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CLASSIC ANATOMICAL MODELS ARE STILL EFFECTIVE IN THE DIDACTICS OF HUMAN ANATOMY

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Abstract: We present a study on the efficacy of an anatomical model of the brainstem used for teaching first-year medical students. The model was handmade by the authors and entails the following structures: brainstem, vertebral arteries, basal artery with its ramifications, nuclei of all cranial nerves with their structure, function, and localization. In order to investigate the usefulness of the model, we compared performance between three groups of students (in total 104 students) – one group learned with the model and the remaining groups learned using traditional methods. All students underwent a test examination. Based on a statistical analysis, students who used the model had better scores ($p<0.001$) than students from the remaining groups, which indicates that the process of acquiring new knowledge is improved, in comparison to traditional methods, by the application of the model. Based on the results, the model is useful in learning the structure of the nuclei of the following cranial nerves: glossopharyngeal nerve, abducens nerve, facial nerve, and trigeminal nerve. Following the teaching course, self-assessment of students who used the model was higher than those who used traditional methods ($p = 0.004$). The described model is a useful teaching tool that helps in teaching anatomy in our department.

Keywords: anatomical model of the brainstem, glossopharyngeal nerve, abducens nerve, facial nerve, trigeminal nerve.

Introduction

A large amount of information that has to be taken in by first-year medical students is enormous, which poses a challenge. All students are fascinated by anatomy, but the process of learning is very demanding. One of the problems faced by students is the difficulty in getting to know structures that cannot be seen directly on specimens. Some complicated anatomical structures are presented only in figures, including nuclei of the cranial nerves. Everyone who teaches anatomy knows how difficult it is for the students to learn the location and function of cranial nerves. Cranial nerve nuclei are presented in figures in books and atlases, but all figures, being two-dimensional, are of limited value in showing the topographical complexity. With the introduction of advanced technologies to the teaching of anatomy, anatomical models play an ever decreasing role. However, anatomical models can be still useful in some areas of anatomy [1]. In contrast to figures, models shown the three-dimensional nature of particular anatomical structures [2,3]. This not only helps in learning anatomy, but also makes the whole process more attractive, thereby encouraging student to learn [4]. Most of anatomical models are manufactured with the use of standard molds that cannot present subtle details, which limits the representation of topography. For that reason, we decided to create a new anatomical model for our students using standard sculpting techniques. Herein, we present a study on the efficacy of using such a model for teaching anatomy.

The main aim of this article is preliminary test of the efficacy of new method of teaching. We expected that students' knowledge of the cranial nerves will be better in group taught using model than in the groups not taught yet about cranial nerves and taught in traditional way. Additionally we have tested hypotheses about relationship of teaching method with self-assessment of knowledge of cranial nerve nuclei, self-assessment of one's own spatial skills, course satisfaction and assessment of test difficulty.

Materials and methods

We created the model based on anatomical handbooks and atlases. A project of the model was drafted. A scaffoldding for the model was created with steel bars and measured 170 cm in height and 100 cm in width (Figure 1).

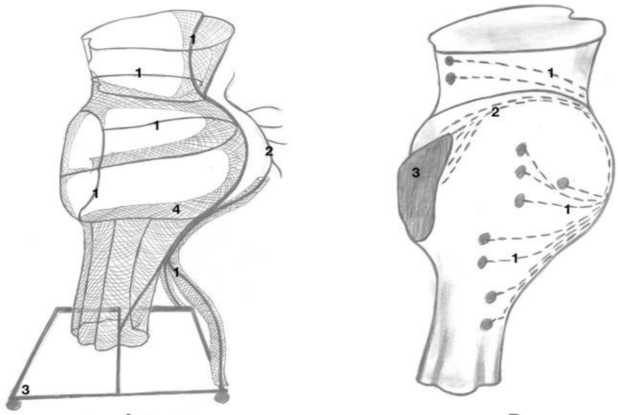

Figure 1. Short description of model construction: A1.Metal scaffolding supporting the structure. A2.Metal scaffolding imitating blood vessels. A3.Model base with wheels. A4.Metal net acting as a foundation for the sculpture. B1.Electric wires running from each nucelus to the periphery. B2.Direct pathway markings of hidden wires to the dashboard. B3.Dashboard with buttons.

The final shape was sculpted (Figure 2).

Figure 2. Model before painting – view from the left side.

The model was painted in different colors to delineate particular structures: motor nuclei and nerve fibers originating from them were colored in red, sensory nuclei and fibers terminating in them were colored in blue, and parasympathetic nuclei and fibers were colored in black. Electrical wires were supplied to every nuclei and soldered to diodes in appropriate colors. A dashboard board was fitted with 24 buttons that were labelled with the names of particular nuclei. The nuclei were segregated in three rows: 1) sensory nuclei, 2) motor nuclei, and 3) parasympathetic nuclei (Table 1).

Structures representing the brainstem were colored in grey, which is similar to the color of brainstem specimens. The right side of the rhomboid fossa was covered with a Plexiglas plate. Blood vessels were painted in red. The model was placed on a transportation trey to move it between teaching rooms (Figure 3).

Table 1. Classification of cranial nerve nuclei on model dashboard

Character of Nucleus	Name of Cranial Nerve Nucleus									
Motor Nucleus	Principle nucleus of the oculomotor nerve III	Central nucleus of the oculomotor nerve III	Caudal part of the central nerve of the oculomotor nerve III	Nucleus of the trochlear nerve IV	Nucleus of abducens nerve VI	Nucleus of the hypoglossal nerve XII	Nucleus of the trigeminal nerve V	Nucleus of the facial nerve VII	Nucleus ambiguus IX,X,XI	Nucleus of the accessory nerve XI
Sensory Nucleus	Mesencephalic nucleus of the trigeminal nerve V	Pontine nucleus of the trigeminal nerve V	Spinal nucleus of the trigeminal nerve V	Anterior cochlear nucleus VIII	Posterior cochlear nucleus VIII	Inferior Vestibular nucleus VIII	Superior vestibular nucleus VIII	Medial vestibular nucleus VIII	Lateral vestibular nucleus VIII	Solitary nucleus VII, IX, X
Parasympathetic Nucleus	Accessory nucleus of the oculomotor nerve III	Superior Salivary nucleus VII	Inferior salivary nucleus IX	Dorsal vagal nucleus X						

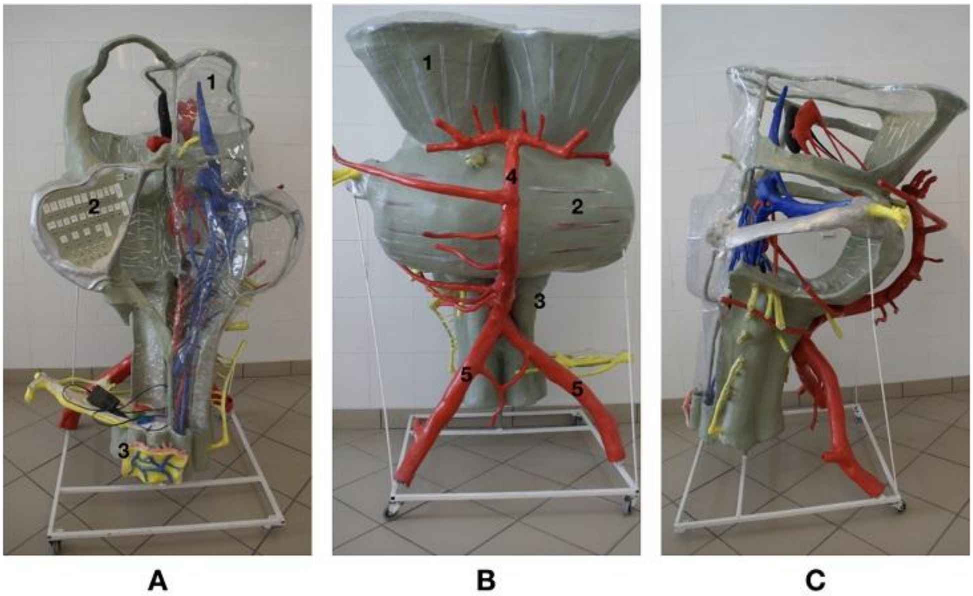

Figure 3:A. Model – view from the back; B. Model – view from the front; C. Model – view from the right side. A1.Posterior surface of the midbrain made of transparent acrylic glass. A2.Dashboard with buttons. A3.Spinal meninges with internal vertebral venous plexus. B1. Cerebral peduncles. B2.Pons. B3.Medulla oblongata. B4.Basilar artery with branches. B5.Vertebral arteries.

In order to investigate the efficacy of the model for teaching, we created a test examination and a survey. The examination comprised of 10 questions referring to cranial nerves (III-XII). The survey comprised of four questions: 1) level of knowledge of the cranial nerves, 2) level of spatial imagination of students, 3) satisfaction from the course, and 4) difficulty of the test. All survey questions were answered on a scale from 1 to 6 (1 – very low, 6 – very high). We enrolled 104 students, who were divided into the following three groups:

1. Traditional group (T) comprising of 27 students. These students underwent the examination after hand-book and atlas-based self-study that lasted 15 minutes.
2. Students learning with the model (M); 43 students. The students underwent the examination after an introduction to the model made by a teacher and then had 15 minutes for self-study.
3. Control group (C) comprising of 34 students. These students underwent the examination just after course commencement.

We tested students in two phases. Phase 1 – 48 students who attended the course in the morning (between 8 am and 10 am); Phase 2 – 56 students who attended the course between 11 am and 1 pm.
The results were analyzed statistically using Pearson's correlation coefficient, ANOVA and Generalized Linear Models. Analyzes were done using IBM SPSS v. 24 [5].

Results

Descriptive statistics of the analyzed variables and their first-order correlations are presented separately for study groups in Table 2.

Table 2. Descriptive statistics of the analyzed variables and their first-order correlations (Pearson's coefficients) presented separately for study groups.

Group	Variable	M	SD	1.	2.	3.	4.	5.	6.
Traditional	1. Gender	1.37	0.492						
(n=27)	2. Time of the day in which the course was held	1.52	0.509	0.13					
	3. Test score (points)	6.93	1.880	-0.30	-0.08				
	4. Self-assessment of knowledge of cranial nerve nuclei	3.56	0.751	-0.06	0.02	-0.16			
	5. Self-assessment of one's own spatial skills	4.00	1.240	0.50**	-0.06	-0.12	0.33		
	6. Course satisfaction	4.00	1.330	0.00	-0.34	-0.12	0.04	0.14	
	7. Assessment of test difficulty	5.52	2.293	0.23	0.09	-0.40*	-0.02	-0.04	0.03
Model	1. Gender	1.47	0.505						
(n=43)	2. Time of the day in which the course was held	1.47	0.505	0.07					
	3. Test score (points)	8.58	1.468	-0.25	0.27				
	4. Self-assessment of knowledge of cranial nerve nuclei	4.12	0.762	0.17	0.23	0.04			
	5. Self-assessment of one's own spatial skills	4.16	0.998	0.22	0.18	0.23	0.26		
	6. Course satisfaction	5.35	0.923	0.10	0.15	0.13	0.38*	0.20	
	7. Assessment of test difficulty	6.23	1.716	0.15	0.28	-0.12	-0.20	-0.18	-0.23
Control	2. Time of the day in which the course was held	1.35	0.485						
(n=34)	3. Test score (points)	5.65	2.255		0.06				

In the traditional group (T), men rated their spatial skills better than women. The difference between correlation coefficients was not significant (z=1.26; p=0.104).
We found a negative correlation between the perceived test difficulty and the test score in groups T and K. In group T, this correlation was statistically significant; in group K, it was insignificant. The difference between correlations was not significant (z=-1.17; p=0.121).
In group M, we found a correlation between course satisfaction and the self-assessed level of knowledge. The difference in correlation coefficients between group T and group M was close to being significant (z=-1.39; p=0.08).
Course satisfaction had a closer relationship to the time of the day, in which the course was held, in group M than in group T. In group T, students were more satisfied in the morning, and in group M in the afternoon. The difference between correlation coefficients was statistically significant (z=-1.96; p=0.025)**)**.

Comparison of teaching methods

We used two-way analysis of variance to investigate the influence of teaching method on learning effects controlling course time (daytime). We used simple contrast to test the hypothesis abut differences between group M and other groups. The relationship between the time of the day, in which the course was held, and test scores was not significant ($F(1, 100) = 0.854$; $p = 0.358$). The main effect of teaching method was significant ($F(2, 100) = 23.224$; $p < 0.001$; $\eta^2 = 0.32$). Students in group M had significantly higher examination scores than students from groups T (d=-1.67; p<0.001) and C (d=-2.90; p<0.001) (Figure 4).

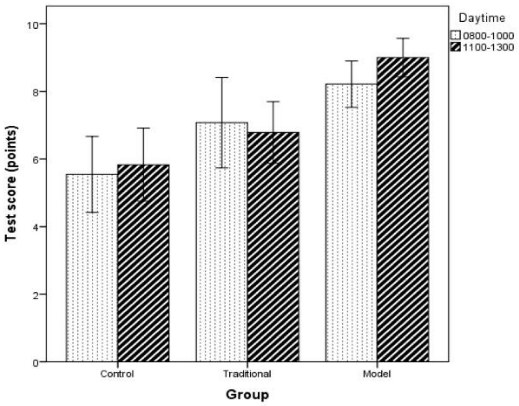

Figure 4. Mean test scores with 95% confidence intervals in student groups differing in teaching method and time of the day in which the corse was held.

Assessment of fields of knowledge in which the model was helpful

In Table 3, we present the frequency (*f*) and percentage (*p*) of correct answers to individual test questions in three groups. For clarity, they are presented according to the level of difficulty in the control group. This order will be preserved in the following analyses.

In order to compare the influence of individual teaching methods on responses to particular questions Generalized Linear Models (GENLIN) were used, where questions were modeled as repeated measures and binomial logit model was applied. Test of interaction between group and repeated responses was insignificant ($\chi^2(17) = 18.16$; $p = 0.379$) – the effect of teaching method was comparable on all questions.

Moreover, we compared, pairwise, responses to each question in three groups (using Bonferroni correction). We found 4 patterns of differences:

1. As regards question 3 that refers to the trigeminal nerve (the simplest question), we found no differences between groups.
2. Differences between group M and group C but not group T occurred in case of question 7 (glossopharyngeal nerve; $p = 0.03$), question 4 (abducens nerve; $p = 0.018$), and question 5 (facial nerve; $p = 0.420$),) question 10 (hypoglossal nerve; $p < 0.001$) and question 9 (accessory nerve; $p < 0.001$), the latter being the most challenging
3. As regards question 1 (oculomotor nerve), question 8 (vagal nerve), , and question 2 (trochlear nerve), we found better scores in favor of group M in comparison to group C ($p < 0.001$; $p = 0.017$; $p = 0.007$, respectively) and in comparison to group T ($p = 0.023$; $p = 0.017$; $p = 0.015$, respectively).
4. As regards question 6 (vestibulocochlear nerve) and, we found differences between group C and group T ($p < 0.001$),only. There were no differences between group M and group T or group C. In the case of these two areas, both methods are equally efficacious (Table 3; Figure 5).

Table 3. Correct answers to individual questions in study groups.

Question	Control (n=34)		Traditional (n=27)		Model (n=43)	
	f	*p*	*f*	*p*	*f*	*p*
Q3 (Trigeminal nerve)	29	0.85	20	0.74	40	0.93
Q7 (Glossopharyngeal nerve)	24	0.71	23	0.85	40	0.93
Q6 (Vestibulocochlear nerve)	23	0.68	27	1.00	38	0.88
Q4 (Abducens nerve)	21	0.62	22	0.81	38	0.88
Q5 (Facial nerve)	20	0.59	19	0.70	36	0.84
Q1 (Oculomotor nerve)	17	0.50	18	0.67	40	0.93
Q8 (Vagal nerve)	16	0.47	12	0.44	33	0.77
Q10 (Hypoglossal nerve)	16	0.47	18	0.67	39	0.91
Q2 (Trochlear nerve)	15	0.44	12	0.44	33	0.77
Q9 (Accessory nerve)	11	0.32	16	0.59	32	0.74

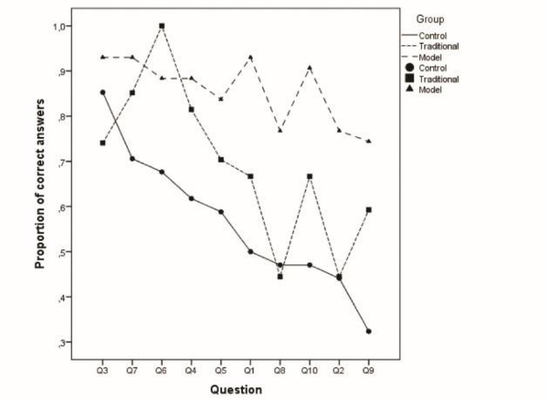

Figure 5.Proportion of correct answers in study groups. Questions are ordered according to difficulty.

Comparison of group T and group K in terms of the remaining variables

Hypotheses about relationship of teaching method with self-assessment of knowledge of cranial nerve nuclei, self-assessment of one's own spatial skills, course satisfaction and assessment of test difficulty were tested using 3-way ANOVA, taking into account teaching method, daytime and gender of subjects as factors.

Based on self-assessment of students, we found that students from group M were more certain of their own knowledge ($F(1, 62) = 9,06$; $p= 0.004$; $\eta2 =0.13$).

In the analysis of self-assessment of spatial imagination, we found an interaction effect between gender and group, which was close to being significant ($F(1, 62) = 3.12$; $p=0.082$; $\eta2 =0.05$). As regards the tests of simple effects, we found that women in group T, after the course, perceived their own spatial imagination skills worse than men ($d= -1.312$; $p=0.002$); in group M, that effect was not found ($d=-0.392$; $p=0.218$) (Figure 6 left).

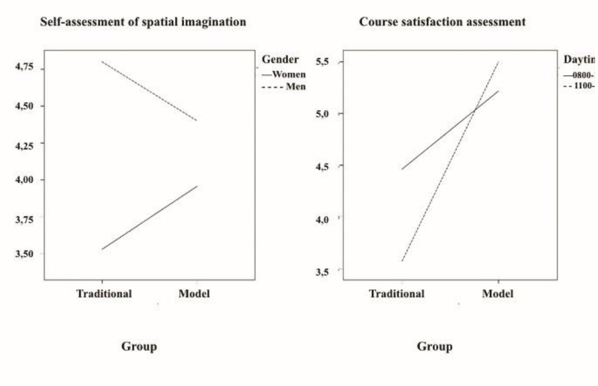

Figure 6. Self-assessment of spatial imagination-interaction of gender and teaching method. (left). Course satisfaction assessment - interaction of daytime and teaching method (right).

As regards the analysis of course satisfaction, there was a significant effect of an interaction between student group and the time of the day in which the course was held ($F(1, 62) =6.09$; $p=0.016$; $\eta2 =0.09$). Based on the tests of simple contrasts, the afternoon group T had a worse course satisfaction than the morning group ($d= 1,069$; $p=0,017$); this effect was not found in group M ($d=-0.285$; $p=0.395$). Moreover, course satisfaction was higher in students who used the tested model in the afternoon than in the morning (Figure 7).

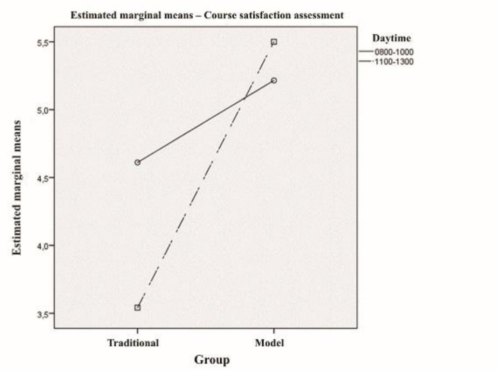

Figure 7. Course satisfaction assessment.

We did not find any relationship between the perceived level of test difficulty and the tested independent variables (group, course time, gender).

Discussion

A significantly improved self-assessment of spatial skills in group T, in contrast to group M in which this effect was not found, could indicate a psychological mechanism that can be associated with using a spatial model whilst learning. This mechanism is especially favorable for women, in whom the use of a spatial model can alleviate the impact of the auto-stereotype of the woman that can, in turn, influence learning efficacy.

The fact that we found a negative correlation between the perceived test difficulty and test scores in group T and group C can point towards an effect of an increased certainty of the acquired knowledge with the traditional methods. This effect is not universally favorable in the teaching process.

Satisfaction effect.

The significant correlation between course satisfaction and the perceived knowledge certainty in group M indicates that working with an anatomical model leads to a closer association between learning satisfaction and the acquired knowledge in comparison to the traditional method. Perhaps, other factors than knowledge itself play a greater role, for instance, learning environment.

Comparison of efficacy of teaching methods.

Based on our research, the time of day in which the course was held did not influence final test scores. The fact that students from group M had higher test scores than student from group C and group T indicates that learning with the use of an anatomical model is improved in comparison to the traditional method. There are scientific reports on the efficacy of digital models in education. Similar results were obtained by Nicholson et al. in the study on the computer-generated three-dimensional model for teaching ear anatomy [6].

The significant differences between the studied groups with respect to particular cranial nerves substantiate the efficacy of the tested anatomical model. Based on our research, employing an anatomical model gives the most visible effects with respect to those cranial nerve nuclei that are most difficult to get to know, i.e., the nuclei of the glossopharyngeal, abducens, facial, and trigeminal nerves. Learning about the nuclei of the oculomotor, vagal, and hypoglossal nerves with traditional methods is not efficacious.

Moreover, we found that women had higher test scores in both groups. This can be due to the fact that women spend more time learning and are accustomed to acquiring a large body of new information.

Moreover, the use of the tested anatomical model "alleviated" the difficulties associated with a different time of the day in which the course was held. Although the course in group M was assessed more favorably, this effect was not significant. The later in the day the course is held, the greater is the effect on course satisfaction of using the model.

There have been tremendous changes in the process of teaching human anatomy since its beginning to the present day. We have witnessed how the teaching process have been influenced by modern technology [7-10]. Since the very beginning of teaching medicine, anatomical models have played a very important role [11]. With the current technological advancements, three-dimensional interactive models are put aside. However, our research shows that such models can still be used for teaching anatomy. The model of cranial nerve nuclei that was made in our department is an object of interest for medical students who always surround it during anatomy courses.

It should be underscored that the fact that the model was handmade with the use of simple and affordable materials has some advantages: 1. The model is multidimensional, in contrast to the commercially available models that are made with the use of molds. The student can walk around the model, touch every structure, and acquire the relevant knowledge of particular cranial nerve nuclei. 2. Each nucleus is lit up with a diode, which further enhances learning. 3. The model can be improved in future by adding other structures, for instance, nerve pathways. 4. The model can be made at a low cost.

I hope that this article will inspire other authors to personally engage in creating anatomical models.

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