15 min) may positively influence cognitive performance (verbal, numeric, and reasoning abilities and an overall score) in adolescent girls but not in boys[20]. Furthermore, this study uses subjective data participants; do not consider their extracurricular physical activity and walking intensity to school. The majority of walking studies to school were based on parents' reports[21].

The current study examined the relationship between (i) ognitive performances (executive function, selective attention and reaction time) (ii) and perceived difficulty in fine motor coordination tasks after walking to school among 12-13 young boys.

### *Participants*

Fifteen right-handed children (age = 12.33 ± 0.9 years, body height = 157 ± 8.4, body mass = 45.4 ± 8.1 kg and MAS = 13.8 ± 1; mean ± SD) volunteered to participate in this study. They had no previous experience of the tasks they were asked to perform. All subjects participated in their physical activity classes 1–2 times per week and they did not have any outside-school activities. The protocol was explained in full and any questions were answered before a written informed consent was obtained from the children's parents and the children themselves. The study design received clearance from the Institutional Research Board before the commencement of this study procedure. The University Scientific Board approved this study with the number H2017/86. Participants visited the laboratory on four occasions in order to complete a familiarization session and three experimental trials.

### *Procedure*

During the familiarization session, participants threw a bloc of ten darts in each condition and then performed the Yo-Yo intermittent recovery test (Yo-Yo) in order to determine the maximal aerobic velocity (MAV)[22]. The Yo-Yo protocol was performed on a nonslip wooden floor of an indoor gym. Participants then participated in three experimental trials in a randomized manner at the same time of day (07:00 h), separated at least by five days. The three trials consisted of a no-walking session (no-WS: Control session (CS)) (Subjects performed a dart-throwing test and cognitive tasks)[15] and two 15-min walking sessions (WS), with each WS trial performed at a different intensity as reported by[4]. After each WS subjects performed a dart-throwing test in two experimental sessions and cognitive tasks.

All WS trials were performed on the same motorized treadmill (COSMED T170, Italy). The intensity of each WS was determined as follows:

WS 1 = intensity at 30% of maximal aerobic speed

WS 2 = intensity at 50% of maximal aerobic speed

After each dart throw, the score for the dart was recorded and then the dart was collected for the next throw[23]. An official dartboard was placed on a wall so that its center was at eye level for each subject. Participants threw ten darts from two distances in randomized order. The first distance was 2 m (SD); the second was at the regular distance of 2.37 m (LD). The two distances were marked by a line on the floor[15]. After each session, a questionnaire to asses PD (DP-15) was completed by the subjects. This scale is composed of 15 points numbered 1–15 and is anchored at the two extremities by verbal labels – "Extremely easy" and "Extremely difficult" [24].

### *Yo-Yo intermittent recovery test*

The Yo-Yo IR1 consisted of repeated 2 × 20-m of running at a progressively increased speed controlled by audio beeps from a tape recorder[25]. Between each running bout the participants had a 10-s rest period. When the participant failed to reach the finishing line in time twice, the distance covered was recorded and represented the test result. The test was performed indoor (on a 2-m-wide and 20-m-long running lane marked by cones). Six participants performed the test simultaneously with strong verbal encouragement provided to the subjects throughout the test. Total distance was reported as the performance criterion in the Yo-Yo IR1[26].

### *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 using three scores. The first was the mean score of the ten 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 10, 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[15].

### *The barrage test (i.e. a paper-pencil test)*

The barrage test is a psychometric task, which measure visual-spatial ability, attention, and recognition. It involves visual discrimination; the subject must circle all the targets (bells) that are encountered. A total of 35 targets (bells), were distributed equally in seven columns. In each column, there was the same number of targets (N = 5) and of distracters (N = 40). All drawings were black – like Chinese shadows. Subject performance was evaluated quantitatively (number of bells crossed and omitted). The duration of the test was 3 min, a higher number of correct responses reflecting better performance[27].

### *The choice RT (Using React's software)*

A colored geometric form (used as a "target") was presented to the subject. When the test was started, there was a succession of different colored geometric forms. When the target appeared, the subject was required to press a button as soon as possible, and the computer calculated the RT. The time between presenting each form was 300 ms and each subject had 20 targets presented[15]. Scores were expressed in seconds; higher scores reflect poorer performance.

### *Trail making test*

This is a test exploring mental flexibility EF (aptitude to move quickly from one task to another)[28]. In Part A, circles were numbered 1–25 and presented randomly on a sheet of paper; subjects were required to draw lines to connect the numbers in ascending order. In Part B, the circle included both numbers (1–15) and letters (A–L); as in Part A, the child was required to draw lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e. 1-A-2-B-3-C, etc.); the child was also instructed to connect the circles as quickly as possible without lifting the pen or pencil from the paper. The duration of the test was 3 min for each part. The trail-making test (TMT) measures visual conceptual and visuo-motor tracking. TMT part A purportedly measures attention, visual search, and motor function, whereas TMT part B is seen as a measure of EF, speed of attention, visual search, and motor function[29]. Outcome measures for both tasks included time to completion and number of errors[29]. Results for both TMT A and B are reported as the number of seconds required to complete the task[30] errors committed and corrected. Higher scores reveal greater impairment.

### *Statistical analysis*

All statistical tests were processed using STATISTICA Software (StatSoft, Paris, France). Data were reported as mean ± SD. The Kolmogorov–Smirnov test of normality revealed the data which were normally distributed; therefore, parametric tests were performed. To examine the associations between cognitive performance and other variables, Pearson correlation analyzes were used.

Performance measures and difficulty of perception were analyzed using a two-way ANOVA with repeated measures [2(Distance) × 3(walking session)]. ANOVA with repeated measures used to analyze walking sessions and cognitive performance. When appropriate, significant differences between means were assessed using post hoc tests. Effect sizes were calculated as partial eta-squared $\eta^2$ to estimate the meaningfulness of significant findings. Partial eta squared values of 0.01, 0.06 and 0.13 represent small, moderate, and large effect sizes, respectively. The level of statistical significance was set at $p < 0.05$.

## Results

Analysis of the performance throws (mean scores: measure of accuracy) resulted in no significant interaction effect walking session × distance of throw ($F_{(2,22)} = 0.41$; $p = 0.66$; $\eta^2 = 0.036$). There was a significant main effect for walking session (WS) ($F_{(2,22)} = 4.68$; $p = 0.02$; $\eta^2 = 0.298$) and distance of throw ($F_{(2,22)} = 8.21$; $p = 0.01$; $\eta^2 = 0.427$). Post-hoc analyses demonstrated a significant difference between mean scores after the two walking sessions (WS1 and WS2). The mean scores were significantly higher after WS1 and WS2 for both long- and short-distance (LD and SD) throws ($p < 0.05$). Furthermore, there were significant differences between mean scores after WS 2 between SD and LD ($p = 0.03$). Additionally, the ANOVA revealed no significant effect of walking session ($F_{(2,22)} = 1.27$; $p = 0.29$; $\eta^2 = 0.103$) and distance of throw ($F_{(2,22)} = 0.37$; $p = 0.55$; $\eta^2 = 0.033$) for errors (numbers of zeros). Finally, ANOVA also revealed a significant walking session effect ($F_{(2,22)} = 5.75$; $p = 0.009$; $\eta^2 = 0.343$) for the consistency which the darts were thrown. The pos-hoc analysis showed that the coefficient of variation (CV) of the mean of the scores was significantly different only in the CS between SD and LD. CV was better after WS1 than WS2 and CS (respectively).

Analysis revealed a significant effect of walking session ($F_{(2,22)} = 4.44$; $p = 0.024$; $\eta^2 = 0.287$) for EF (average time in TMT part A). The post-hoc analysis showed that completion time (TMT part A) was significantly different after both WS1 and WS2 in comparison by CS (Table1). No significant difference was found for committed and corrected errors in TMT part A.

Analysis revealed significant effect of walking session ($F_{(2,22)} = 4.54$; $p = 0.022$; $\eta^2 = 0.292$) for EF (average time in TMT part B). Post-hoc analyses demonstrated a significant difference between time in TMT part B after the two walking sessions (WS1 and WS2) in comparison by CS (Figure1). Moreover, significant difference was found in committed errors in TMT part B ($F_{(2,22)} = 7.78$; $p = 0.002$; $\eta^2 = 0.414$) (Table1). Post-hoc analysis shows that better performance was recorded after WS1 in comparison by WS2 and CS (respectively). Results showed significant positive correlations after CS between committed errors in TMT part A and corrected errors in TMT part B ($r = 0.63$; $p < 0.05$). Results showed also a significant positive correlation after CS in EF (TMT part B) between average time and corrected errors ($r = 0.67$; $p < 0.05$). The links between fine motor coordination skills and EF were investigated. Data's showed no significant difference between measured variables in fine coordination task (throwing task) and TMT (part A and B) after CS and WS1. There was a significant positive correlation after WS2 between mean score in LD and committed errors (TMT part B) ($r = 0.76$; $p < 0.01$). Moreover, a significant negative correlation was found between committed errors (TMT part B) and both CV and number of zeros ($r = -0.6$; $p < 0.05$; $r = -0.64$; $p < 0.05$) (respectively).

Analysis of reaction time data's, results showed a no significant main effect of walking session ($F_{(2,22)} = 1.97$; $p = 0.163$; $\eta^2 = 0.152$) on average time in reaction time (Table 1). There was a significant positive correlation between RT and average time after WS2 ($r = 0.58$; $p < 0.05$). No significant correlation was found between RT and measured variables in fine coordination task after all sessions.

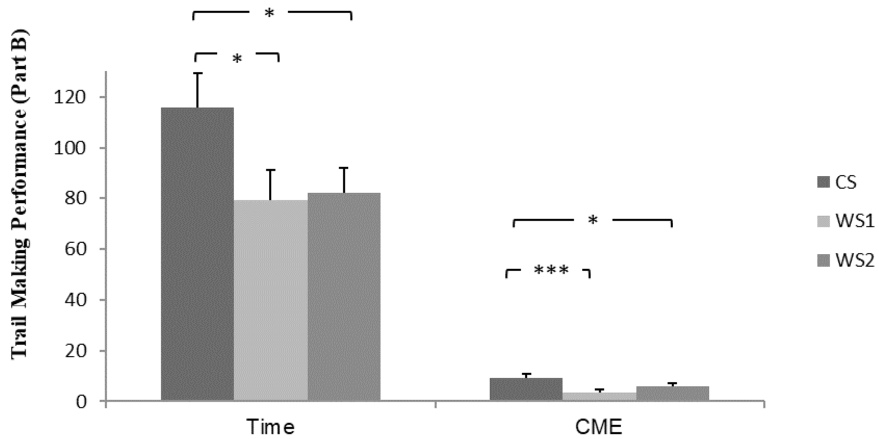
Table 1. Mean ± SD values for cognitive performances measures: RT; barrage test; and EF (TMT parts A and B) at CS, WS1 and WS2.

| | | CS | WS1 | WS2 | $F_{(2,22)}$ | p | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| TMT Part A | Average time (s) | 45,02±18,75 | 31,43±9,56* | 31,94±12,62* | 4,442 | 0,024 | 0,288 |
| | Committed errors | 0,33±1,15 | 0±0 | 0,25±0,45 | 0,67 | 0,52 | |
| | Corrected errors | 0±0 | 0±0 | 0,17±0,39 | 2,2 | 0,13 | |
| TMT Part B | Average time (s) | 115,7±46,7 | 79,2±41,5* | 82±34,9* | 4,546 | 0,022 | 0,292 |
| | Committed errors | 9,25±5,24 | 3,42±4,54*** | 6,08±3,6* | 7,781 | 0,003 | 0,414 |
| | Corrected errors | 0,42±0,79 | 1,08±2,84 | 0,33±0,65 | 0,788 | 0,467 | 0,067 |
| Barrage test | Crossed bells (CB) | 32,08±1,56 | 33,17±1,75 | 33,08±1,56 | 1,801 | 0,189 | 0,141 |
| | Unbarred bells (CNB) | 2,92±1,56 | 1,83±1,75 | 1,92±1,56 | 1,801 | 0,189 | 0,141 |
| Reaction Time | Average time (s) | 0,42±0,04 | 0,4±0,03 | 0,39±0,05 | 1,971 | 0,163 | 0,152 |

* Significantly different from CS at p < .05; ** p < .01; *** p < .001.

The ANOVA of selective attention revealed a no significant walking session effect ($F_{(2,22)} = 1.801$; $p = 0.189$; $\eta^2 = 0.141$) for SA (Table 1). There was no significant correlation between all variables of our study in CS and WS1. In WS2, there was a significant positive correlation between SA (Crossed bells) and EF (committed errors in TMT part B) (r = 0.76; p < 0.01). Results also showed significant negative correlations only after WS2 between SA (Unbarred bells) and FE (committed errors in TMT part B) (r = - 0.76; p < 0.01). In addition, significant correlation was found only after WS2 between SA and accuracy measures (errors and mean scores). Results showed significant negative correlation between SA (Crossed bells) and errors in LD (r = - 0.57; p < 0.05), in contrary a positive significant correlation between SA (Unbarred bells) and errors in LD (r = 0.57; p < 0.05). Finally, there was a significant positive correlation between SA (Crossed bells) and means scores in SD (r = 0.66; p < 0.05). A significant negative correlation was found between SA (Unbarred bells) and means scores in SD (r = -0.66; p < 0.05).

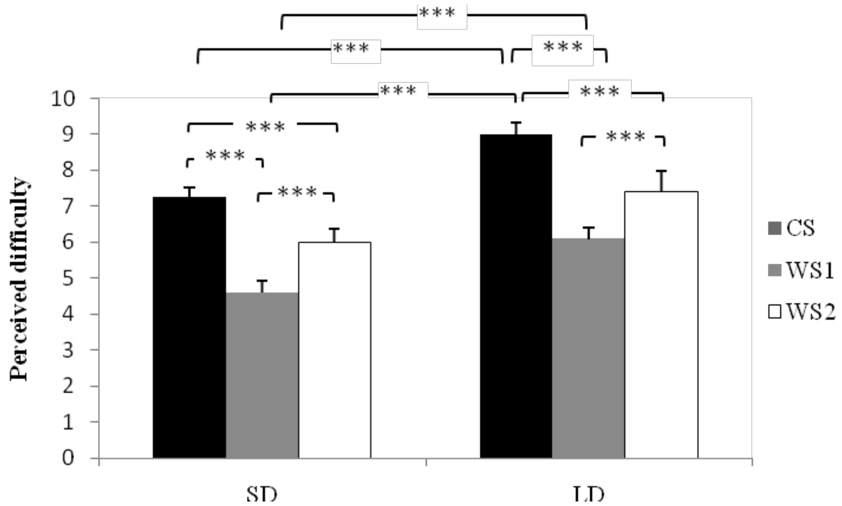
Figure 1. Average time completion and committed error in Trail Making Test (Part B) (second and number of error, respectively) at CS, WS1 and WS2. CS indicates Control session; WS30%: Walking session at 30% of the maximal aerobic velocity (MAV); WS50%: Walking session at 50% of the MAV.




*, ***: significant difference between CS, WS1 and at the level of p < 0.05 and p< 0.001 for the same condition respectively.

There was a significant main effect of walking session for perceived difficulty (PD) ($F_{(2,22)}= 11.54$; $p < 0.001$; $\eta^2 = 0.512$). Additionally, the ANOVA revealed significant effect of distance of throw ($F_{(2,22)} = 50.72$; $p < 0.001$;$\eta^2 = 0.821$) (Figure 2). However, the interaction walking session × distance of throw was not significant ($F_{(2,22)} = 0.412$; $p > 0.05$;$\eta^2 = 0.036$). The pos-hoc analysis showed that PD was better after WS1 for both short and long distance compared to WS1 and CS (respectively). Moreover, in CS, PD was correlated significantly with both average time in TMT part A (r = 0.58; p < 0.05) in SD and negatively with committed errors in TMT part B in SD and LD of throw (r = -0.75; p < 0.01; r = - 0.71; p < 0.01). No significant correlation was found between PD and variables of study in WS1. In WS2, there was a significant positive correlation between PD and EF (average time in TMT part B) in both SD (r = 0.66; p < 0.05) and LD of throw (r = 0.56; p < 0.05).

Figure 2. Perceived difficulty score on SD and LD at CS, WS1 and WS2. CS indicates Control session; WS30%, Walking session at 30% of the maximal aerobic velocity (MAV); WS50%, Walking session at 50% of the MAV; SD, Short distance of throw; LD, Long distance of throw.




*, **, ***: significant difference between CS, WS1 and at the level of p < 0.05 and p< 0.001 for the same condition respectively.

Table 2. Correlations between cognitive performances measures: reaction time (RT); barrage test; and executive function (TMT parts A and B), dart throwing scores: CV; Errors; and Mean scores) and perceived difficulty score (PD) at CS.

| CS | | TMT Part A | | | TMT Part B | | | Barrage test | | RT | PD | | CV | | Errors | | Mean scores | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Time(s)** | **CME** | **CRE** | **Time(s)** | **CME** | **CRE** | **CB** | **UBB** | **Time(s)** | **SD** | **LD** | **SD** | **LD** | **SD** | **LD** | **SD** | **LD** |
| TMT Part A | Time(s) | 1 | -0,02 | 0 | 0,07 | -0,49 | 0,19 | 0,02 | -0,02 | 0,06 | 0,58$^{*}$ | 0,44 | 0,1 | 0,44 | 0,29 | 0,45 | -0,22 | -0,4 |
| | CME | -0,02 | 1 | 0 | 0,43 | 0,17 | 0,63$^{*}$ | -0,02 | 0,02 | -0,01 | -0,32 | -0,45 | -0,07 | -0,07 | -0,15 | 0,02 | 0,15 | 0,16 |
| | CRE | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TMT Part B | Time(s) | 0,07 | 0,43 | 0 | 1 | 0,47 | 0,67$^{*}$ | -0,07 | 0,07 | 0,25 | -0,32 | -0,18 | -0,13 | 0,08 | -0,06 | 0,16 | -0,12 | -0,04 |
| | CME | -0,49 | 0,17 | 0 | 0,47 | 1 | 0,34 | -0,29 | 0,29 | -0,35 | -0,75$^{**}$ | -0,71$^{**}$ | -0,25 | 0,01 | -0,4 | 0,05 | 0,18 | -0,11 |
| | CRE | 0,19 | 0,63$^{*}$ | 0 | 0,67$^{*}$ | 0,34 | 1 | 0,04 | -0,04 | 0,16 | -0,21 | -0,24 | 0,01 | 0,41 | -0,18 | 0,56$^{*}$ | 0 | -0,29 |
| Barrage test | CB | 0,02 | -0,02 | 0 | -0,07 | -0,29 | 0,04 | 1 | -1$^{***}$ | 0,45 | 0,04 | 0,21 | -0,23 | -0,33 | 0,07 | -0,2 | 0,14 | 0,39 |
| | UBB | -0,02 | 0,02 | 0 | 0,07 | 0,29 | -0,04 | -1$^{***}$ | 1 | -0,45 | -0,04 | -0,21 | 0,23 | 0,33 | -0,07 | 0,2 | -0,14 | -0,39 |
| RT | Time(s) | 0,06 | -0,01 | 0 | 0,25 | -0,35 | 0,16 | 0,45 | -0,45 | 1 | 0,34 | 0,48 | 0,12 | -0,07 | 0,29 | 0,12 | -0,18 | 0,2 |
| PD | SD | 0,58$^{*}$ | -0,32 | 0 | -0,32 | -0,75$^{**}$ | -0,21 | 0,04 | -0,04 | 0,34 | 1 | 0,9$^{***}$ | 0,38 | 0,21 | 0,44 | 0,23 | -0,28 | -0,05 |
| | LD | 0,44 | -0,45 | 0 | -0,18 | -0,71$^{**}$ | -0,24 | 0,21 | -0,21 | 0,48 | 0,9$^{***}$ | 1 | 0,46 | 0,15 | 0,52 | 0,11 | -0,48 | -0,05 |
| CV | SD | 0,1 | -0,07 | 0 | -0,13 | -0,25 | 0,01 | -0,23 | 0,23 | 0,12 | 0,38 | 0,46 | 1 | 0,67$^{*}$ | 0,79$^{**}$ | 0,5 | -0,7$^{**}$ | -0,43 |
| | LD | 0,44 | -0,07 | 0 | 0,08 | 0,01 | 0,41 | -0,33 | 0,33 | -0,07 | 0,21 | 0,15 | 0,67$^{*}$ | 1 | 0,47 | 0,93$^{***}$ | -0,47 | -0,79$^{**}$ |
| Errors | SD | 0,29 | -0,15 | 0 | -0,06 | -0,4 | -0,18 | 0,07 | -0,07 | 0,29 | 0,44 | 0,52 | 0,79$^{**}$ | 0,47 | 1 | 0,36 | -0,52 | -0,1 |
| | LD | 0,45 | 0,02 | 0 | 0,16 | 0,05 | 0,56$^{*}$ | -0,2 | 0,2 | 0,12 | 0,23 | 0,11 | 0,5 | 0,93$^{***}$ | 0,36 | 1 | -0,32 | -0,66$^{*}$ |
| Mean scores | SD | -0,22 | 0,15 | 0 | -0,12 | 0,18 | 0 | 0,14 | -0,14 | -0,18 | -0,28 | -0,48 | -0,7$^{**}$ | -0,47 | -0,52 | -0,32 | 1 | 0,61$^{*}$ |
| | LD | -0,4 | 0,16 | 0 | -0,04 | -0,11 | -0,29 | 0,39 | -0,39 | 0,2 | -0,05 | -0,05 | -0,43 | -0,79$^{**}$ | -0,1 | -0,66$^{*}$ | 0,61$^{*}$ | 1 |

* Significantly different from CS at p < .05; ** p < .01; *** p < .001. CS indicates Control session; CME: Committed error; CRE: Corrected errors; CB: Crossed bells; UBB: Unbarred bells; RT: Reaction time; SD: Short distance of throw; LD: Long distance of throw.

Table 3. Correlations between cognitive performances measures: reaction time (RT); barrage test; and executive function (TMT parts A and B), dart throwing scores: CV; Errors; and Mean scores) and perceived difficulty score (PD) at WS1.

| 30% | | TMT Part A | | | TMT Part B | | | Barrage test | | RT | PD | | CV | | Errors | | Mean scores | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Time(s) | CME | CRE | Time(s) | CME | CRE | CB | UBB | Time(s) | SD | LD | SD | LD | SD | LD | SD | LD |
| TMT Part A | Time(s) | 1 | 0 | 0 | 0 | 0,02 | 0,21 | -0,46 | 0,46 | -0,2 | 0,09 | 0 | 0,02 | -0,2 | -0,39 | -0,09 | -0,14 | -0,02 |
| | CME | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CRE | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TMT Part B | Time(s) | 0 | 0 | 0 | 1 | 0,54 | -0,17 | 0,35 | -0,35 | -0,21 | -0,28 | -0,54 | -0,16 | -0,08 | 0,02 | -0,13 | -0,1 | 0,07 |
| | CME | 0,02 | 0 | 0 | 0,54 | 1 | 0,47 | 0,28 | -0,28 | 0,26 | 0,31 | -0,36 | 0,16 | -0,37 | -0,09 | -0,44 | -0,24 | 0,15 |
| | CRE | 0,21 | 0 | 0 | -0,17 | 0,47 | 1 | -0,06 | 0,06 | 0,16 | 0,3 | 0,07 | 0,18 | -0,3 | -0,39 | -0,2 | -0,14 | -0,12 |
| Barrage test | CB | -0,46 | 0 | 0 | 0,35 | 0,28 | -0,06 | 1 | -1*** | -0,09 | -0,14 | 0,25 | 0,48 | -0,22 | 0,3 | -0,28 | 0,28 | 0,27 |
| | UBB | 0,46 | 0 | 0 | -0,35 | -0,28 | 0,06 | -1*** | 1 | 0,09 | 0,14 | -0,25 | -0,48 | 0,22 | -0,3 | 0,28 | -0,28 | -0,27 |
| RT | Time(s) | -0,2 | 0 | 0 | -0,21 | 0,26 | 0,16 | -0,09 | 0,09 | 1 | 0,3 | 0,33 | -0,4 | -0,2 | -0,51 | -0,37 | 0,08 | -0,34 |
| PD | SD | 0,09 | 0 | 0 | -0,28 | 0,31 | 0,3 | -0,14 | 0,14 | 0,3 | 1 | 0,19 | 0,39 | -0,68 | -0,4 | -0,65 | -0,37 | 0,36 |
| | LD | 0 | 0 | 0 | -0,54 | -0,36 | 0,07 | 0,25 | -0,25 | 0,33 | 0,19 | 1 | 0,71** | -0,1 | 0,03 | -0,2 | 0,07 | 0,08 |
| CV | SD | 0,02 | 0 | 0 | -0,16 | 0,16 | 0,18 | 0,48 | -0,48 | -0,4 | 0,39 | 0,71** | 1 | -0,39 | -0,34 | -0,5 | -0,06 | 0,36 |
| | LD | -0,2 | 0 | 0 | -0,08 | -0,37 | -0,3 | -0,22 | 0,22 | -0,2 | -0,68* | -0,1 | -0,39 | 1 | 0,46 | 0,93*** | 0,52 | -0,72** |
| Errors | SD | -0,39 | 0 | 0 | 0,02 | -0,09 | -0,39 | 0,3 | -0,3 | -0,51 | -0,4 | 0,03 | -0,34 | 0,46 | 1 | 0,35 | 0,46 | -0,14 |
| | LD | -0,09 | 0 | 0 | -0,13 | -0,44 | -0,2 | -0,28 | 0,28 | -0,37 | -0,65* | -0,2 | -0,5 | 0,93*** | 0,35 | 1 | 0,66* | -0,77** |
| Mean scores | SD | -0,14 | 0 | 0 | -0,1 | -0,24 | -0,14 | 0,28 | -0,28 | 0,08 | -0,37 | 0,07 | -0,06 | 0,52 | 0,46 | 0,66* | 1 | -0,48 |
| | LD | -0,02 | 0 | 0 | 0,07 | 0,15 | -0,12 | 0,27 | -0,27 | -0,34 | 0,36 | 0,08 | 0,36 | -0,72** | -0,14 | -0,77** | -0,48 | 1 |

Table 4. Correlations between cognitive performances measures: reaction time (RT); barrage test; and executive function (TMT parts A and B), dart throwing scores: CV; Errors; and Mean scores) and perceived difficulty score (PD) at WS2.

| 50% | | TMT Part A | | | TMT Part B | | | Barrage test | | RT | PD | | CV | | Errors | | Mean scores | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Time(s) | CME | CRE | Time(s) | CME | CRE | CB | UBB | Time(s) | SD | LD | SD | LD | SD | LD | SD | LD |
| TMT Part A | Time(s) | 1 | 0,19 | -0,11 | 0,27 | 0,13 | 0,31 | 0,36 | -0,36 | 0,58* | 0 | -0,06 | -0,12 | -0,01 | -0,27 | -0,09 | 0,07 | -0,17 |
| | CME | 0,19 | 1 | 0,77** | -0,32 | -0,01 | -0,31 | -0,16 | 0,16 | 0,25 | -0,22 | -0,49 | 0,08 | 0,04 | 0,24 | 0,19 | 0,1 | -0,23 |
| | CRE | -0,11 | 0,77** | 1 | -0,41 | -0,14 | -0,24 | -0,17 | 0,17 | 0,36 | 0 | -0,17 | -0,25 | -0,13 | -0,11 | -0,09 | 0,28 | -0,19 |
| TMT Part B | Time(s) | 0,27 | -0,32 | -0,41 | 1 | 0,48 | 0,22 | 0,46 | -0,46 | -0,15 | 0,66* | 0,56* | 0,09 | -0,29 | 0,04 | -0,27 | 0,02 | 0,41 |
| | CME | 0,13 | -0,01 | -0,14 | 0,48 | 1 | 0,37 | 0,76** | -0,76** | -0,12 | 0,1 | -0,16 | 0,07 | -0,6* | 0,14 | -0,64* | 0,46 | 0,76** |
| | CRE | 0,31 | -0,31 | -0,24 | 0,22 | 0,37 | 1 | 0,51 | -0,51 | 0,36 | 0,08 | 0,02 | -0,41 | -0,32 | -0,26 | -0,41 | 0,58* | 0,28 |
| Barrage test | CB | 0,36 | -0,16 | -0,17 | 0,46 | 0,76** | 0,51 | 1 | -1*** | 0,16 | 0,26 | 0,1 | -0,32 | -0,39 | -0,34 | -0,57* | 0,66* | 0,45 |
| | UBB | -0,36 | 0,16 | 0,17 | -0,46 | -0,76** | -0,51 | -1*** | 1 | -0,16 | -0,26 | -0,1 | 0,32 | 0,39 | 0,34 | 0,57* | -0,66* | -0,45 |
| RT | Time(s) | 0,58* | 0,25 | 0,36 | -0,15 | -0,12 | 0,36 | 0,16 | -0,16 | 1 | -0,11 | -0,14 | -0,28 | 0,08 | -0,34 | -0,07 | 0,24 | -0,25 |
| PD | SD | 0 | -0,22 | 0 | 0,66* | 0,1 | 0,08 | 0,26 | -0,26 | -0,11 | 1 | 0,9*** | -0,25 | -0,44 | -0,29 | -0,41 | 0 | 0,25 |
| | LD | -0,06 | -0,49 | -0,17 | 0,56* | -0,16 | 0,02 | 0,1 | -0,1 | -0,14 | 0,9*** | 1 | -0,27 | -0,21 | -0,41 | -0,27 | -0,12 | 0,01 |
| CV | SD | -0,12 | 0,08 | -0,25 | 0,09 | 0,07 | -0,41 | -0,32 | 0,32 | -0,28 | -0,25 | -0,27 | 1 | 0,27 | 0,9*** | 0,44 | -0,71** | 0,07 |
| | LD | -0,01 | 0,04 | -0,13 | -0,29 | -0,6* | -0,32 | -0,39 | 0,39 | 0,08 | -0,44 | -0,21 | 0,27 | 1 | 0,22 | 0,91*** | -0,27 | -0,81*** |
| Errors | SD | -0,27 | 0,24 | -0,11 | 0,04 | 0,14 | -0,26 | -0,34 | 0,34 | -0,34 | -0,29 | -0,41 | 0,9*** | 0,22 | 1 | 0,46 | -0,49 | 0,13 |
| | LD | -0,09 | 0,19 | -0,09 | -0,27 | -0,64* | -0,41 | -0,57* | 0,57* | -0,07 | -0,41 | -0,27 | 0,44 | 0,91*** | 0,46 | 1 | -0,46 | -0,69** |
| Mean scores | SD | 0,07 | 0,1 | 0,28 | 0,02 | 0,46 | 0,58* | 0,66* | -0,66* | 0,24 | 0 | -0,12 | -0,71** | -0,27 | -0,49 | -0,46 | 1 | 0,17 |
| | LD | -0,17 | -0,23 | -0,19 | 0,41 | 0,76** | 0,28 | 0,45 | -0,45 | -0,25 | 0,25 | 0,01 | 0,07 | -0,81*** | 0,13 | -0,69** | 0,17 | 1 |

* Significantly different from CS at $p < .05$; ** $p < .01$; *** $p < .001$. CS indicates Control session; CME: Committed error; CRE: Corrected errors; CB: Crossed bells; UBB: Unbarred bells; RT: Reaction time; SD: Short distance of throw; LD: Long distance of throw.

## Discussion

The aim of this study was to explore the relationship of the cognitive performances (executive function, selective attention and reaction time) and perceived difficulty in fine motor coordination tasks after the portion of active transport to school. The data supported the hypothesis that achieving walking session to school with appropriate intensity enables differential improvement on the measured cognitive variables (executive function, selective attention and reaction time). Findings confirm that only EF (cognitive flexibility) can be improved by gains in speed process and in errors committed numbers. Positives changes in psychomotor performance were demonstrated by accessing throwing tasks and a diminution PD scores in the same fine motor coordination tasks was observed.

Improvement in EF was demonstrated by the decrease in time completion for trail-making task (part A and B) and committed errors only in trail-making task (part B). To our knowledge, this is the first study that shows that the improvement in cognitive function differs between the processes and it was related to intensities of walking session to school. Previous findings suggest that active commuting to school was associated with better in boys was positively associated with objectively PA assessment[31] and cognitive performance (namely: verbal ability, numeric ability, reasoning ability, overall cognitive performance) in adolescent girls who spent more than 15 minutes than those who spent less time[20]. Other researchers have suggested that in older adults performing an executive processing task, response times decreased and response errors increased when walking at faster speed compared with walking at slower speed[32]. On the other hand, the young healthy subjects can increase the ability to walk at higher speeds and a difficult cognitive task with no drop in performance[33]. In addition, the majority of studies observed positive associations between PA and number of tests measuring EF[34,35,36]. Furthermore, three studies have identified no significant positive associations[37,38,39]. Despite the fact that it is not yet clear the typical physical activity patterns of children involving performance at the executive level[10]. Studies stipulate that children are engaged in low-intensity physical that can place a demand on their executive functioning[10]. The variation in the level of cognitive commitment of activity and age[40] may influence the development of the executive function. Recently, EF was included as a predictor of early academic achievement[41].

In line with our main finding, the associations between physical activity and cognition, several mechanisms have been suggested to explain a beneficial effect of physical activity on cognition[42]. The effect of exercise on the brain could be the result of several factors including increased flow of blood and oxygen to the brain[43]. Other explanation supports the hypothesis of levels of chemicals and increased activity-dependent synaptic plasticity[44]. Moreover, previous studies conducted with children have indicated increased efficiency in neural processing and changes in brain structures[45,46]. In addition, the moderate arousal level has been associated with the increased performance on the Trail-making test and these findings are discussed in light of the inverted-U hypothesis[47].

Concerning the performance in the throwing task registered after the two experimental sessions, secondary findings of the present study showed that the mean scores and the standard deviations of the mean score (CV) were better after WS1 compared to WS2 and CS (respectively). After WS1 sessions, our results showed that means score were not significantly different in comparison with WS2. In addition, no significant difference was recorded between WS1 and WS2 in errors (number of zeros). However, the standard deviations of the mean score were significantly different only in LD after SW1 in comparison with WS2 conditions. It is difficult to compare our results with those in the scientific literature due the lack of previous study. In addition, the result of the present study could be attributed to the consistency improvement. The enhancement of the subject performance is linked to its ability to reduce disparities between the thrown. Strong positive correlations between the number of zeros scored and the standard deviation for only LD after WS2 support these findings.

Further explanation for the results considers that the improvement of psychomotor performance can be explained by the increase of the activity from the same groups of muscles essential to the test. In this context, the current results support the view that there is a trade-off between force and accuracy[48,49]. This compromise was found in other studies of darts and tennis and badminton serves[50,51,52] but not in all studies of darts throwing task[53]. That is, these results appear to be in dispute with those of Elghoul et al.[15], and the improved psychomotor performance is correlated with executive function for the throws long distances.

In the morning, our results showed that PD values were significantly higher after the no-walking session in comparison with WS2 and WS1 conditions ($p$<0.001) respectively. However, the PD scores were significantly higher after no-WS both for SD and LD ($p$<0.001). In addition, no significant correlations between PD and performances measures were found. One of the main findings in the current study was that PD of a throwing darts task at a dartboard was better after WS1 in both SD and LD. It seems that the same task was perceived less difficult after SW1 than SW2 and no-WS conditions (respectively). Previous studies have shown that the concept of task difficulty is commonly introduced into psychological models dealing with motivation and emotion[54]. PD reflects mainly the amount of resources, or effort, that subjects have invested in the task in order to reach a given level of performance[55]. PD could be considered as an indicator of the amount of effort that a subject intends to invest and/or has invested on the task. This finding may be supported by mean scores result which better after WS1. Therefore, subjective goal-difficulty could have a positive effect on performance; in addition effects intensity walking, time of day, time awake, and the distance the darts need to be thrown[56].

Beyond the contradiction regarding the effect of an active transport to school, gender and age of the participants[31], our results induce new findings. It seems that 15 min duration of walking session at 50% of MAS causes fatigue to our subjects but allows better EF improvement. In addition, the active walk to school with low intensity (30% of MAS) was sufficient to produce positives changes in psychomotor performance and diminution in PD scores in comparison with passive transport to the school. The results of our study show that perceived difficulty supports this finding.

The strength of this study come from the use of objective measures to assess walking sessions with different intensities, which gives an accurate result and possible reflection in order to better understand what beneficial for children. Also, this study used several measures for cognitive processes, examining the relationships between cognitive and psychomotor performances. It is worth noting that effect sizes of this study were consistent with medium to large effect. However, this study focuses on fine motor coordination only. By including individual differences in gross motor coordination and physical activity level, the exact nature of the link between cognitive performance and psychomotor skills could be more resolved.

## Conclusions

In conclusion, our results show evidence of a positive relationship of active walk to school with both cognitive and fine motor coordination performance. In addition, findings support decrease in the value of PD for the same psychomotor tasks. Additional explanations are needed to adjust the intensity and the duration of walking sessions to the demands of students or educators. However, more intervention studies are warranted in order to clarify possible mechanisms that made optimal relationship. In addition, it would be interesting to investigate whether using objective measures of commuting to school with different level of physical activity and tasks may provide more information on the relationships that we have found. The mode of transport to school can be retained as a source of differentiation between students.

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## *Corresponding author*


Elghoul Yousri
Mharza Road km1.5; 208, n10; Sfax 3003, Tunisia.
E-mail: elghoulyousri@yahoo.fr



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