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UPPER-SECONDARY SCHOOL STUDENTS' CEREBRAL DOMINANCE AND LEARNING STYLES: THE MEDIATION OF CHRONOTYPES

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Abstract

Learning styles, cerebral dominance and chronotypes are among the factors that have been determined to be effective on individuals' learning. It is stated in the literature that these three variables are interrelated or affect each other. Therefore, the aim of the study is to determine the extent to which students' cerebral dominance predicts their learning styles and whether chronotypes have an effect on this level of prediction as a moderating variable. In the research, the "Morningness-Eveningness Stability Scale improved" (MESSI), the "Kolb Learning Style Inventory" (KLSI) and the "Hermann Brain Dominance Instrument" (HBDI) were used as data collection tools. The selection of upper-secondary schools included in the sample was made in a district of Antalya province with the convenience sampling method. The sample of 593 students who agreed to respond to the scale was formed from 9th, 10th, 11th, and 12th grade students studying at these upper-secondary schools in the 2021-2022 academic year. According to the analysis results of the structural equation model (SEM) obtained in the study, it was concluded that there were significant positive correlations between learning styles and the sub-dimensions of cerebral dominance; however, chronotypes did not significantly mediate the determined correlations. The findings of this study may provide implications for determining learning styles, which have proven effects on student performance in the teaching-learning process, and, by establishing relationships between individuals' brain structures and chronotypes, the characteristics that direct learning preferences.

Keywords: *cerebral dominance, chronotypes, learning styles, structural equation model, upper-secondary school*

Introduction

Studies in the field of education emphasise that individual differences of students should be taken into account in the teaching-learning process. As a matter of fact, the individual differences of students significantly affect the quality of learning. The first difference that comes to mind when it comes to individual difference in education is intelligence, but it is undeniable that many individual factors have an effect on learning. One of the factors affecting learning is the learning style of the individual (Dikmen et al., 2018). Learning style is concerned with how the individual learns rather than how much he learns and is defined as "the methods preferred by the individual in the process of receiving and processing information" (Jonassen & Grabowski, 2012). In Kolb's learning style inventory, students are classified in terms of learning styles according to their preferences for how they comprehend knowledge and how they internalise knowledge (Felder, 1996; Kolb & Kolb, 2005a). In the teaching-learning process, too, the teaching methods preferred according to students' learning styles, which reflect their learning preferences, enable students to perform better (Felder, 1993). In order to facilitate individuals' learning and to increase their awareness of their learning preferences,

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it can be seen that in the field of educational sciences, brain-based studies have mostly been associated with learning (D'Amato & Wang, 2015). According to Ned Herrmann's whole brain model, in which the brain is expressed in four quadrants according to the relationship between the right and left hemispheres, it has been reported that the brain is associated with learning (Herrmann, 1996). Both hemispheres interact with each other under normal conditions and each individual's brain structure consists of a different perception and learning system. Therefore, defining how the brain learns facilitates people's learning and makes understanding long-term and powerful (Arıcan & Polat 2020). Just as individuals' brain structures form different learning characteristics, their biological activities can also be effective on their learning. In fact, chronotypes, which are defined as the tendencies of individuals to prefer working/learning at different times of the day, also have an effect on learning (Horne & Ostberg, 1976). Individuals' chronotypes gradually deteriorate with advancing age (Pıçak et al., 2010). While morning types are common in primary school children, their tendency to become evening types increases with children's transition to puberty (Arbabi et al., 2015). In particular, irregular sleep habits in individuals can lead to negative consequences for their learning outcomes (Škvorc & Bjelajac, 2016).

Literature Review

Kolb's Learning Styles

There are different approaches to learning styles: the Kolb Learning Style Model (Kolb, 1984), Witkin's Learning Styles (Witkin, 1964), the Canfield Learning Style Model (Canfield, 1988), Silver, Hanson and Strong's Learning Style Model (Silver et al., 1979), the Gregorc Learning Style Model (Gregorc, 1979), the Butler Learning Style Model (Butler, 1987), and the Dunn and Dunn Learning Style Model (Dunn & Dunn, 1979). Kolb's Learning Style Model is divided into four basic categories, namely "Concrete Experience, learning by feeling", "Reflective Observation, learning by observing", "Abstract Conceptualisation, learning by thinking", and "Active Experimentation, learning by doing" (Kolb, 1984). According to Kolb (1984), individuals may prefer different ways of learning, or use the different ways of learning together. The dimensions of "concrete experience" and "abstract conceptualisation" reveal the environment in which people live and their perception preferences. In Kolb's model, abstract conceptualisation and concrete experience constitute the "perception" dimension.

Perception encompasses the individual's learning with emotional attitudes from concrete experiences, or developing symbolic contexts from experiences. "Reflective observation" and "active experimentation" explain the "transformation" dimension that reveals individuals' ability to blend and process information (Gencel, 2007; Jonassen & Grabowski, 2012; Kolb, 1984). Kolb arranged the perception and transformation dimensions into four quadrants. He specified each of these quadrants as a learning style. Each quadrant specified in Kolb's learning styles does not present the individual's dominant learning style by itself. Rather, everyone's learning style is defined as "a combination of the four quadrants" and the combined scores obtained from the quadrants in the model find out the individual's preferences, ranging "from abstract to concrete and from active to reflective" (Kolb & Kolb, 2005a). In the teaching-learning process, teachers' planning of the process by considering the students' learning styles supports students' high learning performance (Felder, 1993).

Cerebral Dominance

Modern neuroanatomy divides each hemisphere of the brain into four basic lobes, which are named as follows: frontal (just behind the forehead, the anterior part of the brain), parietal (at

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the top, the part of the brain towards the rear), temporal (at the sides, the part of the brain below the temples) and occipital (the most posterior part of the brain) (Ganis et al., 2007). Herrmann's model emerged as a product of studies conducted by evaluating EEG (electroencephalography) data, and from these studies, a model was created that reveals the structure of the human brain. According to the "four-quadrant model of the brain" that was created, the brain's right and left hemispheres are responsible for different functions (Solso et al., 2007). The left hemisphere is "analytical, abstract, verbal, digital, logical, sequential and rational", the right hemisphere is "holistic, concrete, non-verbal, visuospatial, intuitive, simultaneous and analogical" (McCarthy et al., 2006). In the whole brain model, when the hemispheres of the cerebral and limbic system are included, the brain is characterised as four quadrants (Herrmann, 1995). The quadrant which is used dominantly while learning affects individuals' learning preferences. Individuals may choose to use one quadrant or several quadrants while learning new information (Herrmann, 1996). Although each hemisphere has different functions, the brain carries out its functions holistically. For efficient learning, both hemispheres of the brain should be involved in learning activities during learning (Senemoğlu, 2004).

Chronotypes

People show different chronotype characteristics, namely morningness, eveningness and distinctness (intermediate-type), due to differences in biological and behavioural patterns such as the sleep-wake cycle and body temperature (Adan et al., 2012). Chronotypes, which reveal at what time of the day an individual is more prone to learning, are divided into three categories (Horne & Ostberg 1976): These are "morning types, who prefer to go to bed early at night and get up early in the morning", "evening types, who prefer to go to bed late at night and wake up late in the morning", and intermediate types, who exhibit the characteristics of these two types together. Morning types' performance is at the highest level during the morning. Evening types, stay up late at night and wake up late, and their performance is at the highest level at night times (Selvi et al., 2010). Individuals for whom the time period in which they perform at the highest level differs in this cycle, without a clear distinction, constitute the intermediate type. People with various chronotypes differ not only in sleep or wake times, but also in cognitive characteristics. It has been stated in the literature that chronotypes have an effect on individuals' learning, especially with regard to sleep patterns (Škvorc & Bjelajac, 2016).

Relationships between the Variables

While explaining concrete experience, which is the first stage of the learning cycle, Kolb (1984) emphasised that emotions and feelings come to the fore in learning. In this respect, it is directly similar to the characteristic of emotionality which is fostered in the individual by the emotional sub-dimension of cerebral dominance (Du Toit, 2018). In reflective observation, which is the second stage, emphasis is placed on the detailed, planned, organised, and orderly (sequential thinking) characteristics of the individual that are emphasised in the safekeeping sub-dimension of cerebral dominance, such as questioning facts, developing different perspectives, and trying to understand the thinking underlying events and phenomena (Herrmann, 1996; Kolb, 1984). In abstract conceptualisation, on the other hand, the characteristics of the individual have intellectual cerebral dominance, which are described as logical, intellectual, analytical, and reality-based, are parallel with the characteristics of the individual that focus on logic and thought rather than on emotions (Du Toit, 2018). In active experimentation, which is the final stage of the learning cycle, the emphasis is on individuals who learn based on their experiences and practices (Kolb, 1984). Therefore, it shows similarity with the experiential, synthesising and integrative characteristics of the individual specified in the experimental sub-

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dimension of cerebral dominance (Herrmann, 1996). In the current study, hypotheses regarding the correlations between the variables have been formed based on the similarities explained above between the sub-dimensions of cerebral dominance and learning styles. In addition, as stated in the previous sections, based on the view that the effects of cerebral dominance and learning styles, chronotypes are also effective on individuals' learning, and since chronotypes are associated with both cerebral dominance and learning styles, this suggests that chronotypes may have a mediating effect in the correlations established between cerebral dominance and learning styles. In order to test these predicted correlations, hypotheses based on the mediating effect have been formed.

Research Problem

There are studies in the literature that have extensively compared chronotype with various demographic variables (Adan & Natale, 2002; Kim et al., 2002; Natale & Danesi, 2002; Randler, 2007; Randler & Engelke, 2019). In addition to these demographic variables, there are few studies examining the relationships between chronotype and learning styles in undergraduate students (Balcı & Çalışkan, 2022; Davidson & Ritchie, 2006). There are also studies in the literature examining learning styles and brain dominance together (Ali & Kor, 2007; Kırkgöz & Doğanay, 2003; Özgen et al., 2011). As a result of the literature review, no research has been found that examines the relationships between upper-secondary school students' brain dominance, chronotypes and learning styles.

In many countries such as Turkey, the learning of individuals aged 15-18, whose future depends on their success in certain exams, gains more importance compared to other age groups. In this respect, it is considered substantial to investigate the effects of learning style and brain dominance variables, which have been determined to have an effect on learning, on these individuals who emerge from childhood and are referred to as young people and adolescents. Revealing whether the dominant brain regions of young people have a connection with their dominant learning styles may contribute to the literature in terms of investigating the different characteristics of individuals in the learning process. Also, it can be said that the relationship of chronotypes between brain dominance and learning styles may play a significant role, by predicting that the sleep patterns that determine the chronotypes of young people may also change in this age group compared to their childhood.

The study emphasizes that the individual differences of students should be taken into account in the organization of educational activities in the teaching-learning process, and program development. It is important for individuals to be aware of the time in which their mental performance is highest, especially when organizing individual learning activities. Also, it is significant to have self-awareness that can shape their own learning processes in terms of the specified variables, with the awareness that there is a connection between their brain dominance and their preferred learning styles. In the same way, it is useful for an educator to be aware of the need to know the students in terms of the specified variables, in order to organize teaching-learning activities on the basis of students and to raise students' self-awareness. In addition, it can be said that the study will contribute to future research that aims to study individual differences in learning.

This study aims to determine the extent to which students' cerebral dominance predicts their learning styles and whether chronotypes have an effect on this level of prediction as a moderating variable. The hypotheses formed in line with the purpose of the study are given below:

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The Hypotheses Regarding the Correlations between the Variables

H1. "The Intellectual sub-dimension" is positively correlated with "Abstract Conceptualisation".
H2. "The Safekeeping sub-dimension" is positively correlated with "Reflective Observation".
H3. "The Emotional sub-dimension" is positively correlated with "Concrete Experience".
H4. "The Experimental sub-dimension" is positively correlated with "Active Experimentation".
H5. The "Intellectual" (H5a), "Safekeeping" (H5b), "Emotional" (H5c) and "Experimental" (H5d) sub-dimensions are positively correlated with Morningness.
H6. "Morningness" is positively correlated with "Concrete Experience" (H6a), "Reflective Observation" (H6b), "Abstract Conceptualisation" (H6c) and "Active Experimentation" (H6d).
H7. The "Intellectual" (H7a), "Safekeeping" (H7b), "Emotional" (H7c) and "Experimental" (H7d) sub-dimensions are positively correlated with "Eveningness".
H8. "Eveningness" is positively correlated with "Concrete Experience" (H8a), "Reflective Observation" (H8b), "Abstract Conceptualisation" (H8c) and "Active Experimentation" (H8d).
H9. "The Intellectual" (H9a), "Safekeeping" (H9b), "Emotional" (H9c) and "Experimental" (H9d) sub-dimensions are positively correlated with Distinctness.
H10. "Distinctness" is positively correlated with "Concrete Experience" (H10a), "Reflective Observation" (H10b), "Abstract Conceptualisation" (H10c) and "Active Experimentation" (H10d).

The Hypotheses Involving the Mediating Variables

H11. "Morningness" (H11a), "Eveningness" (H11b), and "Distinctness" (H11c) mediate the effect of the "Intellectual" sub-dimension on "Abstract Conceptualisation".
H12. "Morningness" (H12a), "Eveningness" (H12b), and "Distinctness" (H12c) mediate the effect of the "Safekeeping" sub-dimension on "Reflective Observation".
H13. "Morningness" (H13a), "Eveningness" (H13b), and "Distinctness" (H13c) mediate the effect of the "Emotional" sub-dimension on "Concrete Experience".
H14. "Morningness" (H14a), "Eveningness" (H14b), and "Distinctness" (H14c) mediate the effect of the "Experimental" sub-dimension on "Active Experimentation".

Research Methodology

Research Design

The study is based on a correlational research model. Examination of the correlations between variables constitutes the correlational survey model (Karasar, 2011). The research data were collected from upper-secondary school students studying in state upper-secondary schools in a district of Antalya province in Turkey, during the 2020-2021 academic year, by obtaining the necessary permission from the "Directorate of National Education". Also, ethics committee approval for the research was obtained from the "Social and Human Scientific Ethics Committee of Akdeniz University" (Date: August 31, 2021; Code: 159919, Ethics Committee Decision Number: 301). During the data collection process, the scales were administered to the students online due to the COVID-19 pandemic.

Study Group

The accessible population of the research was determined as upper-secondary schools in the province of Antalya in Turkey. The selection of upper-secondary schools included in the sample was made in a district of Antalya province with the convenience sampling method. The

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sample of 593 students who agreed to respond to the scale was formed from 9th, 10th, 11th, and 12th grade students studying at these upper-secondary schools in the 2021-2022 academic year. In structural equation modelling, the ideal sample size has been specified as 20 times the number of parameters to be estimated in the model, and 10 times as a less ideal number (Kline, 2011a). The number of samples in the study is 50 times the number of parameters (11). Among the individuals in the study group, 325 (53.9%) were female and 268 (46.1%) were male. The upper-secondary schools where the participants studied were Anatolian schools (131 people, 21.7%), science schools (158 people, 526.2%), Imam Hatip schools (54, 9.0%), vocational schools (158 people, 26.2%) and medical vocational schools (101 people, 16.7%). Among the participants in the study group, 195 (32.3%) were in the 9th grade, 186 (30.8%) were in the 10th grade, 106 (17.6%) were in the 11th grade, and 116 (17.6%) were in the 12th grade.

Data Collection Tools

In the research, the "Morningness-Eveningness Stability Scale improved" (MESSI), the "Kolb Learning Style Inventory" (KLSI) and the "Hermann Brain Dominance Instrument" (HBDI) were used as data collection tools.

Morningness - Eveningness Stability Scale Improved (MESSI)

Developed by Öğütlü et al., (2021), this scale is used to determine morning and evening types. The scale consists of 15 items and three sub-dimensions. These sub-dimensions are "morningness", "eveningness" and "distinctness". The ways of responding to the Likert scale are in the form of 1-"it is definitely not easy" to 5-"it is extremely easy" in the first item, 1-"I do not feel awake at all" to 5-"I feel very awake" in the second item, 1-"between 0-10 minutes" to "between 5-60 minutes" in the third item, 1-"very low" to 5-"very high" in the fourth and fifth items, and 1-"completely inappropriate" to 5-"completely appropriate" in the other items. The first, second, third, fourth and sixth items of the scale constitute the morningness dimension. The fifth, seventh, thirteenth, fourteenth, and fifteenth items comprise the distinctness (intermediate type) dimension; the eighth, ninth, tenth, eleventh, and twelfth items form the eveningness dimension. The Cronbach alpha coefficients were calculated as .69 for morningness, .76 for distinctness and .40 for eveningness. Values of ($\chi 2 = 2003.85$ / $df = 404$) = 4.95 ($p = .00$), GFI = .78, IFI = .87, CFI = .87, NFI = .85, AGFI = .75, RMSEA = .09, RMR = .50, and SRMR = .07 were obtained from the confirmatory factor analysis.

Confirmatory factor analysis for the MESSI was repeated for this study, and values of ($\chi 2 = 93.36$ / $df = 32$) = 2.93 ($p = .00$), GFI = .97, IFI = .97, CFI = .97, NFI = .95, AGFI = .95, RMSEA = .05, RMR = .23, and SRMR = .04 were obtained. When the obtained values are examined, the fit indices of the model are at an acceptable level (Marsh et al., 1988). The t-values obtained from the model also confirm the significance of the factor loadings. In addition, the Cronbach alpha internal consistency coefficients were also calculated. The Cronbach alpha values were calculated as .71 for the scale, .71 for the morningness dimension, .81 for the distinctness dimension, and .45 for the eveningness dimension. According to the obtained findings, it can be said that the measurements obtained from the scale and its sub-factors are at a reliable level (Büyüköztürk et al., 2016).

Kolb Learning Style Inventory (KLSI)

In this study, the "Kolb Learning Style Inventory" (KLSI) developed by Kolb (1999) and adapted into Turkish by Gencel (2006) was used to determine the learning styles of students. The scale consists of 12 complementary items (Gencel, 2006). Items have four options. The

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number obtained by active learning and reflective thinking shows the x-axis in the coordinate system. The number obtained by the abstract comprehension and concrete experience operation is placed on the y-axis. Combined scores from the scale take a value between –36 and +36. The intersection of the x-axis and y-axis numbers explains the learning style of the individual (Gencel, 2006). As a result of the exploratory factor analysis and reliability analysis, it was determined that the scale, as in its original form, consists of four factors: "abstract conceptualisation", "active experimentation", "concrete experience" and "reflective observation". In the scale, the Cronbach alpha coefficients were .76 for the "concrete experience" factor, .71 for the "reflective observation" factor, .80 for the "abstract conceptualisation" factor, and .75 for the "active experimentation" factor (Gencel, 2006).

Confirmatory factor analysis for the KLSI was repeated for this study, and fit index values of ($\chi 2$ = 2003.85 / df = 404) = 4.95 (p = .001), GFI = .78, IFI = .87, CFI = .87, NFI = .85, AGFI = .75, RMSEA = .09, RMR = .50, and SRMR = .07 were obtained. The obtained values show that the fit indices of the model are at an acceptable level (Marsh et al., 1988). The t-values obtained from the model also confirm the significance of the factor loadings. In addition, the Cronbach Alpha coefficients were .69 for the overall scale, .76 for the "concrete experience" factor, .67 for the "abstract conceptualisation" factor, .76 for the "active experimentation" factor, and .71 for the "reflective observation" factor. According to the findings, it can be said that the measurements obtained from the scale and its sub-factors are at a reliable level (Büyüköztürk et al., 2016).

Hermann Brain Dominance Instrument (HBDI)

The adapted version of Herrmann's four-quadrant "Brain Dominance Instrument (HBDI)" (Herrmann, 1995), adapted by Özden (2009), was used. The scale, which consists of 24-items, was graded as "strongly disagree (1)", "disagree (2)", "undecided (3)", "agree (4)", and "strongly agree (5)". There are six sections in the scale and each section includes four items. In the scale, the total of the first questions measures the dominance of the D (Holistic) quadrant, the total of the second questions measures the dominance of the C (Emotional) quadrant, the total of the third questions measures the dominance of the B (Sequential) quadrant, and the total of the fourth questions measures the dominance of the A (Logical) quadrant. The scores obtained from the brain dominance measurement tool are calculated by considering the highest scores obtained by students from the A, B, C and D quadrants. Moreover, the scale is grouped according to the regions of the brain. The reliability coefficient of the scale was calculated as .71. Exploratory factor analysis showed that as in its original form, the scale consisted of four factors, namely holistic, emotional, sequential, and logical. The Cronbach alpha values were calculated as .71 for the overall scale, .72 for the holistic sub-dimension, .71 for the emotional sub-dimension, .67 for the sequential sub-dimension, and .68 for the logical sub-dimension (Özden, 2003).

Confirmatory factor analysis of the brain dominance instrument was performed again for this study. The goodness-of-fit index values obtained for the scale were ($\chi 2$ = 1194.55 / df = 246) = 4.85 (p = .001), GFI = .83, IFI = .89, CFI = .89, NFI = .87, AGFI = .79, RMSEA = .05, RMR = .08, SRMR = .07. The factor structures were confirmed in the analyses that were made. It was reported that the model showed good fit (Jöreskog & Sörbom, 2006). The t-values obtained from the model also confirm the significance of the factor loadings. Cronbach's alpha coefficients were calculated as .86 for the overall scale, .52 for the holistic sub-dimension, .59 for the emotional sub-dimension, .73 for the sequential sub-dimension and .62 for the logical sub-dimension. According to the reliability coefficients, it can be said that the measurements obtained from the whole scale and its sub-factors are at a reliable level (Büyüköztürk et al., 2016).

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Data Analysis

Structural equation modelling was used to develop a structural model that explains the effects of the upper-secondary school students' chronotype and cerebral dominance on their learning styles. In the analyses, the SPSS-23 program was used for descriptive statistics and correlation calculations, while the LISREL 8.7 program was used for structural equation modelling.

Research Results

Findings for the Hypotheses Regarding the Correlations between the Variables

In the study, the arithmetic mean (*M*), standard deviation (*SD*), and Pearson correlation coefficient (*r*) values of the variables were calculated, and the results are given in Table 1.

Table 1.
Pearson Correlation Coefficient Values of the Variables

Variables	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1.Concrete Experience	2.91	0.39		.342**	.558**	.547*	.373*	.401**	.443**	.437**	.087*	.081*	.161**
2.Reflective Observation	3.07	0.37		1	.429**	.415**	.340**	.330**	.209**	.265**	-.020	.166**	.071
3. Abstract Conceptualisation	3.22	0.41			1	.685**	.437**	.478**	.355**	.225**	.085*	.048	.119**
4. Active Experimentation	3.29	0.44				1	.348**	.450**	.400**	.244**	.049	.062	.176**
5.Intellectual	3.82	0.61					1	.700**	.591**	.579**	.048	.132**	.184**
6.Safekeeping	3.72	0.70						1	.611**	.529**	.126**	.083*	.330**
7.Emotional	4.00	0.56							1	.585**	.072	.067	.175**
8.Experimental	3.75	0.58								1	.044	.115**	.180**
9. Morningness	2.61	0.50									1	-.116**	.144**
10.Eveningness	3.29	0.71										1	.042
11.Distinctness	2.83	0.66											1

*$p < .05$; **$p < .01$

When Table 1 is examined, it can be seen that the morningness-eveningness chronotype levels of the upper-secondary school students are highest in the eveningness sub-dimension ($M = 3.29$), while they are lowest in the morningness sub-dimension ($M = 2.61$); their cerebral dominance is highest in the emotional domain ($M = 4.00$), and lowest in the safekeeping domain ($M = 3.72$); their learning styles are highest in the abstract conceptualisation sub-dimension ($M = 3.22$), and lowest in the concrete experience sub-dimension ($M = 2.91$).

When the correlation coefficients between the variables shown in Table 1 are examined, the highest correlations with the concrete experience learning style are in the emotional ($r =$

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.443) and experimental (r = .437) sub-dimensions of cerebral dominance. It can also be seen that the highest correlations with reflective observation and abstract conceptualisation are in the intellectual (r = .340 and r = .437, respectively) and safekeeping (r = .330 and r = .478, respectively) sub-dimensions, while the highest correlations with active experimentation are in the emotional (r = .400) and safekeeping (r = .450) sub-dimensions. When the correlations of the sub-dimensions of learning styles and cerebral dominance with chronotypes are examined, it can be seen that there are generally low-level significant correlations. The most significant correlations were found for morningness with concrete experience (r = .087) and the safekeeping domain (r = .126); for eveningness with reflective observation (r = .166) and the intellectual domain (r = .132); and for distinctness with active experimentation (r = .176) and the safekeeping domain (r = .330).

Findings for the Hypotheses Involving the Mediating Variables

Mediation analysis was performed to estimate the mediating effect of upper-secondary school students' chronotypes on the relationship between their cerebral dominance and learning styles. The direct and indirect effects of the variables are shown in Table 2.

Table 2
The Estimate of the Direct and Indirect Effects at the 95% Confidence Interval

Dependent Variables	Independent Variables	Direct Effect	Mediating Variables	Indirect Effect	Goodness-of-fit values*
Concrete Experience	Emotional	.70	Morningness	.71	$\chi 2$ / *df* = 5.26; NFI = .74, NNFI = .75, CFI = .78, RMSEA = .09, GFI = .83, AGFI = .79, SRMR = .08.
			Eveningness	.70	$\chi 2$ / *df* = 5.27; NFI = .77, NNFI = .78, CFI = .80, RMSEA = .09, GFI = .83, AGFI = .79, SRMR = .08.
			Distinctness	.73	$\chi 2$ / *df* = 4.83; NFI = .82, NNFI = .80, CFI = .85, RMSEA = .08, GFI = .94, AGFI = .91, SRMR = .06.
Reflective Observation	Safekeeping	.59	Morningness	.61	$\chi 2$ / *df* = 2.98; NFI = .89, NNFI = .92, CFI = .93, RMSEA = .05, GFI = .92, AGFI = .90, SRMR = .05.
			Eveningness	.58	$\chi 2$ / *df* = 3.07; NFI = .90, NNFI = .92, CFI = .93, RMSEA = .05, GFI = .92, AGFI = .90, SRMR = .05.
			Distinctness	.64	$\chi 2$ / *df* = 3.80; NFI = .86, NNFI = .88, CFI = .89, RMSEA = .07, GFI = .90, AGFI = .87, SRMR = .06.
Abstract Conceptualis-ation	Intellectual	.72	Morningness	.71	$\chi 2$ / *df* = 2.24; NFI = .91, NNFI = .94, CFI = .95, RMSEA = .04, GFI = .93, AGFI = .91, SRMR = .05.
			Eveningness	.73	$\chi 2$ / *df* = 1.84; NFI = .95, NNFI = .97, CFI = .97, RMSEA = .03, GFI = .97, AGFI = .96, SRMR = .03.
			Distinctness	.74	$\chi 2$ / *df* = 4.58; NFI = .81, NNFI = .80, CFI = .84, RMSEA = .07, GFI = .93, AGFI = .90, SRMR = .07.

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Active Experimentation	Experimental	.56	Morningness	.55	$\chi 2 / df$ = 1.89; NFI = .91, NNFI = .94, CFI = .95, RMSEA = .04, GFI = .97, AGFI = .96, SRMR = .04.
			Eveningness	.56	$\chi 2 / df$ = 1.79; NFI = .94, NNFI = .96, CFI = .97, RMSEA = .04, GFI = .97, AGFI = .96, SRMR = .04.
			Distinctness	.56	$\chi 2 / df$ = 3.90; NFI = .86, NNFI = .87, CFI = .89, RMSEA = .07, GFI = .88, AGFI = .85, SRMR = .07.

*$\chi 2 / df$ (Chi-square / degrees of freedom); NFI (Normed Fit Index); NNFI (Non-normed Fit Index); CFI (Comparative Fit Index); RMSEA (Root Mean Square Error of Approximation); SRMR (Standardized Root Mean Square Residual); GFI (Goodness of Fit Index); AGFI (Adjusted Goodness of Fit Index).

As can be seen in Table 2, the direct effect of the emotional sub-dimension on concrete experience is .70, and when morningness (.71), eveningness (.70), and distinctness (.73) are added as mediating variables, the effect of the emotional sub-dimension on concrete experience does not decrease. This means that the chronotypes as mediating variables have no effect on the correlation between the emotional sub-dimension and concrete experience. Similarly, the direct effect on reflective observation of the safekeeping sub-dimension is .59; the effect on abstract conceptualisation of the intellectual sub-dimension is .72, and the effect on active experimentation of the experimental sub-dimension is .56. However, the chronotypes do not have partial mediating effects on the correlation between the cerebral dominance variables and learning styles. Accordingly, the cerebral dominance variables affect learning styles, whereas the chronotypes have no effect on this relationship. When the fit indices of the models are examined (in Table 2), it can be seen that the fit indices are good (Kline, 2011b; Schermelleh-Engel et al., 2003).

Discussion

As a result of the study, it was determined that there is a correlation between cerebral dominance and learning styles. Based on this result, it can be said that the different learning characteristics formed by cerebral dominance in individuals are similar to the learning characteristics that form in individuals depending on their learning styles. In fact, there are studies in the literature that have revealed the relationship between learning styles and cerebral dominance (Bielefeldt, 2006; Özgen et al., 2011; Rhodes, 1990; Summers et al., 1993). The sample of these studies mainly consists of undergraduate students. In the four-quadrant brain model created by Herrmann, the parts of the brain are named as intellectual, safekeeping, emotional and experimental. According to this model (Herrmann, 1995), individuals whose intellectual quadrant (quadrant A) is dominant are analysers; they think logically and perform numerical operations (Lumsdaine & Lumsdaine, 1995). Those who predominantly use the A quadrant are logical and choose to learn from a logical and analytical source. In abstract conceptualisation, which is one of Kolb's learning style categories, the learning characteristics seen in individuals are such that, unlike experience-based learning, learning by focusing on logic and opinions is at the centre. In other words, in individuals whose learning style is predominantly abstract conceptualisation, logic is more prominent than emotions (Healey & Jenkins, 2000; Kolb, 1984).

According to the four-quadrant brain model, individuals with a dominant safekeeping quadrant (quadrant B) are organisers; they plan approaches, organise events and evaluate them in detail (Hermann, 1996). Those who are dominant in the B quadrant mostly prefer hands-on learning and are sequentialists (Lumsdaine & Lumsdaine, 1995). Reflective observation, which

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is another stage of Kolb's learning cycle, is the stage in which the difference between what is learned and what is observed is organised by examining and planning in detail. Kolb stated that the reflective observation learning style is an effort to understand the basis of an event or phenomenon. At this stage, the aim is to reflect ideas and opinions on the subject, to question in detail and to achieve certain results (Kolb, 1984). Those who are dominant in the emotional quadrant (quadrant C) think according to their feelings and also have developed interpersonal social relations (Lumsdaine & Lumsdaine, 1995). In concrete experience, which is one of the stages of Kolb's learning styles, learning by feeling comes to the fore (Kolb & Kolb, 2005b). At this stage, it is stated that there are individuals who, rather than thinking about a subject, focus on understanding the situation with their emotions (Kolb, 1984). In Kolb's model of learning styles, active experimentation represents individuals who prefer to learn based on practice. At this stage, individuals' learning through practice and transferring what they have learned to real life are taken as the basis. Rather than observing, participating in activities gains importance (Kolb, 1984; Larkin-Hein & Budny, 2000). Individuals whose experimental quadrant (quadrant D) is dominant learn based on life and experience (Herrmann, 1995). As a result, it can be said that the four-quadrant brain model and the dimensions of Kolb's learning style that are matched above reflect individuals with similar characteristics. In support of these findings, as a result of the study, it was determined that there are significant correlations between the related variables.

As a result of the study, significant correlations of chronotypes with learning styles and the cerebral dominance variables were also obtained, albeit at a low level. However, it was concluded that the chronotype variables do not have a mediating role in the correlation between cerebral dominance and learning styles. There are studies in which undergraduate students are sampled in the literature examining the correlations between learning styles and chronotypes (Balcı & Çalışkan, 2022; Davidson & Ritchie 2016). The chronotype-dependent differences in the structure of the brain (Zaręba, 2019) and the neural mechanisms affecting chronotypes (Rosenberg et al., 2015) have been investigated. In addition, besides the structure of the brain, it has been emphasised by neurophysiological theories that sleep state has an important effect on the functioning of the brain (Albán et al., 2019). The transition towards the evening type, which begins especially in adolescence, makes the individual need more sleep in the morning (Montaruli et al., 2017). It has been determined that in situations where there is no obligation to get up early, young people do not get up early and wake up at later times (Maukonen et al., 2017). Therefore, the evening type is more common in young individuals (Díaz-Morales et al., 2008). It was determined that the upper-secondary school students who made up the sample of the study mostly had the evening chronotype. The need to wake up early in the morning, which life conditions impose on evening types, causes an observable decrease in sleep quality (Taillard et al., 2003).

Sleep quality also has an effect on young individuals' school achievement (Škvorc & Bjelajac, 2016). In the literature, it is stated that with increased insomnia, students' motivation decreases, their depressive moods are observed, and the rates of being late to school and dropping out of school increase (Selvi et al., 2012). In this respect, it can be said that chronotypes, which also provide information about individuals' sleep patterns, are related to both learning styles and cerebral dominance.

Conclusions

According to the analysis results of the structural equation model (SEM) obtained in the study, concrete experience is positively correlated with the emotional subdimension (H3), and the same applies for reflective observation with the safekeeping subdimension (H2), abstract conceptualisation with the intellectual subdimension (H1), and active experimentation with the experimental subdimension (H4). As a result of the mediation analysis, it was determined that

the chronotype variables do not significantly mediate the relationships between learning styles and the cerebral dominance variables. According to this finding, hypotheses H11, H12, H13 and H14 were rejected. It can be said that the correlation levels between the chronotypes and other variables are generally low. The findings with a significant correlation are as follows: (H5). Safekeeping is positively related to Morning Affect. (H6). Morning Affect is positively related to Concrete Experience and Abstract Conceptualisation. (H7). The Intellectual, Safekeeping and Experimental sub-dimensions are positively related to Eveningness. (H8). Eveningness is positively related to Concrete Experience and Reflective Observation. (H9). The Intellectual, Safekeeping, Emotional and Experimental sub-dimensions are positively related to Distinctness. (H10). Distinctness is positively related to Active Experimentation, Abstract Conceptualisation and Concrete Experience.

This study contributes to the literature in terms of revealing the correlations between upper-secondary school students' cerebral dominance, learning styles and chronotypes. The findings may provide implications for determining learning styles, which have proven effects on student performance in the teaching-learning process, and, by establishing relationships between individuals' brain structures and chronotypes, the characteristics that direct learning preferences.

This study yielded findings about upper-secondary school students' learning styles, cerebral dominance and chronotypes. However, it does have some limitations. Firstly, the results of the study are based on self-reported measurements by the upper-secondary school students included in the sample. Future studies can gather more objective data by combining findings from qualitative and quantitative data, such as with mixed models. Moreover, the study is insufficient in terms of explaining the reasons for the correlations between the variables. For future studies, it can be suggested that the aspects of the correlations between the variables be clarified with regression studies that can be made between the related variables. In the study, the hypothetical correlations between cerebral dominance, learning styles and chronotypes are based on hypotheses that can be formed based on the literature. The correlations may have other possibilities, and this may be a suggestion for future studies. The findings obtained in the study reveal that students' learning styles and cerebral dominance are correlated. From this point of view, it can be said that in the teaching-learning process, performing activities in which students can use different brain quadrants can enable the development of different individual characteristics in students and, in parallel with this, strengthen and diversify their existing learning styles.

The authors declare no competing interest.

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