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# Investigation of the relationship between upper extremity lateralization and dual task cost in individuals with hemiplegic cerebral palsy

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## Abstract

**Introduction:** This study aims to investigate the relationship between upper extremity lateralization and dual-task cost in individuals with Hemiplegic Cerebral Palsy (HCP). This is a new and unknown issue in Cerebral Palsy.
**Material and methods:** The descriptive, cross-sectional study was conducted with 63 individuals between the ages of 7 and 17 years: 40 with Hemiplegic Cerebral Palsy and 23 typically-developing peers. The individuals with HCP received a pre-assessment performed with the Gross Motor Function Classification System, Manual Ability Classification System, and Communication Function Classification System. Left-right judgement was assessed by the laterality judgement task, and manual ability was evaluated with the Nine Hole Peg Test (NHPT). Functional tests included upper extremity functional tests; dual-task interference was also assessed between this test and the NHPT.
**Results:** A significant difference was found between the HCP group and the typically-developing group regarding lateralization accuracy and dual-task cost ($p < 0.05$). Lateralization response time was related with dominant cognitive NHPT dual-task cost ($r = 0.327$, $p = 0.040$). Lateralization accuracy was also related to dominant cognitive NHPT dual-task cost, and lateralization response time with non-dominant motor NHPT dual-task cost ($r = -0.360$, $p = 0.023$; $r = 0.312$, $p = 0.050$, respectively).
**Conclusions:** Individuals with HCP have difficulty with dual tasks compared to typically developing peers. A relationship was observed between upper extremity lateralization and dual-task cost in individuals with HCP. This can be a significant consideration when designing more effective intervention approaches on upper extremity lateralization and dual-task individuals with HCP.

**Keywords: cerebral palsy, dual-task, left-right judgement, upper extremity**

## Introduction

Cerebral palsy (CP) is a motor disorder caused by brain damage that occurs congenitally or in the early postnatal period [1]. Individuals with CP have a lower functional capacity in one upper extremity compared to the other. This adversely affects daily living activities [2]. Several studies have already reported longer movement durations, and reduced movement speed, smoothness, reaching and grasping, as well as releasing and manipulating objects; this affects many activities of daily living in children with Hemiplegic Cerebral Palsy (HCP) compared to typically-developing (TD) children [3,4].

In addition to upper extremity motor functional impairments, individuals with CP also experience motor planning and deficits in lateralization [5,6], the right-left discrimination needed to determine which side a limb belongs to. Right-left discrimination requires several cognitive skills, such as the integration of sensory and visual information, as well as the visuospatial ability to mentally manipulate returned images or objects [7]. Lateralization abilities have often been assessed in children with CP and healthy children using a laterality judgement task [6,8,9]. Briefly, the individual is presented with pictures related to a extremity and is required to make a laterality-based judgement between them [10]. The task requires the individual to engage in a spatial orientation and mental problem-solving process [11]. Lateralization is often used as a guide in assessment and rehabilitation studies of motor imagery skills in children with CP [12,13].

A small number of studies have been conducted to test the laterality judgement task in CP [14-16]. However, the current evidence suggests that individuals with HCP are able to complete such judgement tasks, but with lower performance [6,12].

Daily life rarely allows the individual to perform one task at a time. Rather, our daily activities often involve dual-tasking, i.e. performing two or more tasks at the same time, such as walking and walking and talking on the phone, or walking while looking for something in a pocket [17]. Therefore, the performance of dual tasks in individuals with CP is an important consideration. In dual-task assessment, an additional motor or cognitive task is added to the motor or cognitive performance performed by the individual. This capacity to perform two tasks simultaneously is known as dual-task ability [18]. These tasks could be either motor or cognitive. In either case, performing more than one task at the same time requires the central processing capacity to be shared between the two concurrent tasks [17]. A decline in the performance of one or both of the tasks is known as the dual-task cost [19].

Several studies have indicated dual-task interference in both TD and clinical populations [20,21], with greater dual-task interference noted in neurologic populations due to deficits in motor or cognitive processing [22]. Children with CP commonly exhibit deficits in executive function, visual-spatial ability and attention, as well as learning difficulties [23]. These impairments can lead to difficulties under dual-task conditions where cognitive and motor tasks are performed simultaneously [24]. Individuals with CP experience a decline in performance and face challenges while performing dual tasks compared to single tasks [22,25-27].

None of the studies to date have examined the relationship between lateralization and dual-tasking in individuals with HCP. Only one such study has investigated upper extremity dual-task paradigms in children with HCP [21]. Lateralization and dual tasking are related to similar cognitive processes. There is a particular need to better understand the paradigms of upper extremity dual-task performance and lateralization in individuals with CP before implementing training aimed to improve these areas. The aim of this study was therefore to investigate the relationship between upper extremity lateralization and dual-task cost in individuals with HCP; the results will also be compared with those obtained in a group of TD (typically-developing) peers. Our findings are intended to reveal the complexity of the dynamic relationship between upper extremity lateralization and dual tasking in individuals with HCP, and thus, to be able to guide future research in this field.

## Materials and methods

### Participants

The study included 63 individuals aged between 7 and 17 years. This group comprised 40 participants diagnosed with HCP and 23 typically-developing (TD) peers. The inclusion criteria for the participants with HCP comprised permission to take part from their families, MACS (Manual Ability Classification System) Levels I-II-III, GMFCS (Gross Motor Function Classification System) Levels I-II-III, and a score of 24 or higher on the Mini-Mental State Examination for Children. Individuals with HCP were excluded from the study if they had complex and advanced medical problems other than CP, had undergone surgical intervention or Botulinum toxin application in the last six months, or had experienced a fracture in the upper extremity in the last six months. The TD children were recruited through the snowball sampling method, and those with HCP through Special Education and Rehabilitation Centers.

Written informed consent forms were obtained from all individuals participating in the study. The study was approved by the Gaziantep Islam Science and Technology University Ethics Committee for Non-interventional Clinical Research (Protocol Number: 2023/255). This study was conducted following the Principles of the Declaration of Helsinki.

### Outcome measures

The child's age, sex, height, weight, hand preference, and the socio-demographic information of the parent were recorded on the socio-demographic information form.

The the gross motor function levels, manual abilities, and communication skills of the individuals with HCP were evaluated using the Gross Motor Function Classification System (GMFCS), Manual Ability Classification System (MACS), and Communication Function Classification System (CFCS) [28,29]. The GMFCS is a five-level classification system based on child-initiated movements with an emphasis on sitting, movement and mobility [28]. The MACS is a five-level classification system designed to categorise how individuals with CP use their hands to handle objects in daily activities [28]. The CFCS classifies the daily communication performance of children with CP between levels I and V: level I-II-III indicates effective communication skills [29]. In order to meet the motor requirements of the assessments conducted as part of the study, participants were required to have GMFCS and CFCS levels of I-II-III.

The cognitive functions of the participants were evaluated with the Mini-Mental State Exam for Children (MMc), a multifunctional screening tool used to assess cognitive impairments in children with CP [30,31]. The test includes the areas of recording, recall, attention and calculation, temporal orientation, spatial orientation and language [31].

*Laterality judgement task*

Lateralization was evaluated using a laterality judgement task, with the individual choosing the side for the extremity. Laterality (right-left discrimination) was determined using the Recognise Hand program, developed and designed by the NOI group (http://www.noigroup.com/Recognise). The participants were presented with images of right and left hands from different angles on a phone screen, and asked to decide whether the images belonged to the right or left. The participants indidcated their choice by pressing a right or left selection button on the screen. Two practice trials were allowed. After the trial, each participant confirmed verbally that they understood the task instructions. While in a comfortable sitting position, the participants were presented with a total of ten images at 5 s intervals [6]. The task was evaluated based on the percentage of correct answers and reaction time, calculated by the program. Reaction time is expressed in seconds and correct answers are expressed in percentages. It can be stated that as the seconds and percentage values increase, the sharpness of the right-left discrimination (lateralization) improves.

*Nine Hole Peg test*

The Nine Hole Peg Test (NHPT) is a standardized assessment method frequently used to measure manual ability in individuals with CP [32]. In the test, the child is instructed to place nine pegs into the holes on a platform as quickly as possible with their dominant hand and then remove them. The time from the "start" command to the removal of the last peg is recorded. The same procedure is then repeated with the non-dominant hand, so both extremities are evaluated. The participants are familiarized with one practice trial of the test. The NHPT was carried out according to the original instructions [32]. The Intraclass Correlation Coefficient was calculated for the dominant side (ICC = 0.94) and the non-dominant side (ICC = 0.96) [32]. In the reference study, the mean ± SD for the dominant upper extremity was 29.06 ± 7.58 and 146.43 ± 93.63 for the non-dominant upper extremity [32].

*Upper Extremity Functional Assessment*

In the upper extremity functional assessment, the participant was first asked to place their hand on a table at elbow height while in a sitting position. They were then instructed to perform 20 consecutive repetitions of moving their hand to their mouth and then back to the table. The time taken to complete this task was recorded in seconds using a stopwatch. The dominant extremity was evaluated first, followed by the non-dominant extremity. The Intraclass Correlation Coefficient was 0.99 for upper extremity functional test [33].

*Dual-Task Paradigm*

Participants were given a second task during the NHPT and upper extremity functional assessments to evaluate dual-task interference. During the NHPT, the cognitive task was to count backward by one, and the motor task to perform alternate elbow flexion-extension movements with the opposite arm. While performing the upper extremity functional assessment, the cognitive task was to simultaneously list animal names, and the motor task to alternately perform supination-pronation movements with the opposite extremity. During the evaluations, the time was recorded in seconds using a stopwatch. In the dual-task interference assessment, the participants were instructed to perform both tasks without prioritizing one over the other and to do their best. They were also told not to pause for thought. The complexity of the upper extremity functions under dual-task conditions was measured by calculating the 'dual-task cost' for both tasks according to the formula given in the original instructions [20].

*Statistical analysis*

*Post hoc* power analysis were performed using the G*Power application. A significance level of 5% and a power (1-b) of 80% were assumed, and a medium effect size was assumed (d = 0.517) in the population. The sample size was calculated to be 32 individuals [11]. Statistical analyses were conducted using the SPSS 25 (Version 25, Chicago, USA) software package. The normality of the data was determined using the Kolmogorov-Smirnov test. The data was given as arithmetic mean and standard deviation (Mean ± SD). An Independent Sample t-test was used to compare group lateralization values and dual-task cost. The relationship between lateralization and dual-task cost was examined using Pearson correlation analysis.

## Results

The study included 40 children with HCP between the ages of 7-17, with a mean age of 12.47 ± 3.32; additionally, 23 TD children with a mean age of 12.0 ± 2.81 years were also included. The demographic characteristics of the children are presented in table 1.

**Tab. 1.** The physical and sociodemographic characteristics

| | | Hemiplegic Cerebral Palsy | Typically Developing |
|---|---|---|---|
| | | Mean ± SD | Mean ± SD |
| Age | | 12.47 ± 3.32 | 12.0 ± 2.81 |
| BMI (kg/m$^2$) | | 18.57 ± 3.07 | 16.16 ± 2.18 |
| Duration of physiotherapy (years) | | 7.7 ± 3.6 | |
| MMC (0-37) | | 29.17 ± 1.81 | 29.95 ± 0.92 |
| | | n (%) | n (%) |
| Sex | Male<br>Female | 23 (57.5)<br>17 (42.5) | 11 (47.8)<br>12 (52.2) |
| Dominant hand | Right<br>Left | 14 (35.0)<br>26 (65.0) | 17 (73.9)<br>6 (26.1) |
| GMFCS Level | Level I<br>Level II<br>Level III | 20 (50.0)<br>17 (42.5)<br>3 (7.5) | |
| MACS Level | Level I<br>Level II<br>Level III | 15 (37.5)<br>24 (60.0)<br>1 (2.5) | |
| CFCS Level | Level I<br>Level II | 22 (55.0)<br>18 (45.0) | |
| Educational Level of the Children | Primary<br>Secondary School<br>High School | 19 (47.5)<br>16 (40.0)<br>5 (12.5) | 5 (21.7)<br>15 (65.2)<br>3 (13.1) |

BMI- Body Mass Index, CFCS- Communication Function Classification System, GMFCS- Gross Motor Function Classification System, MACS- Manual Ability Classification System, MMC- Mini-Mental State Exam for Children, SD- Standard Deviation

The comparison of lateralization and dual-task cost between groups is presented in table 2. Significant differences were found between the HCP group and the TD group for all parameters ($p < 0.05$). Except for lateralization accuracy and dominant cognitive NHPT dual-task cost.

The relationship between lateralization and dual-task cost in individuals with HCP results, determined using Pearson correlation analysis, is given in Table 3. A relationship was found between lateralization accuracy and dominant cognitive NHPT dual-task cost. A relationship It was determined between lateralization response time and dominant cognitive NHPT dual-task cost, and between lateralization response time and non-dominant motor NHPT dual-task cost ($p < 0.05$, table 3).

## Discussion

This study investigated the relationship between upper extremity lateralization and dual-task cost in individuals with HCP. The results revealed that the HCP individuals demsontrated slower response times to hand lateralization than the TD peers, and dual tasks were more difficult to complete. In addition, a relationship was found between lateralization and NHPT dual-task cost for certain assessment parameters.

Our results indicate that the hemiplegic participants showed no difference in the accuracy of left-right judgements compared to their TD peers [10,16]. In addition, although both groups demonstrated similar accuracy,

**Tab. 2.** Comparison of lateralization and dual-task cost between groups

| | Hemiplegic Cerebral Palsy Mean ± SD | Typically Developing Mean ± SD | t | p |
|---|---|---|---|---|
| Lateralization accuracy (%) | 46.37 ± 18.43 | 53.69 ± 16.04 | 1.589 | 0.117 |
| Lateralization response time (seconds) | 2.42 ± 0.45 | 1.74 ± 0.31 | 6.973 | 0.000* |
| Non-dominant cognitive functional dual-task cost | 32.95 ± 40.93 | 4.19 ± 3.00 | 4.423 | 0.000* |
| Non-dominant motor functional dual-task cost | 38.57 ± 42.48 | 6.29 ± 5.65 | 4.733 | 0.000* |
| Dominant cognitive functional dual-task cost | 39.39 ± 43.12 | 9.31 ± 8.02 | 4.284 | 0.000* |
| Dominant motor functional dual-task cost | 37.69 ± 38.21 | 10.00 ± 7.94 | 4.420 | 0.000* |
| Dominant cognitive NHPT dual-task cost | 12.32 ± 15.29 | 9.39 ± 4.69 | 1.124 | 0.266 |
| Non-dominant cognitive NHPT dual-task cost | 9.72 ± 9.38 | 5.13 ± 3.10 | 2.836 | 0.006* |
| Dominant motor NHPT dual-task cost | 20.42 ± 13.65 | 10.00 ± 9.17 | 3.615 | 0.001* |
| Non-dominant motor NHPT dual-task cost | 19.65 ± 13.29 | 7.78 ± 9.73 | 4.061 | 0.000* |

NHPT- Nine Hole Peg Test, SD- Standard Deviation, t- Independent Sample t-test Coefficient, p- p value, *p < 0.05

**Tab. 3.** The relationship between lateralization and dual-task cost in individuals with HCP

| | Non-dominant cognitive functional dual-task cost | Non-dominant motor functional dual-task cost | Dominant cognitive functional dual-task cost | Dominant motor functional dual-task cost | Dominant cognitive NHPT dual-task cost | Non-dominant cognitive NHPT dual-task cost | Dominant motor NHPT dual-task cost | Non-dominant motor NHPT dual-task cost |
|---|---|---|---|---|---|---|---|---|
| Lateralization accuracy | r = -0.204 p = 0.208 | r = -0.185 p = 0.253 | r = -0.134 p = 0.409 | r = -0.048 p = 0.767 | r = -0.360 p = 0.023* | r = 0.036 p = 0.828 | r = 0.147 p = 0.366 | r = 0.184 p = 0.256 |
| Lateralization response time | r = 0.230 p = 0.154 | r = 0.306 p = 0.555 | r = 0.192 p = 0.235 | r = 0.100 p = 0.539 | r = 0.327 p = 0.040* | r = 0.100 p = 0.538 | r = 0.187 p = 0.248 | r = 0.312 p = 0.050* |

NHPT- Nine Hole Peg Test, r- Pearson correlation analysis, p- p value, *p < 0.05

the HCP group had significantly slower response times. These findings, regarding accuracy in the hand laterality judgement task, are particularly important because the percentage of incorrect decisions may result in fast but inaccurate performances having greater deficits than slow but accurate performances. This indicates that individuals with HCP perform accurately at rates close to TD controls, but they take longer to decide when giving the correct responses. This can be explained by an increase in spatial orientation processes characterized by impairments in the mental representation of the hand, which are associated with upper extremity motor loss.

Neuroimaging studies have indicated that during the process of making a laterality judgement, individuals visualize their own hands in the position of the hand they see on the screen [11,34]. Common limitations highlighted by researchers have been associated with inherent discrepancies between groups and the level of cognitive demand, which was not structured to the basic task abilities of the participants [27]. It is evident that both the laterality judgement task process and the dual-task paradigm inherently involve mental processes. A study examining dual-task interference in groups with neurological disorders found a decrease in the speed of movement during dual-task performances compared to single tasks, with the most significant decrease observed in children with CP [22]. This indicates that individuals with CP experience greater challenges in dual tasks compared to other groups with neurological impairments.

Only a few studies have investigated dual-task interference in children with CP. The experimental paradigms used in these studies have mainly focussed on the effects of dual tasks on the time-distance characteristics of walking, balance, and postural stability [22,27,35,36]; the results indicate a decrease in walking speed, width, and stride length during dual motor tasks compared to single motor tasks. In addition, children with CP were found to demonstrate more body sway than TD children while performing a dual-task while standing [37].

In individuals with CP, the loss of upper extremity motor control results in restrictions in daily life activities and is known to limit the their participation in personal care, social, and environmental roles [21,38]. Accordingly, it can be stated that research on dual tasks in the HCP population should not be limited to the lower extremity, and the effect on the upper extremities should also be investigated more comprehensively. It is recommended that conventional physiotherapy programs for individuals with HCP be supplemented with upper extremity dual-task training and left-right judgements, and their effects be investigated.

The only study investigating the upper extremity dual-task paradigm in CP found that individuals with HCP had higher dual-task conditions and dual-task cost compared to their typically-developing peers, and demsontrated increased activation of the prefrontal cortex [21]. The present study found that the individuals with HCP had higher dual-task cost evaluations compared to typically-developing peers. All these findings indicate that individuals with HCP experience losses in their current functional capacity during complex tasks in daily life. It can also be stated that the additional tasks given during upper extremity motor performances are more challenging for individuals with HCP.

It has been indicated that individuals with CP face problems in the performance of laterality judgement tasks [5,6,12,15,16] and dual tasks [22,25-27,37]. However, none of the studies conducted to date have investigated the relationship between upper extremity lateralization and dual-task cost in children with CP.

In the present study, relationships were found between lateralization accuracy and dominant cognitive NHPT dual-task cost, and between lateralization response time and non-dominant motor NHPT dual-task cost. Even though they might be seen as independent evaluations, these findings suggest a dynamic relationship between laterality judgement tasks and dual-task cost. In conclusion, it can be stated that improving one of these two factors might have positive effects on the other. However, this situation needs to be supported by clearer evidence from future studies. It is recommended that the dual-task cost and accuracy of left-right judgements in individuals with CP be considered and investigated jointly in future research. Research into upper extremity lateralization and dual-task performances is particularly important in children with HCP because upper extremity lateralization and dual-task cost refer to similar cognitive processes.

One of the strengths of this study is that it is the first to investigate upper extremity dual-task cost in conjunction with lateralization in individuals with HCP. It also compares the results of the HCP group with those of a typically-developing control group.

*Limitations*

The main limitation of this study is that the study sample has a wide age range, and that its findings reflect only the results of children with HCP; therefore, the conclusions should not be generalized to other types of CP without further investigation. Enhancing control over the performance of the affected upper extremity may potentially contribute to reduced upper extremity dual-task performance. The relationship between lateralization, dual-task conditions, and upper extremity skills should be considered in the design of rehabilitation protocols.

## Conclusions

Interference between motor and cognitive tasks has significant effects on upper extremity performance in children with TD and HCP. In conclusion, our study clarifies the complex relationship between upper extremity lateralization and dual-task conditions in individuals with HCP. This can be a significant consideration for designing more effective intervention approaches on this subject. Further evaluation of upper extremity lateralization and dual-task cost in assessment and intervention approaches is required to benefit physiotherapists and clinicians working in the field.

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**Conflicts of interest**

The authors declare no conflict of interest.

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