Learning in Education with Augmented Reality on a Smartphone: Individually or Collaborative?

Olaf Pijl (5945232)

O.Pijl@students.uu.nl

Utrecht University

Supervisor: M.M.S. Schaars

Word Count: 6879

09 – 06 – 2019

2018 – 2019 Master thesis Educational Sciences (201600025)

Abstract

Augmented reality (AR) tools designed with the principles from the cognitive theory of multimedia learning (CTML), could enhance learning in education, but previous research has shown contradictory results while working individually or collaboratively with AR. To prove if the CTML principles are responsible for the increasing learning outcomes, current study used AR tools which violated the CTML principles in general to examine the differences in the learning outcomes. Ultimately, a statement can be made if a teacher could implement AR tools which violates CTML principles in their education. Forty-nine Dutch speaking participants from regional training centers in the Netherlands were recruited. Current study used a 2x2 quasi-experimental factorial design. The factors were learning environment (AR/conventional) and group composition (collaboratively/individual). The results were analyzed with ANCOVA analysis with pretest as covariate. All groups scored significantly higher on posttest compared to pretest, but non-significant effects of learning environment and group composition were found, which means that the used AR-tool does not negatively influence the learning outcomes and could be implemented in education. Further research should measure different forms of students' cognitive load and different forms of collaboration in order to positively influence the learning outcomes with AR-tools which violated the CTML principles.

Keywords: augmented reality, learning outcomes, collaboration, cognitive theory of multimedia learning, conventional learning

Learning in Education with Augmented Reality on a Smartphone: Individually or Collaborative

Augmented Reality (AR) tools seem to be a promising potential for education settings, because AR tools could potentially increase students' knowledge learning outcomes (Sotiriou & Bogner, 2008). Previous studies show contradicting results in learning individually or in dyads (Aydin, 2011; Chen, 2008). A meta-analysis concluded that AR could support learning more when students are working as collaborative learners (Phon, Ali, & Halim, 2014). The learning outcomes in the previous studies were gathered by a knowledge pre- and posttest. In previous research, the findings were theoretically underpinned with the principles of the cognitive theory of multimedia learning (CTML, Sommerauer and Muller, 2014). These studies did not intentionally design the AR tools based on the CTML principles, which means that the researchers could not prove that the results in their study were caused by the fact that the AR tools were designed based on the CTML principles. In addition, these studies did not take the practical field of education into account. Most teachers do not have time or money to design AR tools and must use AR tools which they can get from internet. These AR tools are not customizable and may not include all the materials that a teacher wants to use for their lessons, which causes these applications to violate the CTML principles. It is unknown whether using AR tools which violate the CTML principles in educational settings will still increase the learning outcomes of students. The current study examined if AR tools which are not designed based on the CTML principles increased the learning outcomes of students compared to conventional learning based on working collaboratively or individually. If this is the case, teachers could implement AR tools which are not in line with the principles of CTML as effective tools in their education. If not, the theoretical underpinning from Sommerauer and Muller (2014), is confirmed.

Augmented Reality

AR uses technology to combine the real environment with virtual objects (Klopfer & Squire, 2008), and let them coexist and interact with each other (Azuma, 1997). This experience can be created by different devices, such as a head-mounted display (HMD) that creates holograms around an individual or with a camera on a mobile device. The first concept of AR was developed for aircraft electricians. The system created virtual electronic cables on an aircraft to support and teach electricians to place the cables in the right place (Caudell & Mizell, 1992). AR could offer an instructional design in which digital learning materials are implemented in a physical environment. It allows the user to look at the inside of a 3D structure, which could be interactive, and not visible in such way on paper in 2D (Chien, Chen, & Jeng, 2010). AR could make abstract concepts more concrete and understandable (Sotiriou & Bogner, 2008; see Figure 1).

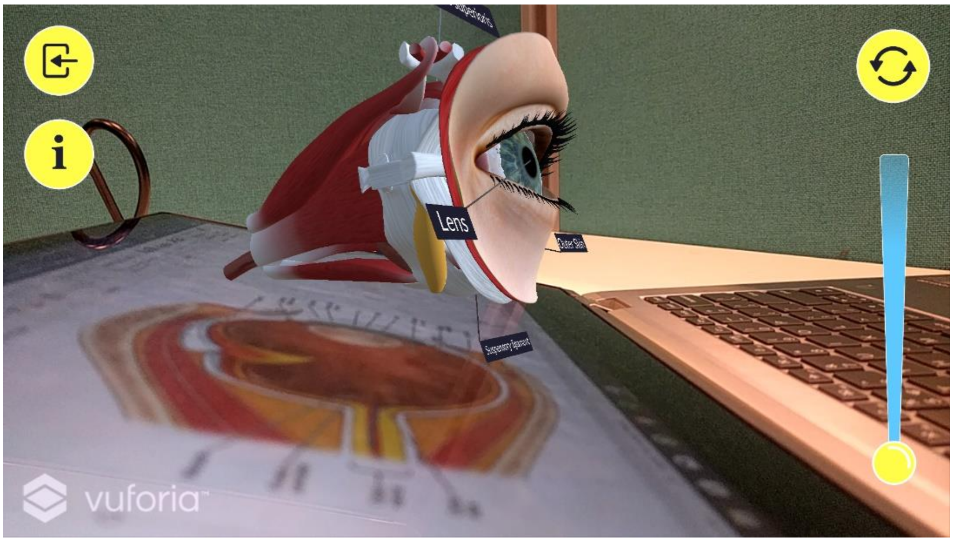


Figure 1. An Impression of ‘The Human Eye. Retrieved on January 23, 2019, from The Eye Brain Application. Screenshot of The Human Eye Application by Author.

AR especially seems effective for understanding complex 3D formats (Rosenbaum, Klopfer, & Perry, 2007) by improving spatial abilities (Martin-Gutierrez et al., 2010), which includes visualization, perception, rotations, relations, and orientation (Maier, 1994). AR could lend itself useful for educational when it comes to learning of 3D complex formats because it shows the ‘inside’ of these 3D models. More recent work of Chien et al. (2010) found that students can learn complex structures of the human skull even better with AR software than conventional methods. This could mean that implementing an AR tool in education works for learning 3D structures. The only problem could be that teachers do not have the time and knowledge to design and test their own AR applications. This means that teachers must choose between online existing AR tools that are not specifically made for their lessons. This could lead to problems such as the application being in a not understandable language, or specific aspects that are interesting for the lesson not being labeled. Imagine that a teacher wants to discuss the eye muscles in a lesson biology. The AR simulation of the human eye in figure 1 does not has any labels corresponding to the muscles of the human eye, but the AR simulation in figure 1 does display the eye muscles. The only problem is that it does not contains any label referring to those muscles. Due to this fact, the teachers have to give an instruction in which these muscles are explicitly mentioned.

Individual Learning Outcomes

In an experimental study of Sommerauer and Muller (2014), individually acquiring and retaining mathematical knowledge from visitors in a mathematics exhibition was measured. The AR group showed higher results on acquiring and retaining mathematical knowledge. However, this study was only focussed on retrieving information. Therefore, it is still unknown if this works for more complex learning tasks such as problem solving skills. Sommerauer and Müller (2014) argued that the higher learning gains in maths could be explained by the cognitive theory of multimedia learning (CTML; Mayer, 1997).

CTML states that learners process information via a verbal system and a visual system. In CTML, there are three cognitive processes that the learner will engage while learning: (1) selecting of visual and verbal information, (2) organizing this information, and (3) integrating and making connections between the visual and verbal information (Mayer, 1996). In addition, CLML provides five principles to help learners understand content with the use of multimedia: (1) multiple representation principle: present explanations in words combined with pictures, (2) contiguity principle: present words and pictures close to each other, (3) split-attention principle: present explanations in verbal instead of in text on screen, (4) individual difference principle: leaners with less prior knowledge show more effects on the first three principles, (5) coherence principle: use few instead of many extraneous words en pictures (Mayer & Moreno, 1998). Sommerauer and Muller (2014) stated that they cannot prove that their AR design including the CTML principles caused their findings. They provided theoretical arguments that the implementations of the principles of CTML in AR resulted in an effective educational tool. Their experiment was not set up to prove that the CTML principles caused the effects in their experiment. They suggest that further research should experiment with AR experiences that intentionally violate these principles to provide prove that the CTML principles caused the higher learning gains in math.

Different studies state that if AR is designed in-line with these multimedia principles, it could explain why using AR increases the learning outcomes compared to conventional learning without AR (Ibáñez, Di Serio, Villarán, & Kloos, 2014; Parhizkar et al., 2012; Sommerauer & Müller, 2014). This could be explained by the fact that these principles lower the cognitive effort of the individual learner. This could create more cognitive 'space' for learning and improve the learning outcomes (Ibàñez et al., 2014).

This cognitive space can be explained by the cognitive load theory (CLT; Sweller, 1998). CLT states that there are three kinds of cognitive loads while learning: intrinsic load, extraneous load and germane load. Intrinsic load is imposed by the difficulty of an assignment. Extraneous load is affected by processes that are irrelevant for learning, such as using bad CTML design principles. Germane load is caused by processes, such as connecting new information with information that is already known and relevant for learning. Good designs of AR tools can alter the extraneous load of students, which creates more space for intrinsic load and germane load (Paas, Renkl, & Sweller, 2003), which eventually could lead to higher learning outcomes (Ibàñez et al., 2014). However, as soon as the AR software is not designed in line with the CTML principles the extraneous load could increase and hinder learning due to cognitive overload, which could result in lower learning outcomes.

Collaborative Learners vs. Individual Learners

Learning individually seems to differ compared to collaborative learning (Parsons, Ryu, & Cranshaw, 2006). Collaborative learning can be described as working together on a joint task with two or more individuals to acquire a shared goal (Dillenbourg, 1999; Laal, 2013).

In an experiment were students worked in a laboratory as collaborative learners or individually on a task in which the students had to identify laboratory equipment's, the collaborative learners scored higher on academic achievement and had positive attitudes towards sciences (Aydin, 2011). In another research (Chen, 2008) students had a higher understanding of the basic concepts about protein structures when working alone with AR than working collaborative peers on a task with AR, which was in contradiction with the expectations of the researcher. Chen (2008) used a pre- and posttest knowledge test and a cognitive load questionnaire. It seems that the collaborative group reported a higher cognitive load compared to the individual group. One explanation could be that the peers had to pay more attention to what their peer said and asked, which could alter the extraneous load of the students. Another remark of Chen (2008) was that the students had equal amount of time to study the materials. The peers had to pay attention to the materials and to their peers, and therefore it could be that they did not have enough time to finish the assignment.

A meta-analysis from Phon et al. (2014) on learning with AR tools and collaboration showed that AR had more positive effects on learning performances when working in pairs compared to working alone. The researchers argued that these higher results are established by giving responsibility to the students, face to face communication and creating a dependency between the dyads. Collaborative instructions could foster the development of problem-solving skills and create opportunities for social interaction such as discussions, task division, planning, consultation, explaining, arguing, listening (McManus & Gettinger, 1996; Peterson & Swing, 1985). These activities are established by social interaction, which could not be possible when learning individually (Cleveland-Innes & Emes, 2005). This could explain why working as collaborative learners showed higher academic achievements compared to individually. In line with Chen (2008), Phon et al. (2014) argued that students also reported that using AR caused extraneous cognitive load due to a large amount of information. Higher extraneous load could alter the cognitive space from the students, which could result in lesser cognitive space for intrinsic and germane cognitive load (Paas et al., 2003). Due to the fact that there is less intrinsic and germane cognitive load, it could result in lower learning outcomes because of cognitive overload (Ibàñez et al., 2014). It is interesting that Phon et al. (2014) found that students reported extraneous load as result of working with AR and still managed to have higher learning outcomes compared to working individually. Phon et al. (2014) argued that further research in collaboration with AR should utilizing on proper instructions strategies.

Nebel et al. (2017) tried to look upon different instruction strategies of collaboration. Nebel et al. (2017) performed a study in which students had to collaborate to complete a task. In this study the researchers measured performance and cognitive load. The performance was measured with knowledge questions and spatial orientation questions. The cognitive load was measured as a sum of intrinsic load, extraneous load, and germane load. Nebel et al. (2017) offered two different kinds of collaboration to the students: *voluntary cooperation group*: each student had access to the same information and did not necessary need each other to complete the task), and *increased task interdependence group*: each student had access to specific information, so collaboration was essential for completing the task. Researchers did not find a difference in cognitive load between the two groups. They did find that the *increased task interdependence group* outperformed the *voluntary cooperation group*. The researchers stated that the increased cognitive load did not harmed the learning outcomes, but the cognitive load was used to enable learning. This could imply that while designing a learning environment with AR and collaboration, the students have access to difference kinds of information to complete the task.

Current Study

Based on the findings above, AR seems suitable for implementation as a supportive tool in education of learning complex 3D structures, but there are some aspects that have not been explicitly addressed. Sommerauer and Müller (2014) suggest that further research should study the effects of AR experiences that intentionally violate CLMT principles in general, in order to provide proof for that the CTML principles caused the effects in their experiment. In addition, Sommerauer and Müller (2014) only measured information retrieving, future research should take a more complex task into account. Moreover, there is a challenge in designing an effective collaborative learning environment (Phon et al. 2014). Nebel et al. (2017) suggest that working as collaborative interdependent learners increases the learning results of the students.

This study is designed to give insight in the differences in learning outcomes while using AR tools which intentionally violates the CTML principles compared to learning with the absent of AR tools. Therefore, the research question of this study is ‘Does the use of AR-tools which violate the CTML principles create differences in learning outcomes compared to conventional education?‘.

The AR tool used in this study could increase the learning outcomes of the students, due to the fact that AR reported higher results in learning outcomes of learning complex 3D models (Chien et al., 2010; Martin-Gutierrez et al., 2010; Rosenbaum et al., 2007). Yet, AR tools which are not designed based on the CTML principles, could cause more extraneous cognitive load, which eventually could lead to cognitive overload (Ibàñez et al., 2014; Parhizkar et al., 2012; Sommerauer & Müller, 2014). Because of the contradicting findings in previous literature, a null-hypothesis and alternative hypothesis were created:

H_0 = There is a non-significant main effect for the learning environment (AR / conventional) on the posttest.

H_a = There is a significant main effect for the learning environment (AR / conventional) on the posttest.

In addition, this study looks upon the effects of working as collaborative interdependent learners with an AR tool compared to working individually with an AR tool on the learning results. In the study from Nebel et al. (2017) the students worked as interdependent learners, which caused higher learning outcomes from the students, but they also reported higher levels of extraneous cognitive load, which could hinder learning due to cognitive overload (Ibàñez et al., 2014; Paas et al., 2003). As a result of the contradicting findings in previous literature, the current study used AR tools which violate the CTML principles. It is unclear what the effect of violating the CTML principles is and therefore a null-hypothesis and alternative hypothesis were created:

H_0 = There is a non-significant main effect for group composition (individually / collaborative) on the posttest.

H_a = There is a significant main effect for group composition (individually / collaborative) on the posttest.

Method

Design

This study will examine the learning outcomes of AR tools in education compared to conventional education in a medical domain. The current study is based on a design from a previous study with AR and learning outcomes of Sommerauer and Müller (2014) who used two groups: with AR / without AR. Also, this study is based on the study from Chen (2008) who investigated how the learning outcomes differ between working in dyads or individually with AR. The combination of these previous studies created a quasi-experimental 2x2 factorial design. The factors will be: (1) educational setting (AR/conventional), and (2) group composition (collaborative interdependent dyads or individually). This means that there will be four independend groups: (1) AR dyads, (2) AR individually, (3) conventional dyads, (4) conventional individually.

Participants

Dutch speaking ‘health and well-being level four’-students (41 women, eight men, M_{age} = 17,90 years, SD = 2.04, age range: 16-26 years) from the regional training center (ROC) in Hilversum, which offers secondary vocational education, in the Netherlands, were recruited via the teachers of the ROC. The students were not compensated with a reward for participating in current research. The students were retrieved from four similar classes. Each class was randomly assigned to a group. Two classes were assigned to one of the two experimental groups: (1) AR dyads (eight women, M_{age} = 17,25 years, SD = 1.67, age range: 16-21 years), (2) AR individually (eight women, three men, M_{age} = 18,09 years, SD = 2.91, age range:16-26 years). The other two classes were assigned to the control groups: (3) conventional dyads (12 women, three men, M_{age} = 18,36 years, SD = 1.97, age range: 16-22 years, (4) conventional individual (13 women, two men, M_{age} = 17,90 years, SD = 1.54, age range: 16-22 years). The prior knowledge of the human brain from the four groups did not significantly differ between the groups, F (3, 45) = .80, p = .50.

Most of these participants have worked before with AR in a biology course. In this course, the teacher gave the students a HMD. The HMD showed a hologram of the human heart and students had to discover and explain what happens in different conditions (e.g. heart attack). All the participants received an informed consent from a teacher of the ROC in which the experiment was explained (Appendix A). The teacher also verbally explained the content of the experiment to the participants. If the participants did not want to participate, the participants could work on their regular educational materials from the ROC. If the participants wanted to participate, they signed the informed consent form and handed it in to the teacher.

Materials

AR. The researcher of the current study searched for an application that could intentionally violate the CLMT principles in general. The 'Human Brain' application (Magic Software, 2017a; 2017b) seemed to be a suitable application, because the researcher could not customize the application. The Human Brain app consisted of an AR simulation in which a 3D model of the human brain was simulated. The human brain was a subject that matched the education of the participants in the application, the participants could turn the brain around, zoom in, and 'peel off' layers to see the inner parts of the human brain(see Figure 2). The application contained a 3D model from biology nature, which made the application relevant for the participants (Rosenbaum et al., 2007). The participants used their own smartphone to work on with the human brain application.

A consequence of the fact that the researcher could not customize the application is that the application violates three out of five CTML principles. First, multiple representation principle: the application did not present explanation in words combined with pictures. The labels in the application were in English, while the participants were Dutch. Secondly, the contiguity principle: due to the fact that the applications did not present matching words, the words and pictures were not close to each other. Last, the split-attention principle: there were no verbal explanations.

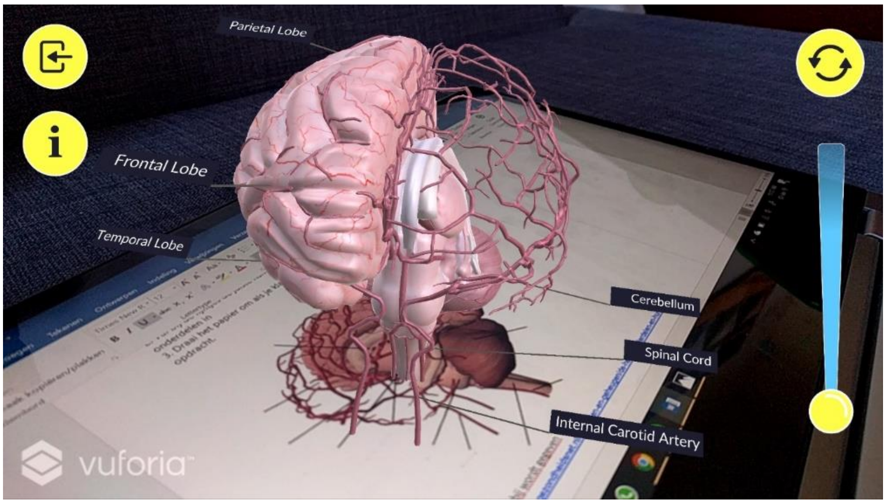


Figure 2. An Impression of 'The Human Brain'. Retrieved on January 3, 2019, from The Human Brain Application. Screenshot of The Human Brain Application by Author.

AR assignments. Two Dutch assignments (with AR tools and without) and two Dutch information forms about the human brain were designed based on the AR tool (see Appendix B). The assignments of this research were designed based on assignments that the students received in their lessons before. Based on that fact, a completing task in which participants had to put names at the parts of the human brain, was constructed. The AR participants had to locate parts of the human brain in the AR tool while working on the assignment. When the part of the brain was located, participants had to write down the name and information about the functions of that specific part. Based on the instruction strategy from Nebel et al. (2017) the interdependent dyad received one assignment form together and each participant received an individual handout with specific information about the human brain. The handouts contained different parts of information, pictures, and names of specific parts of the brain. The information was retrieved from the Dutch Brain Foundation (2019). Participants were forbidden to show the information forms to each other, which caused that they were interdependent to complete the assignment. The individual assignment was identical to the dyads' assignments, but participants received all the information at once and did not have to collaborate. The assignments were piloted with a subject matter expert, who was a biology teacher on the ROC, and six participants to determine the amount of time needed to complete the assignment and correctness of the materials. The amount of time to complete the assignment was 20 minutes. To make sure each participant had enough time to complete the assignment, the time limit was set to 30 minutes.

Conventional assignment. Two conventional assignments about the human brain were created for the conventional groups. 'Conventional' means that there was no AR tool included while completing the assignment. The participants received the same information and almost the same assignment. The only difference was that participants did not had to locate specific parts of the human brain with the AR application, but in the information that was provided. The assignments had a collaborative and individually version (see Table 1 for overview all received assignments per group). In the collaborative version, information was provided separately again. These assignments were piloted. The assignments were equal in length and difficulty, but without the AR tools.

Table 1

Overview of Received Information and Assignments Forms per Group

Groups	Received materials
AR dyads	Participant A: brain information form A
	Participant B: brain Information form B
	Both: AR assignment form
Conventional dyads	Participant C: brain information form A
	Participant D: brain information form B
	Both: conventional assignment form

AR individually	Brain information form A + B, and AR assignment form
Conventional individually	Brain information form A + B, and conventional assignment form

Posttest. A 17-item posttest with questions about the location of specific parts and functions of these parts from the human brain was created (see Appendix C). The posttest was used to measure the knowledge of the participants after the experiment. The posttest started with demographic questions about gender, age, and student number. Followed by six multiple choice questions with three answer options, which will be referred to as the *content questions* (CQ). The CQ were created to measure knowledge about the functions of specific parts of the brain. For each correct answer, one point could be received. Beside the CQ questions, eleven questions were created to measure the spatial ability of the participants, which will be referred to as *spatial ability questions* (SAQ). The SAQ asked where specific parts of the human brain were located. For each correct location, one point could be received

Due to the fact that the measuring instrument is dichotomous (correct/wrong), a principal component analysis could not be performed. For a principal component analysis, the variable must be measured at interval level (Field, 2013, pp. 650). The posttest was created based on experiences from the teachers of the participants. The teachers confirmed the level of difficulty of the questions was corresponding to the level that the participants could handle. This covered the face validity. The content of the questions were scientific facts retrieved from the Dutch Brain Foundation (Hersenstichting, 2019). The Brain Foundation is an organization which invests in research on brain disorders. All questions in the questionnaire were based on knowledge from the Brain Foundation, which covers the content validity.

The Cronbach's alpha for the 17-item multiple-choice posttest was .58. This cannot be considered adequate for research purposes, a closer examination of the questionnaire item-total statistic indicated that alpha would increase to .72 if three items were deleted. These questions were content questions. The low Cronbach's alpha could be explained by the fact that AR is especially good for learning complex structure instead of knowledge of the functions from those specific locations (Martin-gutierrez et al., 2010; Rosenbaum et al., 2007). The Cronbach's alpha for the remaining 14-item posttest was .72. This can be considered as good for research purposes (Evers, Lucassen, Meijer, & Sijtsma, 2009). All subsequent analyses are based on participants 'responses to the remaining fourteen items.

Pretest. The pretest was created to measure the prior knowledge of the participants and was used as covariate to correct the scores on the posttest. The pretest was identical to the posttest, but items were presented in a different order (see appendix D for overview of corresponding items). Since three questions were deleted from the posttest due to the reliability analysis, these items were also deleted from the posttest. For interpretation of the score on the posttest it was necessary that the pre- and posttest were identical to each other. By that fact, three items from the 17 multiple-choice pretests were deleted to make the pretest identical to the posttest. To check the reliability of the pretest, the Cronbach's alpha was calculated. The Cronbach's alpha for the remaining 14-item pretest was .38. This cannot be considered as good for research purposes (Evers et al., 2009). The low Cronbach's alpha could be the result of the fact that the participants did not had any prior knowledge of the covered materials. In another similar study, the Cronbach's alpha of the pretest was also low (Jarrett, Ferry, & Takacs, 2012; Lindell & Olsen, 2002). The researchers argue that the low alpha is a result of student guessing the right questions. This could be also the case in current research. The material covered in the experiment was not taught yet. The covered materials were taught in school after the experiment took place. Therefore, no extra items will be deleted from the pretest. All subsequent analyses are based on participants ‘responses to the remaining fourteen items.

Procedure

Two teachers were trained to collect the data commissioned by the researcher. The researcher of this study was present while collecting the data but did not interfere while the teachers were performing the experiment. The experiment was performed by the teachers of the ROC. Each group was placed in a different classroom. All participants received an informed consent individually before the experiment started, afterwards the teacher gave the experiment explanation. The AR groups downloaded the application of the human brain on their smartphones. All participants received a pre-test that had to be filled in individually. The pretest lasted ten minutes. Next, the AR dyads received the AR dyads assignment and conventional dyads received the conventional dyads assignment. The additional information was handed out to each participant individually and may not be shared with each other, this was mentioned explicitly. The participants were corrected when they ‘forgot’ this rule, but this did not occur much. The AR individuals received the AR individual assignment and conventional individuals received the conventional dyads assignment. All the participants started at the same time. After 30 minutes, the participants received a cue that their time was expired, and all materials were handed in. Finally, all participant received an individual posttest which lasted ten minutes. Total time of the experiment was 60 minutes.

Analytic Approach

The collected data was analyzed in SPSS version 25 and stored anonymously on a secure server from Utrecht University. A paired sample t-test with an α of .05 was used to analyze the results of the posttest compared to the pretest. A 2x2 ANCOVA with the factors *learning environment* (AR / conventional) and *group composition* (individually / collaborative interdependent learners was applied to analyze effects of the factors on the posttest. As pretest was expected to impact on this relationship, it was measured and included in the analysis as a covariate.

Results

First of all, a paired sample *t* test with an α of .05 was used to compare the mean score on the pretest against the mean score on the posttest (see table 2 for desciptive statistics). All the participants scored an average of 2.35 points, 95% CI [1.48, 3.21], higher on the posttest. This difference was statistically significant, $t(48) = 5{,}47$, $p < .001$, with an large effect, $d = 0.95$ (Cohen, 1988). It was concluded that the assumptions of normality and normality of difference scores were not violated for the pre- and posttest after outputting and visually inspecting the relevant histograms.

Table 2

Scores on Pre- and Posttest

	n	*M*	*SD*
Pretest	49	7.18	2.19
Posttest	49	9.53	2.77

Descriptives ANCOVA. A 2x 2 ANCOVA was used to compare the effects of *learning environment* (AR and coventional) and *groupsize* (individually and dyads) on the posttest. As pretest was expected to impact on this relationship, it was measured and included in the analysis as a covariate.. The score on the posttest could range from one to a maximal score of fourteen. Table 3 shows the descriptive statistics with the mean score on the posttest

Table 3

Descriptive statistics for Different Groups Mean score on the Posttest

	Individual			Collaborative		
	n	*M*	*SD*	*n*	*M*	*SD*
AR	11	10.73	2.05	8	9.63	2.26
Conventional	15	9.67	2.55	15	8.87	3.44

Assumtions ANCOVA. Examination of the Shapiro- Wilk statistic and histograms for each group on the posttest indicated that the ANCOVA assumption of normality was not violated exept for *AR*, $W(19) = .87$, $p = .01$. The assumption of normality was not violated for the covariate *pretest*. ANCOVA is considered robust against small to moderate violations of the normality assumption if the covariate does not violated the assumption of normality (Allen, Bennett, & Heritage, 2014), which is the case for the covariate *pretest*. Eximanation of the Shapiro- Wilk statistic and histograms for each group on the pretest indicated that the ANCOVA assumption of normality was not violated. Scatterplots indicated that there was a linear relationship between the covariate pre- and posttest, and that the regression slopes were homogeneous. Levene's test was statistically non-significant, indication homogeneity of variances, $F = 1.70$, $p = .181$. Finally, the assumptions of the homogeneity of regression slopes and homogeneity of variances were supported by the absence of a significant learningenvironment-by-covariate interaction, $F\ (1, 43) = .232$, $p = .632$, and groupcomposition-by-covariate interaction, $F\ (1, 43) = .05$, $p = .828$, and a non significant Levene's test, $F\ (3, 45) = 1.58$, $p = .207$, respectively.

Results ANCOVA. The 2x2 ANCOVA indicated that after accounting for the effects of the pretest, there was a non significant main effect of learning environment on the posttest, $F\ (1, 44) = 2.83$, $p = .100$, $\eta^2 = .06$. In addition, there was a non significant main effect of groupcomposition on the posttest, $F\ (1, 44) = 3.40$, $p = .052$, $\eta^2 = .08$. No interaction between learning environment and groupcomposition was found, F (1, 44) = .03, p = .863, η^2 = .001. Table 4 shows the results of the 2x2 ANCOVA.

Table 4

Results from 2x2 ANCOVA for Posttest with Factors Learning Environment and Group Composition

Source	*SS*	*Df*	*MS*	*F*	*p*	*η2*
Model	78.48	4	19.62	2.98	.03	.21
Intercept	155.56	1	155.56	23.63	<. 001	.35
Score_PRE	45.40	1	45.40	6.90	.01	.14
Learning environment	18.62	1	18.62	2.83	.10	.06
Group composition	26.33	1	26.33	3.40	.05	.08
Learning environment * Group composition	.20	1	.20	.03	.86	.001
Error	289.72	44	6.59			
Total	4819.00	49				

Note. R^2 = .21

Discussion

As described previously, the aim of this study is to give insight in the differences in learning outcomes while using AR tools which violates the CTML principles with the following research question: ‘Does the use of AR-tools which violate the CTML-principles create differences in learning outcomes compared to conventional education?‘. In addition, this study looks at the effects of working as collaborative interdependent learners with an AR tool compared to working individually with an AR tool on the learning outcomes. The results showed a significant difference between the pre- and posttest for all groups. Nonetheless, no significant effects of the use of AR-tools on learning outcomes compared to conventional learning were found. Additionally, no significant effects were found between working as collaborative interdependent learners and individual leaners on learning outcomes.

Learning environment. After analyzing the data, no significant effect of the learning environment (AR / coventional) on the posttest was found. These results could prove the theory from Sommerauer and Muller (2014). The researchers described their AR-tool was intentionally not designed based on the CTML principles, however they theorized the benefits of the CTML principles in their AR-tool resulting in possibly higher learning outcomes. Since they did not design their AR tool on the CTML on purpose they could not prove that the CTML principles caused the differences in learning outcomes. In another study (Turan, Meral, & Sahin, 2018), the researchers did a similar experiment as the current study, but the researchers used AR tools that were in line with the CTML principles. The researchers found a result in which the participants achieved higher learning outcomes compared to conventional learning methods. In addition, students reported lower cognitive load while using AR tools. In contrast to this, the current study did not find any effects of using AR tools which violate the CTML principles. This could indicate that using AR-tools which are designed in line with CTML principles gives increased learning outcomes compared to AR which violate these CTML principles.

This conclusion could be explained by the fact that AR tools which design is based on the CTML principles could lower the extraneous cognitive load of the students, which creates more cognitive space for intrinsic and germane cognitive load (Ibàñez et al., 2014; Paas et al., 2003). The increased intrinsic and germane cognitive load could support the learning of the students and caused a difference in score on the posttest (Paas et al., 2003). Nevertheless, the current study did not find any significantly differences between using AR tools which violated the CTML principles, resulting in that the AR tools did not had a negative effect on the learning outcomes from the participants. This could mean that teachers could implement AR tools which violate the CTML principles in their education, because it will not influence the learning outcomes of the participants negatively. Additionally, there is a possibility that AR affects other variables instead of the learning outcomes, such as motivation and a students' creativity (Wei, Weng, Liu, & Wang, 2015). Further explorative studies could give insight in which different variables, such as motivation, are positively correlated with the use of AR tools that are not in line with CTML principles.

Group composition. Results showed a non-significant effect of group composition on the posttest. A previous study from Chen (2008) indicates that working individually resulted in higher learning outcomes for students. In contrast, a meta-analysis concluded that that higher learning outcomes were achieved when working collaboratively (Phon et al., 2014). Both studies argue that students reported high levels of cognitive load. Phon et al. (2014) concluded that utilizing proper instructional strategies for collaborative learning combined with AR-tools may provide benefits that may lead to higher learning outcomes. Nebel et al. (2017) found that working as collaborative interdependent learners, the learning results of the students increased compared to working as voluntary cooperation. Due to that fact, in current research the participants worked as collaborative interdependent learners. The result of current study is not consisted with the studies from Chen (2008) and Phon et al. (2014). In the current study, the participants worked as collaborative interdependent leaners or individually which not significantly influenced the learning outcomes.

Morrison et al. (2009) identified that using a handheld AR tool is challenging for maintaining awareness for the environment around the user. In current research, both participants which worked as collaborative interdependent learners had their own device that showed the AR stimulation of the human brain. Due to this fact, participants could lose their awareness for their surrounds, which made the use of the AR tool an individual process. They basically did work as collaborative interdependent leaners while using AR, but only while filling in the assignment forms. This could explain why no differences were found while using AR in this study. On the other hand, the participants still worked as collaborative interdependent learners and had enough time while filling in the assignments and still no significant differences were found.

Another reason could be that the collaborative learners in this study did not have enough experiences to collaborate with each other. Nebel et al. (2017) tried to explain the advantage of working as interdependent learners with the theory ‘collective working-memory effect (CWME)’ from Kirschner, Paas, and Kirschner (2011). This theory states that the individual extraneous cognitive load that is created by the task, could be divided among the collaborating learners, which could lower the individual cognitive load and create more cognitive space for intrinsic and germane load (Kirschner et al., 2011). The increased intrinsic and germane load could increase the learning outcomes (Paas et al., 2003). While working together on a task, the communication and coordination of information could cost cognitive effort, which could be advantageous for learning if the communication and coordination impose the germane cognitive load (Ciborra & Olson, 1988). However, when the communication and coordination are ineffective, extraneous cognitive load could be imposed (Ciborra & Olson, 1988) which could be disadvantageous for the learning outcomes (Paas et al., 2003).

In this study the AR-tool violated three CTML principles, (1) *multiple representation*: present explanations in words combined with pictures, (2) *principle contiguity principle*: present words and pictures close to each other, and (3) *split-attention principle*: present explanations in verbal instead of in text on screen (Mayer & Moreno, 1998). Due to the fact that these principles were violated in this experiment, the extraneous load could already increase, despite working individually or collaboratively. This could cause that while working as ‘novice’ collaborative interdependent learner in current research, the cognitive costs for coordination of the information between the dyads could be increased even more. It could be that, due to cognitive costs caused by the communication and coordination of information, the CWME did not occur at the interdependent learners group in current research.

Further research could first learn the participants how to work as an effective collaborative interdependent learner before starting the experiment. By doing so, the collaborative interdependent learners had more experience with the communication and coordination of information, which could lead that CWME effect occurs and impose the germane cognitive load of the participants.

Limitations

The number of participants in this study was relatively low. A power analysis showed that 251 participants will provide enough power. In this study 49 participants were used, which is more than 5 times lower than is needed to be able to make an adequate conclusion. The low number of participants was because a large portion of the students did not show up to their lessons. One week before starting the experiment, the participants received a message with a study advice. Negative advices could result in a decrease in the amount of students that were present during the lessons.

In addition, the pretest gave a low Cronbach's alpha (.37). The low Cronbach's alpha could be the result due to the fact that the participants did not have any prior knowledge at all and the questionnaire was relatively short. This resulted in an inadequate measuring instrument which was still used as covariate. This could mean that the posttest was corrected with inadequate data from the pretest, which could lead to different results. If the measuring instrument had more items, the internal consistency could increase.

Furthermore, this research did not take the cognitive load of the students in account. The insight in cognitive load could give more insights in the results that were found. A lot of research over the years on AR and cognitive load is done (Chen, 2008; Phon et al., 2014;

Turan et al., 2018; Wu, Hwang, Yang, & Chen, 2018), but still contradicting results were found. This could be explained by the fact each researcher had its own perspective on cognitive load. For example, some researchers used cognitive overload (Turan et al., 2018), which showed a lower cognitive load while using AR. Other researchers made a distiction in the term congitive load and used ‘mental effort’ and ‘mental load’ (Wu et al., 2018) and did not find significantly differences in cognitive load (both of these studies used AR tools which were in line with the CTML principles). This makes it difficult to explain how cognitive load influences learning outcomes with AR with and without the design principles of the CTML. Further research should experiment with different kind of measuring instruments of cognitive load compared to the learning outcomes. In addition, more research is necessary to measure the effects of cognitive load from the students and the use of different forms of collaboration. The insight of cognitive load could give insight how the cognitive load enhances the learning outcomes of the students, which is still unclear today.

However further research is necessary to gain a more complete understandig of different forms of collaboration with AR-tools, the findings of the current study indicate that AR-tools that violate the CTML principles could used in educational settings, due to the fact that it does not negatively influences the learning outcomes. Research on this topic should continue and teachers should experiment with different forms of collaboration and share their knowledge with each other. Publishers of educational books should develop AR-tools in which teachers could create and manage their own content corresponding to the materials in their educational books. AR-tools could be the future of learning.

References

Allen, P., Bennett, K., & Heritage, B. (2014). *SPSS statistics version 22: a practical guide*. Australia: Cengage Learning Australia.

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology*, *84*(3), 26.

Aydin, S. (2011). Effect of cooperative learning and traditional methods on students' achievements and identifications of laboratory equipments in science-technology laboratory course. *Educational Research and Reviews*, *6*(9), 636-644.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments*, *6*(4), 355-385. doi: 10.1162/pres.1997.6.4.355

Caudell, T. P., & Mizell, D. W. (1992, January). Augmented reality: An application of heads-up display technology to manual manufacturing processes. In *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences* (Vol. 2, pp. 659-669). IEEE.

Chen, Y. C. (2008). Peer learning in an AR-based learning environment. In *16th International Conference on Computers in Education* (pp. 291-295).

Chien, C. H., Chen, C. H., & Jeng, T. S. (2010, March). An interactive augmented reality system for learning anatomy structure. In *Proceedings of the International Multiconference of Engineers and Computer Scientists* (Vol. 1, pp. 17-19). Hong Kong, China: International Association of Engineers.

Ciborra, C. C., & Olson, M. H. (1988). Encountering electronic work groups: A transaction costs perspective. *Office Technology and People*, *4*(4), 285-298. doi: 10.1108/eb022667

Cleveland-Innes, M. F., & Emes, C. (2005). Social and academic interaction in higher education contexts and the effect on deep learning. *NASPA Journal*, *42*(2), 241-262.

doi: 10.2202/1949-6605.1475

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology*, *78*, 98–104.

Dillenbourg P. (1999) What do you mean by collaborative learning? In P. Dillenbourg (Ed), *Collaborative-learning: Cognitive and computational approaches* (pp.1-19). Oxford: Elsevier

Evers, A. V. A. M., Lucassen, W., Meijer, R., & Sijtsma, K. (2009). *COTAN beoordelingssysteem voor de kwaliteit van tests (geheel herziene versie).* Amsterdam: NIP.

Hersenstichting. (2019). Alles over de hersenen. Retrieved from https://www.hersenstichting.nl/alles-over-hersenen/de-hersenen/anatomie

Ibáñez, M. B., Di Serio, Á., Villarán, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & Education*, *71*, 1-13. doi: 10.1016/j.compedu.2013.09.004

Jarrett, L., Ferry, B., & Takacs, G. (2012). Development and validation of a concept inventory for introductory-level climate change science. *International Journal of Innovation in Science and Mathematics Education*, *20*(2), 25-41.

Kirschner, F., Paas, F., & Kirschner, P. A. (2011). Task complexity as a driver for collaborative learning efficiency: The collective working-memory effect. *Applied Cognitive Psychology*, *25*(4), 615–624. doi: 10.1002/acp.1730

Klopfer, E., & Squire, K. (2008). Environmental detectives: The development of an augmented reality platform for environmental simulations. *Educational Technology Research & Development*, *56*(2), 203–228. doi: 10.1007/s11423-007-9037-6

Laal, M. (2013). Positive interdependence in collaborative learning. *Procedia Social &*

Behavioral Science, *93*, 1433-1437.

Lindell, R. S., & Olsen, J. P. (2002, August). Developing the lunar phases concept inventory. In *Proceedings of the 2002 Physics Education Research Conference*. New York: PERC Publishing

Magic Software (2017). The human eye Android. Retrieved from https://play.google.com/store/apps/details?id=com.magicsw.humaneyear&rdid=com.magicsw.humaneyear

Magic Software (2017a). The human brain Android. Retrieved from https://play.google.com/store/apps/details?id=com.magicsw.humanbrainar

Magic Software (2017b). The human brain iOS. Retrieved from https://itunes.apple.com/us/app/human-brain-augmented-realit/id1309056713?mt=8

Maier, P.H. (1994). *Räumliches Vorstellungsvermögen.* Frankfurt am Main, Germany: Peter Lang

Martin-Gutierrez, J., Saorin, J. L., Contero, M., Alcaniz, M., Perez-Lopez, D. C., & Ortega, M. (2010). Design and validation of an augmented book for spatial abilities development in engineering students. *Computers & Graphics*, *34*(1), 77–91. doi: 10.1016/j.cag.2009.11.003

Mayer, R. E. (1996). Learning strategies for making sense out of expository text: The SOI model for guiding three cognitive processes in knowledge construction. *Educational Psychology Review*, *8*(4), 357-371.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist*, *32*(1), 1-19.

Mayer, R. E., & Moreno, R. (1998). A cognitive theory of multimedia learning: Implications for design principles. *Journal of Educational Psychology*, *91*(2), 358-368.

McManus, S. M., & Gettinger, M. (1996). Teacher and student evaluations of cooperative learning and observed interactive behaviors. *The Journal of Educational Research*, *90*(1), 13-22. doi: 10.1080/00220671.1996.9944439

Morrison, A., Oulasvirta, A., Peltonen, P., Lemmela, S., Jacucci, G., Reitmayr, G., ... & Juustila, A. (2009, April). Like bees around the hive: A comparative study of a mobile augmented reality map. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1889-1898). ACM.

Nebel, S., Schneider, S., Beege, M., Kolda, F., Mackiewicz, V., & Rey, G. D. (2017). You cannot do this alone! Increasing task interdependence in cooperative educational videogames to encourage collaboration. *Educational Technology Research and Development*, *65*(4), 993-1014. doi: 10.1007/s11423-017-9511-8

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist*, *38*(1), 1-4. doi: 10.1207/S15326985EP3801_1

Parhizkar, B., Obeidy, W. K., Chowdhury, S. A., Gebril, Z. M., Ngan, M. N. A., & Lashkari, A. H. (2012, May). Android mobile augmented reality application based on different learning theories for primary school children. In *2012 International Conference on Multimedia Computing and Systems* (pp. 404-408). IEEE.

Parsons, D., Ryu, H., & Cranshaw, M. (2006, July). A study of design requirements for mobile learning environments. In *Sixth IEEE International Conference on Advanced Learning Technologies (ICALT'06),* (pp. 96-100). IEEE.

Peterson, P.L. & Swing, S. R. (1985). Students cognitions as mediators of the effectiveness of small-group learning. *Journal of Educational Psychology. 77*(3), 299-312.

Phon, D. N. E., Ali, M. B., & Halim, N. D. A. (2014, April). Collaborative augmented reality in education: A review. In *2014 International Conference on Teaching and Learning in Computing and Engineering* (pp. 78-83). IEEE. doi: 10.1109/LaTiCE.2014.23

Rosenbaum, E., Klopfer, E., & Perry, J. (2007). On location learning: authentic applied science with networked augmented realities. *Journal of Science Education & Technology, 16*(1), 31–45. doi: 10.1007/s10956-006-9036-0

Sommerauer, P., & Müller, O. (2014). Augmented reality in informal learning environments: A field experiment in a mathematics exhibition. *Computers & Education*, *79*, 59-68. doi: 10.1016/j.compedu.2014.07.013

Sotiriou, S., & Bogner, F. X. (2008). Visualizing the invisible: Augmented reality as an innovative science education scheme. *Advanced Science Letters*, *1*(1), 114-122. doi: 10.1166/asl.2008.012

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*(2), 257-285. doi: 10.1207/s15516709cog1202_4

Turan, Z., Meral, E., & Sahin, I. F. (2018). The impact of mobile augmented reality in geography education: achievements, cognitive loads and views of university students. *Journal of Geography in Higher Education*, *42*(3), 427-441. doi: 10.1080/03098265.2018.1455174

Wei, X., Weng, D., Liu, Y., & Wang, Y. (2015). Teaching based on augmented reality for a technical creative design course. *Computers & Education, 81*, 221-234. doi: 10.1016/j.compedu.2014.10.017

Wu, P. H., Hwang, G. J., Yang, M. L., & Chen, C. H. (2018). Impacts of integrating the repertory grid into an augmented reality-based learning design on students' learning achievements, cognitive load and degree of satisfaction. *Interactive Learning Environments*, *26*(2), 221-234. doi: 10.1080/10494820.2017.1294608

Appendix A

Informed consent

Beste leerling,

Wie ben ik?

Mijn naam is Olaf Pijl en ik ben een student op de Universiteit van Utrecht. Ik doe een onderzoek naar Augmented Reality voor de opleiding onderwijswetenschappen. Ik word begeleid door M.M.H Schaars.

Wat is het doel van het onderzoek?

Dit onderzoek gaat proberen erachter te komen of jullie beter alleen of samen kunnen werken aan een opdracht met Augmented Reality

Wat houdt het onderzoek in?

In dit onderzoek ga jij een opdracht over maken over het brein, waarin een Augement Reality applicatie gaat gebruikt worden. Deze kun je gratis downloaden op jouw eigen telefoon. Voor de opdracht krijg jij een korte vragenlijst die kijkt wat jij weet over de onderwerpen. Daarna ga je aan de slag met de opdracht. Na de opdracht krijg je weer een toets om te kijken wat hebt geleerd van de opdracht. De opdracht duurt ongeveer een half uurtje.

Privacy en vertrouwelijkheid

Alle gegevens worden vertrouwelijk behandeld en anoniem verwerkt. Dat wil zeggen dat straks in de uitkomsten van het onderzoek niet te zien is welke antwoorden jij gegeven hebt. De gegevens worden alleen voor onderzoeks- en opleidingsdoeleinden gebruikt. Jouw docent krijgt jouw vragenlijsten niet te zien.

Mogelijkheid tot vragen, informatie en toestemming

Als je nog vragen hebt over het onderzoek, stel die dan nu aan één van de onderzoekers of stuur een mail aan: **Olaf Pijl, O.Pijl@students.uu.nl.** Voor verdere vragen over de cursus en opdracht die wij maken kun je contact opnemen met: M.M.H. Schaars, M.M.H.schaars@uu.nl.

Als je mee wilt doen aan het onderzoek, **vul dan het formulier op de achterzijde in**. Je kunt het formulier inleveren bij een van de onderzoekers.

Met vriendelijke groet,

Olaf Pijl

TOESTEMMINGSVERKLARING

voor deelname aan wetenschappelijk onderzoek

Ik heb uitleg gekregen over het onderzoek. De informatie over het onderzoek heb ik goed gelezen. Ik heb mijn eventuele vragen over het onderzoek gesteld. Ik heb goed nagedacht over of ik aan het onderzoek wil deelnemen. Ik mag op ieder moment stoppen met het onderzoek als ik dat wil. Ik hoef niet uit te leggen waarom ik wil stoppen.

☐ Ik doe wel mee aan het onderzoek

Zet hiernaast een kruisje in het vakje dat voor jou van toepassing is

☐ Ik doe niet mee aan het onderzoek

Naam :

School :

Klas :

Geboortedatum :

Datum :

Handtekening :

Als je informatie wilt ontvangen over de uitkomsten van het onderzoek, vul dan hier je e-mail adres in:

Appendix B

The Materials

Instruction Form: Group AR individual

Beste student,

Leuk dat je mee doet aan dit onderzoek! Dit formulier mag je de hele tijd bij je houden en is bedoel om te uit te leggen wat de bedoeling is van dit experiment. De opdracht bestaat uit drie delen:

1. Individuele toets 1
2. Opdracht met Augmented Realitiy
3. Individuele toets 2

Stap 1: download de applicatie 'the human brain'
Download de (gratis) applicatie op je telefoon door naar de volgende internetpagina te gaan op je telefoon. Via de onderstaande websites word je doorverwezen naar de App- of Playstore.

Heb jij een Android telefoon **(let op de hoofdletters)**: ---> bit.ly/2CUGFeg
Heb jij een Apple telefoon **(let op de hoofdletters)**: ---> apple.co/2GY2ptH

Stap 2: toets 1
Je start zo met 'toets 1' en dit staat ook bovenaan het formulier dat je krijgt. Hier heb je **10 minuten** de tijd voor. Deze toets is om te kijken hoeveel je al weet van het onderwerp en maak je individueel, zonder overleg. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in.** Als je klaar bent draai het formulier om en wacht je tot de rest ook klaar is.

Stap 3: Opdracht met Augmented Reality
Je krijgt zo 3 formulieren.

Formulier 1: Informatie
Je krijgt zo individueel een formulier waar bovenaan staat 'INFO'. Op dit formulier staat informatie die je nodig hebt om de opdracht af te maken.

Formulier 2: Scan object
Dit formulier is voor de applicatie bedoeld. Als je de app opent richt je de camera op de afbeelding van de hersenen. Op je telefoon verschijnen dan de hersenen. De hersenen kun je rond draaien, inzoomen met je vingers op je scherm en er omheen draaien met je camera. Ook kan je met het blauwe schuifje rechts lagen van de hersenen weg halen en toevoegen. Als je er niet uitkomt, steek je vinger op.

Formulier 2: Opdracht AR2
Dit is de opdracht die je alleen gaat invullen. Zorg dat je weet waar de verschillende onderdelen in de hersen zijn en wat deze kunnen, want je krijgt hierna weer een toets om te kijken wat je geleerd hebt. Je krijgt voor deze opdracht 25 minuten.

Stap 4:
Je krijgt 'toets 2'. Deze moet je weer individueel zonder overleg invullen. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in.** Als je klaar bent draai het formulier om en ga je wat voor jezelf doen.

Instruction Form: Group AR Collaborative

Beste student,

Leuk dat je mee doet aan dit onderzoek! Dit formulier mag je de hele tijd bij je houden en is bedoel om te uit te leggen wat de bedoeling is van dit experiment. De opdracht bestaat uit drie delen:

1. Individuele deel (1)
2. Gezamenlijke opdracht met Augemented Realitiy
3. Individuele deel (2)

Stap 1: download de applicatie 'the human brain'
Download de (gratis) applicatie op je telefoon door naar de volgende internetpagina te gaan op je telefoon. Via de onderstaande websites word je doorverwezen naar de App- of Playstore.

Heb jij een Android telefoon **(let op de hoofdletters)**: ---> bit.ly/2CUGFeg
Heb jij een Apple telefoon **(let op de hoofdletters)**: ---> apple.co/2GY2ptH

Stap 2: deel 1
Je start zo met 'deel 1' en dit staat ook bovenaan het formulier dat je krijgt. Hier heb je **10 minuten** de tijd voor. Dit deel is om te kijken hoeveel je al weet van het onderwerp en maak je individueel, zonder overleg. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in.** Als je klaar bent draai het formulier om en wacht je tot de rest ook klaar is.

Stap 3: Gezamenlijke opdracht met Augmented Reality
Je krijgt zo 3 formulieren.

Formulier 1: Informatie
Je krijgt zo individueel een formulier waar bovenaan staat 'INFO 1' **of** 'INFO 2'. Dit papier is alleen voor jouw ogen en om het onderzoek goed te laten verlopen is het ook erg belangrijk dat je dit niet laat zien aan je duo. Op dit formulier staat informatie die je nodig hebt om de opdracht af te maken.

Formulier 2: Scan object
Dit formulier is voor de applicatie bedoeld. Als je de app opent richt je de camera op de afbeelding van de hersenen. Op je telefoon verschijnen dan de hersenen. De hersenen kun je rond draaien, inzoomen met je vingers op je scherm en er omheen draaien met je camera. Ook kan je met het blauwe schuifje rechts lagen van de hersenen weg halen en toevoegen. Als je er niet uitkomt, overleg eerst samen. Steek daarna pas je vinger op.

Formulier 3: Opdracht AR2
Dit is de opdracht die jullie samen gaan invullen. Let wel op tijdens het invullen dat je goed samen werkt, **zonder** dat je formulieren INFO 1 & INFO 2 aan elkaar laat zien. **Zorg dat je aan het einde allebei kunt uitleggen waar bepaalde onderdelen van de hersenen zitten en wat ze doen.** Je krijgt hierna weer een individueel deel om te kijken wat je geleerd hebt. Jullie krijgen voor deze opdracht 25 minuten.

Stap 4: (zie achterkant)

Je krijgt 'deel 2'. Deze moet je weer individueel zonder overleg invullen. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in**. Als je klaar bent draai het formulier om en ga je wat voor jezelf doen.

Als je nog wat wilt vertellen over de opdracht, individuele delen 1&2 of app kun je dat hieronder kwijt:

Instruction Form: Group Conventional Individual

Beste student,

Leuk dat je mee doet aan dit onderzoek! Dit formulier mag je de hele tijd bij je houden en is bedoel om te uit te leggen wat de bedoeling is van dit experiment. De opdracht bestaat uit drie delen:

1. Individuele deel (1)
2. Opdracht
3. Individuele deel (2)

Stap 1: deel 1
Je start zo met 'deel 1' en dit staat ook bovenaan je formulier. Hier heb je **10 minuten** de tijd voor. Dit deel is om te kijken hoeveel je al weet van het onderwerp en maak je individueel, zonder overleg. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in.** Als je klaar bent draai het formulier om en wacht je totdat de rest ook klaar is

Stap 2: Opdracht
Je krijgt zo 2 formulieren.

Formulier 1: Informatie
Je krijgt zo individueel een formulier waar bovenaan staat 'INFO'. Op dit formulier staat informatie die je nodig hebt om de opdracht af te maken.

Formulier 2: Opdracht
Dit is de opdracht die je alleen gaat invullen. Zorg dat je weet waar de verschillende onderdelen in de hersen zijn en wat deze kunnen, want je krijgt hierna weer een individueel deel om te kijken wat je geleerd hebt. Je krijgt voor deze opdracht 25 minuten.

Stap 3: deel 2
Je krijgt 'deel 2'. Deze moet je weer individueel zonder overleg invullen. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in**. Als je klaar bent draai het formulier om en ga je wat voor jezelf doen.

Instruction Form: Group Conventional Collaborative

Beste student,

Leuk dat je mee doet aan dit onderzoek! Dit formulier mag je de hele tijd bij je houden en is bedoel om te uit te leggen wat de bedoeling is van dit experiment. De opdracht bestaat uit drie delen:

1. Individuele deel (1)
2. Gezamenlijke opdracht
3. Individuele deel (2)

Stap 1: deel 1
Je start zo met 'deel 1' en dit staat ook bovenaan je formulier. Hier heb je **10 minuten** de tijd voor. Deze deel is om te kijken hoeveel je al weet van het onderwerp en maak je individueel, zonder overleg. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in.** Als je klaar bent draai het formulier om en wacht je totdat de rest ook klaar is

Stap 2: Gezamenlijke opdracht
Je krijgt zo 2 formulieren.

Formulier 1: Informatie
Je krijgt zo individueel een formulier waar bovenaan staat 'INFO 1' of 'INFO 2'. Dit papier is alleen voor jouw ogen en om het onderzoek goed te laten verlopen is het ook erg belangrijk dat je dit niet laat zien aan je duo. Op dit formulier staat informatie die je nodig hebt om de opdracht af te maken.

Formulier 2: Opdracht
Dit is de opdracht die jullie samen gaan invullen. Let wel op tijdens het invullen dat je goed samen werkt, **zonder** dat je formulieren INFO 1 & INFO 2 aan elkaar laat zien. **Zorg dat je aan het einde allebei kunt uitleggen waar bepaalde onderdelen van de hersenen zitten en wat ze doen.** Je krijgt hierna weer een individueel deel om te kijken wat je geleerd hebt. Jullie krijgen voor deze opdracht 25 minuten..

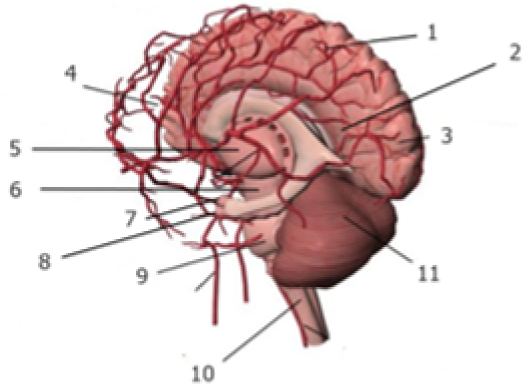
Stap 3: deel 2
Je krijgt 'deel 2'. Deze moet je weer individueel zonder overleg invullen. Als je het antwoord niet zeker weet, omcirkel dan het antwoord wat jou juist lijkt. **Vul dus wel altijd wat in**. Als je klaar bent draai het formulier om en ga je wat voor jezelf doen.

Assignment Form: Group AR Individuals

Opdracht AR2

De onderdelen van de hersenen (bij stap 3 op instructieformulier staat uitleg over de applicatie). Zorg dat je aan het einde kan uitleggen waar bepaalde delen zitten wat ze doen.

1. Probeer de onderdelen waar een cijfer bij staat te vinden in de Human Brain APP. Gebruik hierbij de informatie om deze te vinden. **(TIP: 1 t/m 4 zijn hersenkwabben)**
2. Gevonden? Zet de naam bij het onderdeel
3. Schrijf per onderdeel de hierover bekende informatie op
4. Klaar? Steek je vinger op



Naam onderdeel 1: ………...………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 2: ………...………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 3: ………...………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 4: ………...………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 5: ………………………………………………………………………………..
Informatie: ……………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

Naam onderdeel 6: ………………………………………………………………………………..
Informatie: ……………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

Naam onderdeel 7: ………………………………………………………………………………..
Informatie: ……………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

Naam onderdeel 8: ………………………………………………………………………………..
Informatie: ……………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

Naam onderdeel 9: ………………………………………………………………………………..
Informatie: ……………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

Naam onderdeel 10:………………………………………………………………………………..
Informatie: ……………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

Naam onderdeel 11:………………………………………………………………………………..
Informatie: ……………………………………………………………………………………..
………………………………………………………………………………………………..
………………………………………………………………………………………………..

Assignment Form: Group AR Collaborative

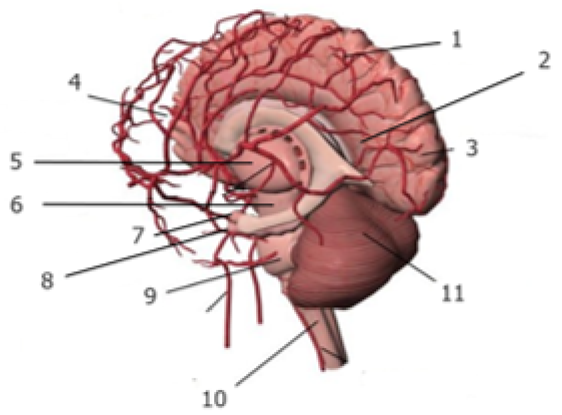
roc podium voor talent

Utrecht University

Opdracht AR2

De onderdelen van de hersenen (bij stap 3 op instructieformulier staat uitleg over de applicatie). Zorg dat jullie allebei aan het einde kan uitleggen waar bepaalde delen zitten wat ze doen.

1. Probeer de onderdelen waar een cijfer bij staat te vinden in de Human Brain APP. Gebruik hierbij de informatie om deze te vinden. **(TIP: 1 t/m 4 zijn hersenkwabben)**
2. Gevonden? Zet de naam bij het onderdeel
3. Schrijf per onderdeel de hierover bekende informatie op
4. Klaar? Steek je vinger op



Naam onderdeel 1: ……………………… Kwab
Informatie: ………………………………………………………………………………………………
……
……
……
……

Naam onderdeel 2: ……………………… Kwab
Informatie: ………………………………………………………………………………………………
……
……
……
……

Naam onderdeel 3: ……………………… Kwab
Informatie: ………………………………………………………………………………………………
……
……
……
……

Naam onderdeel 4: ……………………… Kwab
Informatie: ………………………………………………………………………………………………

Naam onderdeel 5: ……………………………………………………………………………..
Informatie: …………………………………………………………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….

Naam onderdeel 6: ……………………………………………………………………………..
Informatie: …………………………………………………………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….

Naam onderdeel 7: ……………………………………………………………………………..
Informatie: …………………………………………………………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….

Naam onderdeel 8: ……………………………………………………………………………..
Informatie: …………………………………………………………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….

Naam onderdeel 9: ……………………………………………………………………………..
Informatie: …………………………………………………………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….

Naam onderdeel 10:……………………………………………………………………………..
Informatie: …………………………………………………………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….

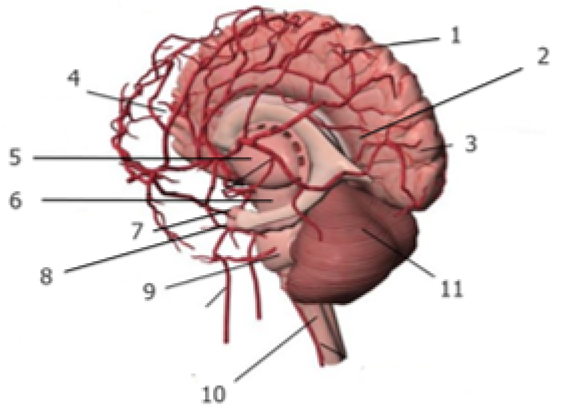
Naam onderdeel 11:……………………………………………………………………………..
Informatie: …………………………………………………………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….
…………………………………………………………………………………………….

Assignment Form: Group Conventional Individuals

Gezamenlijke Opdracht

De onderdelen van de hersenen. Zorg dat jullie allebei aan het einde van deze opdracht kunnen vertellen waar onderdelen van de hersenen zitten en wat deze doen.

1. Probeer de onderdelen van de hersenen waar een cijfer bij staat te vinden in de bijgeleverde informatie. **(TIP: 1 t/m 4 zijn hersenkwabben)**
2. Gevonden? Zet de naam bij het onderdeel
3. Schrijf per onderdeel de hierover bekende informatie op
4. Klaar? Steek je vinger op



Naam onderdeel 1: ……………………… Kwab
Informatie: …………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 2: ……………………… Kwab
Informatie: …………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 3: ……………………… Kwab
Informatie: …………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 4: ……………………… Kwab
Informatie: …………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 5: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Naam onderdeel 6: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Naam onderdeel 7: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Naam onderdeel 8: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Naam onderdeel 9: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Naam onderdeel 10:……………………………………………………………………………
Informatie: ………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

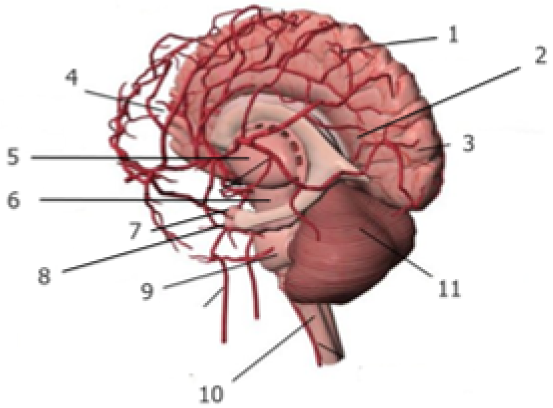
Naam onderdeel 11:……………………………………………………………………………
Informatie: ………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Assignment Form: Group Conventional Collaborative

Opdracht

De onderdelen van de hersenen. Zorg dat je aan het einde van deze opdracht kunt vertellen waar onderdelen van de hersenen zitten en wat deze doen.

1. Probeer de onderdelen van de hersenen waar een cijfer bij staat te vinden in de bijgeleverde informatie. **(TIP: 1 t/m 4 zijn hersenkwabben)**
2. Gevonden? Zet de naam bij het onderdeel
3. Schrijf per onderdeel de hierover bekende informatie op
4. Klaar? Steek je vinger op



Naam onderdeel 1: ……………………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 2: ……………………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 3: ……………………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 4: ……………………… Kwab
Informatie: ……………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Naam onderdeel 5: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Naam onderdeel 6: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Naam onderdeel 7: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

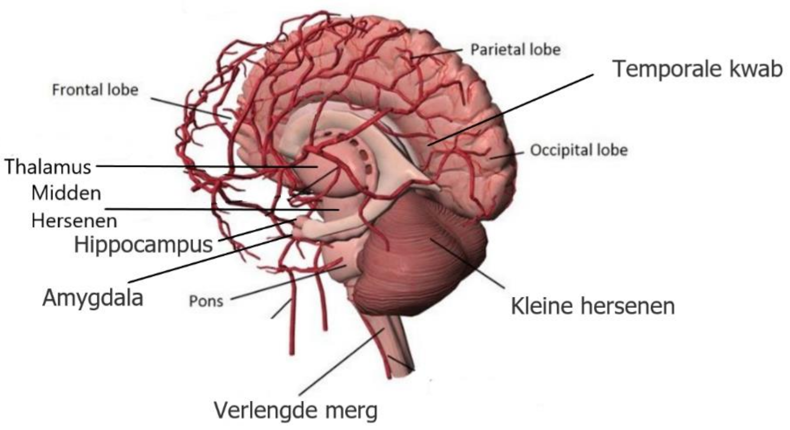
Naam onderdeel 8: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Naam onderdeel 9: ……………………………………………………………………………
Informatie: ………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Naam onderdeel 10:……………………………………………………………………………
Informatie: ………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Naam onderdeel 11:……………………………………………………………………………
Informatie: ………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

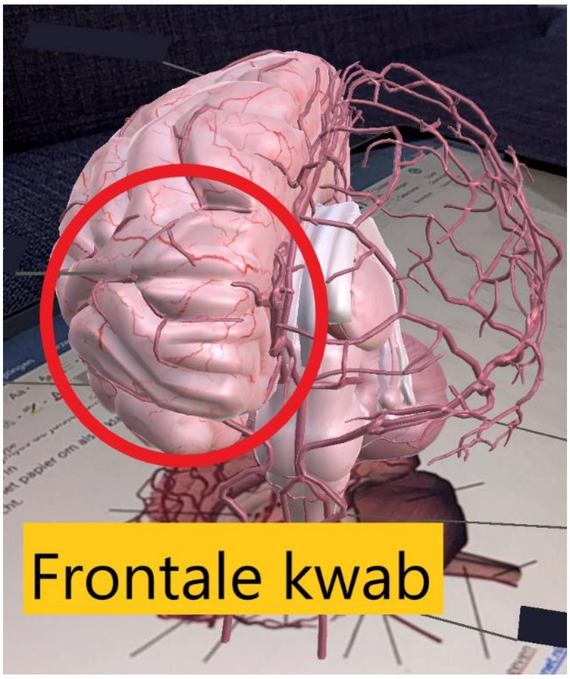
Answers of the Assignment:



1. Perietaal kwab
2. Temporale kwab
3. Occipitaal kwab
4. Frontale kwab
5. Thalamus
6. Midden hersenen
7. Hippocampus
8. Amygdala
9. Pons
10. Verlengde merg
11. Kleine hersenen

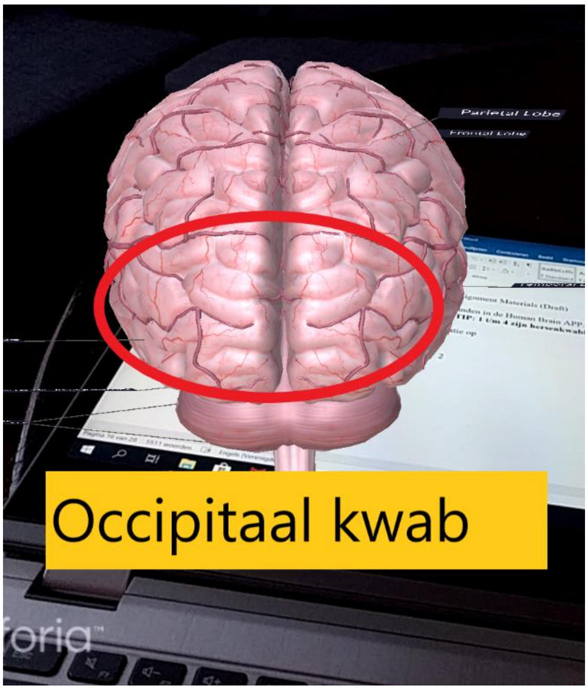
Information about the human brain for the individual groups. (Retrieved from https://www.hersenstichting.nl/alles-over-hersenen/de-hersenen/anatomie)

Frontaalkwab



Dit is de grootste van de vier hersenkwabben en neemt eenderde deel van de totale hersenschors in beslag. Dit deel van de hersenen wordt gezien als het meest geavanceerde deel, verantwoordelijk voor het menselijke zelfbewustzijn

Occipitaalkwab

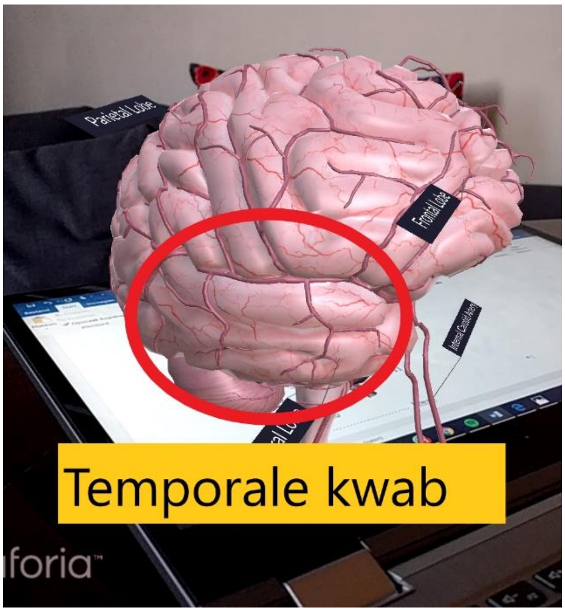


Dit is de kleinste hersenkwab, die betrokken is bij het zien. Van opzij gezien: het aan de achterzijde gelegen deel van de hersenschors.

Pariëtaalkwab

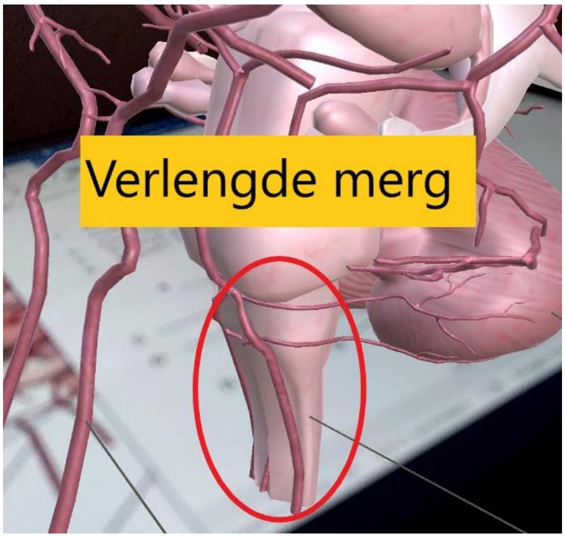
Van opzij gezien: het aan de achter/bovenzijde gelegen deel van de hersenschors. Dit deel van de schors is betrokken bij zintuiglijke en cognitieve functies, zoals aandacht, ruimtelijk inzicht, lezen en rekenen.

Temporale kwabben



De temporale kwabben liggen in de hersenen net achter de oren. Ze zijn gelegen aan beide zijden van het hoofd. Er zijn er dus twee van. De temporale kwabben zijn betrokken bij geluid, maar ook bij het begrijpen van taal.

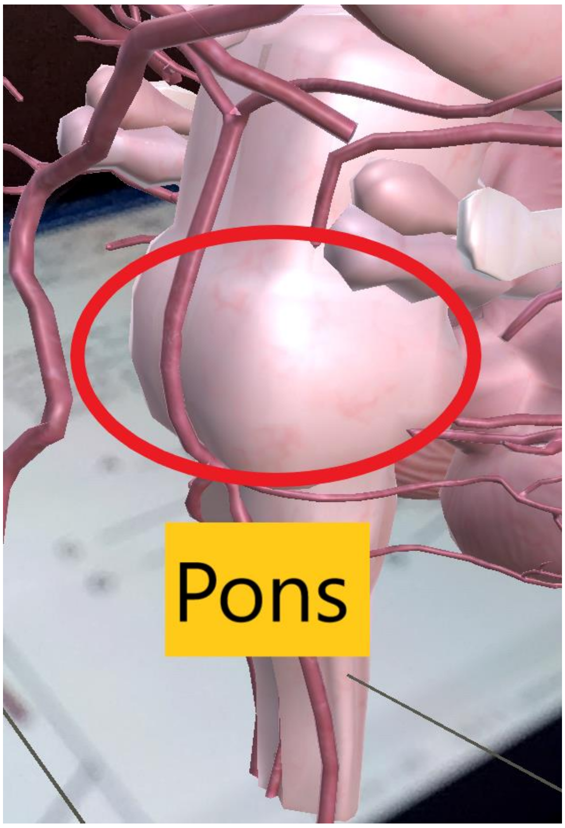
Verlengde merg



Het verlengde merg is het overgangsgebied van het ruggenmerg naar de hersenen en maakt dus onderdeel uit van de hersenstam. Het verlengde merg is niet groter dan het laatste kootje van de pink, maar het is van vitaal belang.

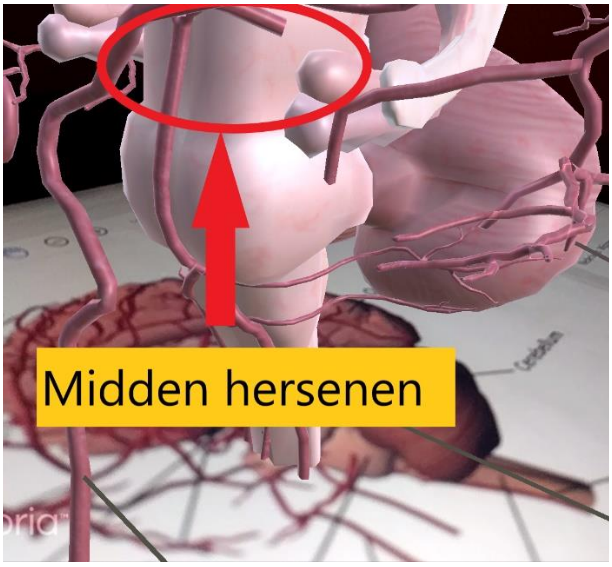
Het bevat bijvoorbeeld kernen die betrokken zijn bij het regelen van de ademhaling, hartslag, slikken, de omvang van de kleine bloedvaten en daarmee indirect de bloeddruk, waken, slapen, hoesten, braken en andere vitale functies. Daarnaast bevat het verlengde merg de piramidekruising. Hier steken zenuwbanen over zodat de linker hersenhelft de rechterkant van het lichaam bedient en andersom. Het is een belangrijk schakelcentrum tussen het ruggenmerg en de overige hersendelen.

Pons



De pons is ook wel bekend als de brug van Varol. Het is een forse uitstulping van zenuwvezels tussen het verlengde merg en de tussenhersenen. De pons houdt met twee stevige armen de kleine hersenen vast en verzorgt daarmee het contact tussen de grote en kleine hersenen. Het is ook een onderdeel van de hersenstam. De pons zorgt ervoor dat prikkels van het evenwichts- en gehoororgaan doorgegeven worden aan de kleine hersenen.

Middenhersenen

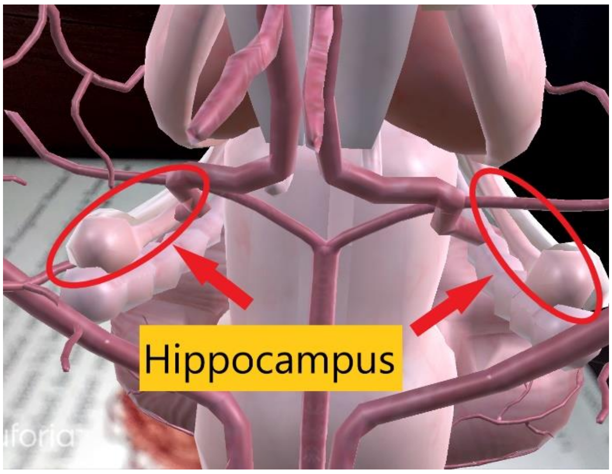


De middenhersenen zijn het bovenste deel van de hersenstam (boven de pons). De middenhersenen zijn betrokken bij de regulatie van zintuiglijke en motorische functies en spelen bijvoorbeeld een rol bij het tot stand komen van oogbewegingen. Ook visuele en auditieve reflexen worden hier gecoördineerd.

Kleine Hersenen

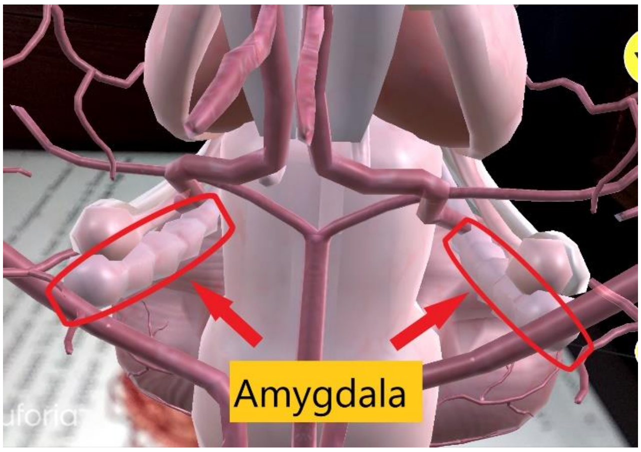
Ook cerebellum genoemd. De aan de achteronderzijde van de schedel gelegen bal zenuwweefsel. De kleine hersenen omvatten ongeveer 1/8 deel van de hersenmassa. Ze liggen redelijk afgescheiden van de rest van het centraal zenuwstelsel. Het cerebellum is betrokken bij de voortbeweging en bij het bewaren van het evenwicht, maar is niet noodzakelijk voor het samentrekken van spieren of voor de waarneming van de stand van het lichaam. Door een beschadiging van de kleine hersenen worden bewegingen veel minder gecoördineerd, de persoon lijkt wel dronken.

Hippocampus



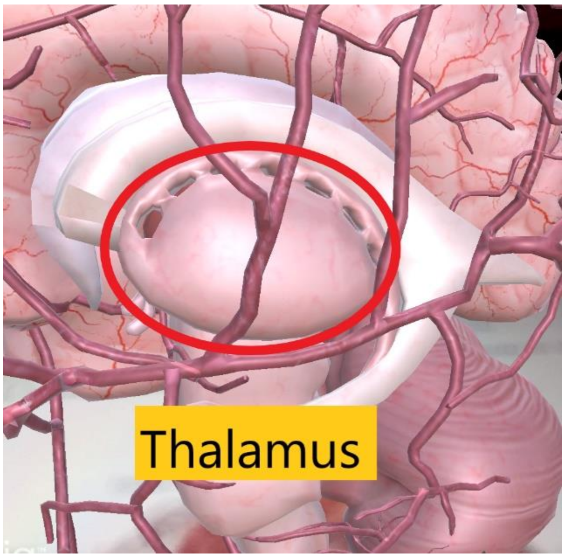
De hippocampus ligt aan de onder/voorkant van de temporaalkwab en maakt onderdeel uit van het limbisch systeem. In beide hersenhelften is een hippocampus aanwezig. De naam komt van het Griekse woord voor zeepaardje, vanwege de gekromde vorm. De hippocampus speelt een belangrijke rol bij de opslag van informatie in het geheugen, de ruimtelijke oriëntatie en het controleren van het gedrag dat van belang is voor overleven.

Amygdala



De amygdala is een amandelvormige structuur die betrokken is bij het aansturen en verwerken van verschillende emoties, en maakt deel uit van het limbisch systeem. De amygdala staat in verbinding met de orbitofrontale cortex, de thalamus, de hypothalamus en de hippocampus. De amygdala stuurt verschillende emoties aan zoals agressie. Angst is één van de belangrijkste emoties die de amygdala reguleert.

Thalamus

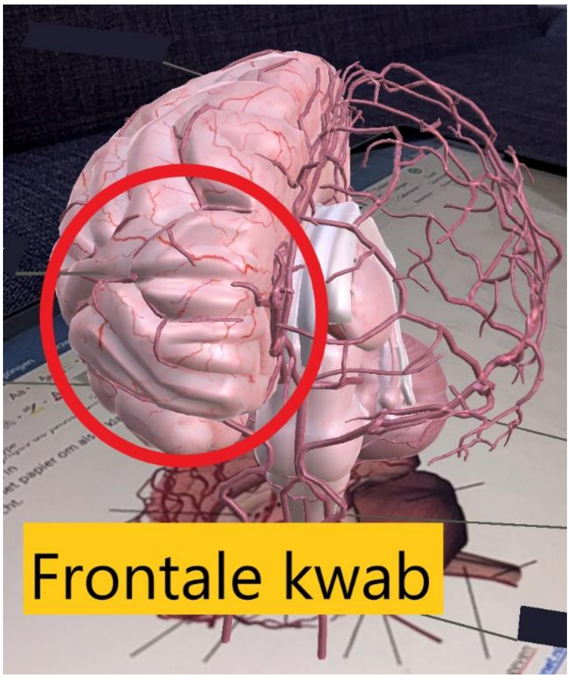


Binnen de hersenen is er een soort centraal punt voor binnenkomende en uitgaande zenuwsignalen: de thalamus. De thalamus speelt een belangrijke rol bij de selectie van prikkels die doorgegeven moeten worden aan de verschillende onderdelen van de hersenschors. Dit maakt dat de thalamus ook wel wordt aangeduid als de 'poort naar de hersenschors'. Alle zintuiglijke informatie, behalve geur, gaat eerst door de thalamus.

Wanneer de hersenschors hier opdracht toe geeft kan de thalamus ook het doorgeven van bepaalde prikkels onderdrukken. Ook is de thalamus betrokken bij de bewustwording van bepaalde prikkels, waaraan de hersenschors een preciezere betekenis hecht. Het gaat hierbij vooral om de emotionele connotaties die een gebeurtenis oproept. Daarnaast speelt de thalamus een rol bij de handhaving van het bewust zijn.

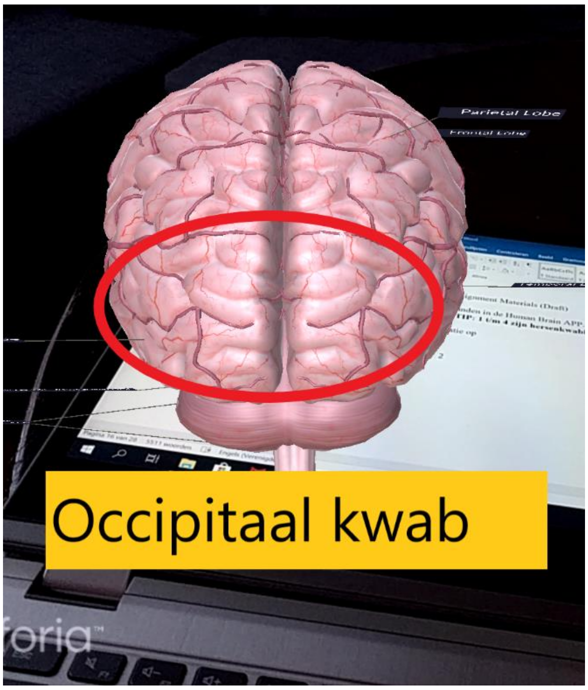
Information about the human brain for the collaborative group: part 1. (Retrieved from https://www.hersenstichting.nl/alles-over-hersenen/de-hersenen/anatomie)

Frontaalkwab



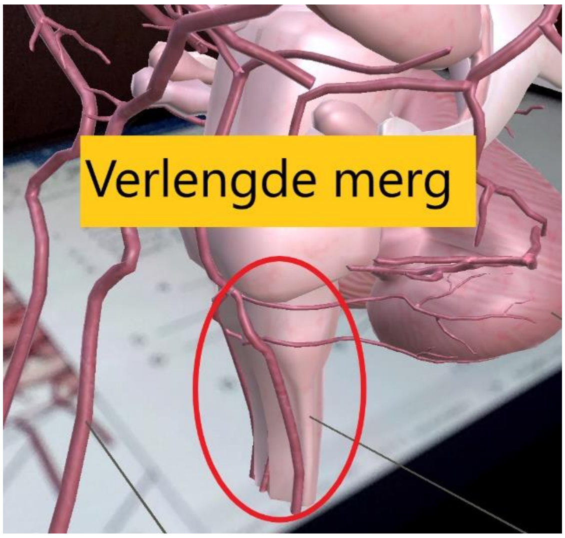
Dit is de grootste van de vier hersenkwabben en neemt een derde deel van de totale hersenschors in beslag. Dit deel van de hersenen wordt gezien als het meest geavanceerde deel, verantwoordelijk voor het menselijke zelfbewustzijn

Occipitaalkwab



Dit is de kleinste hersenkwab, die betrokken is bij het zien. Van opzij gezien: het aan de achterzijde gelegen deel van de hersenschors.

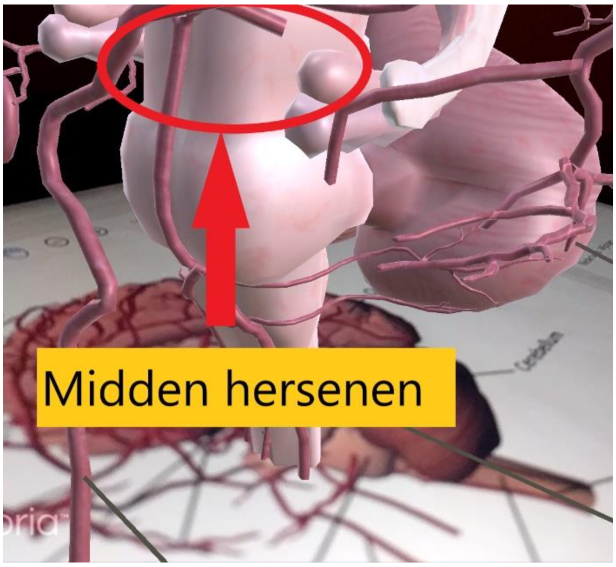
Verlengde merg



Het verlengde merg is het overgangsgebied van het ruggenmerg naar de hersenen en maakt dus onderdeel uit van de hersenstam. Het verlengde merg is niet groter dan het laatste kootje van de pink, maar het is van vitaal belang.

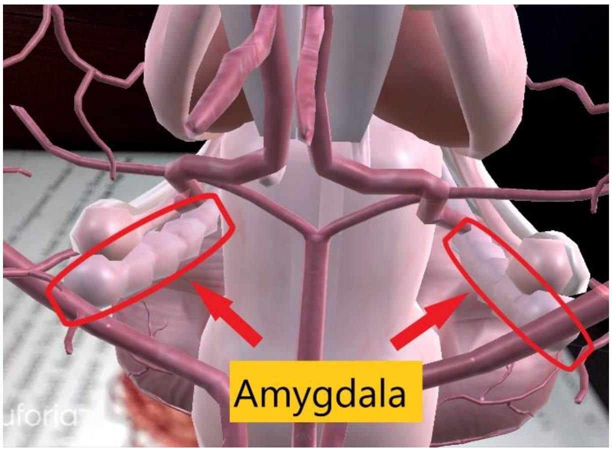
Het bevat bijvoorbeeld kernen die betrokken zijn bij het regelen van de ademhaling, hartslag, slikken, de omvang van de kleine bloedvaten en daarmee indirect de bloeddruk, waken, slapen, hoesten, braken en andere vitale functies. Daarnaast bevat het verlengde merg de piramidekruising. Hier steken zenuwbanen over zodat de linker hersenhelft de rechterkant van het lichaam bedient en andersom. Het is een belangrijk schakelcentrum tussen het ruggenmerg en de overige hersendelen.

Middenhersenen



De middenhersenen zijn het bovenste deel van de hersenstam (boven de pons). De middenhersenen zijn betrokken bij de regulatie van zintuiglijke en motorische functies en spelen bijvoorbeeld een rol bij het tot stand komen van oogbewegingen. Ook visuele en auditieve reflexen worden hier gecoördineerd.

Amygdala



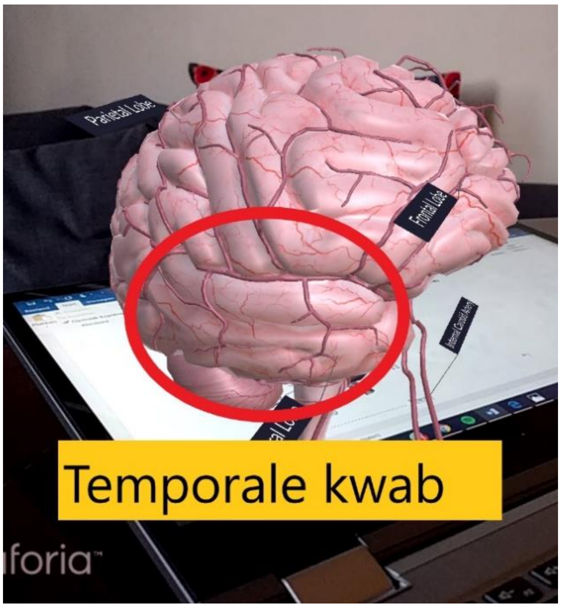
De amygdala is een amandelvormige structuur die betrokken is bij het aansturen en verwerken van verschillende emoties, en maakt deel uit van het limbisch systeem. De amygdala staat in verbinding met de orbitofrontale cortex, de thalamus, de hypothalamus en de hippocampus. De amygdala stuurt verschillende emoties aan zoals agressie. Angst is één van de belangrijkste emoties die de amygdala reguleert.

Information about the human brain for the collaborative group: part 2. (Retrieved from https://www.hersenstichting.nl/alles-over-hersenen/de-hersenen/anatomie)

Pariëtaalkwab

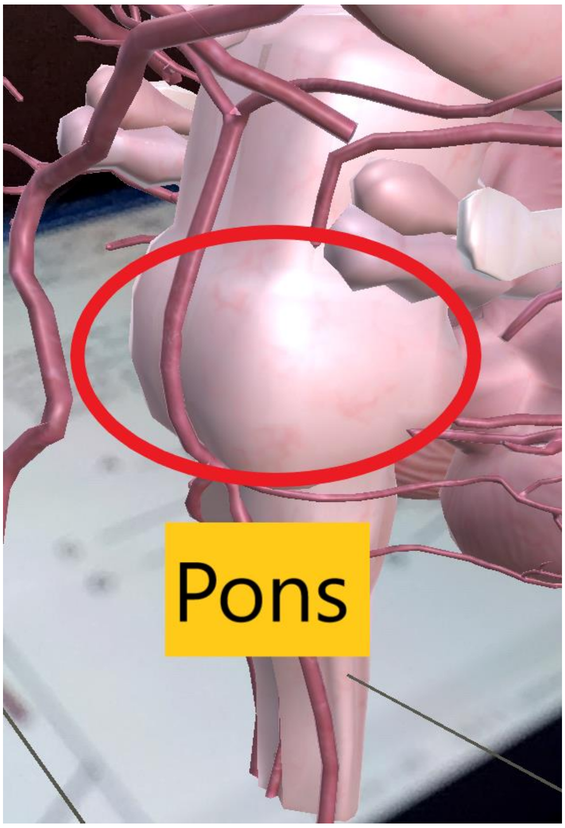
Van opzij gezien: het aan de achter/bovenzijde gelegen deel van de hersenschors. Dit deel van de schors is betrokken bij zintuiglijke en cognitieve functies, zoals aandacht, ruimtelijk inzicht, lezen en rekenen.

Temporale kwabben



De temporale kwabben liggen in de hersenen net achter de oren. Ze zijn gelegen aan beide zijden van het hoofd. Er zijn er dus twee van. De temporale kwabben zijn betrokken bij geluid, maar ook bij het begrijpen van taal.

Pons

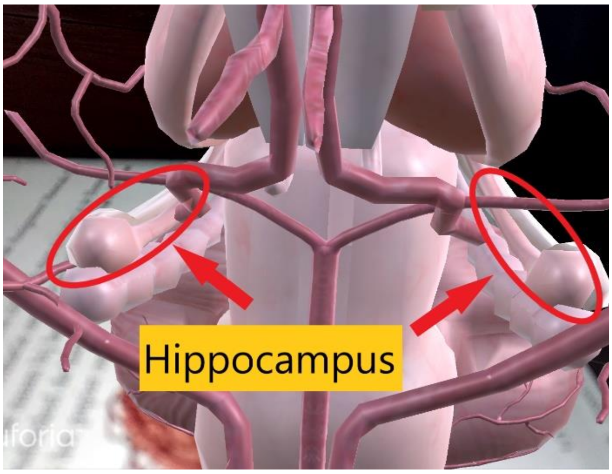


De pons is ook wel bekend als de brug van Varol. Het is een forse uitstulping van zenuwvezels tussen het verlengde merg en de tussenhersenen. De pons houdt met twee stevige armen de kleine hersenen vast en verzorgt daarmee het contact tussen de grote en kleine hersenen. Het is ook een onderdeel van de hersenstam. De pons zorgt ervoor dat prikkels van het evenwichts- en gehoororgaan doorgegeven worden aan de kleine hersenen.

Kleine Hersenen

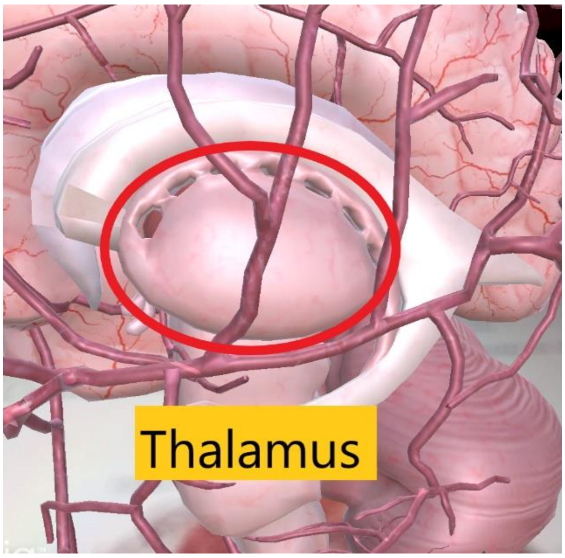
Ook cerebellum genoemd. De aan de achteronderzijde van de schedel gelegen bal zenuwweefsel. De kleine hersenen omvatten ongeveer 1/8 deel van de hersenmassa. Ze liggen redelijk afgescheiden van de rest van het centraal zenuwstelsel. Het cerebellum is betrokken bij de voortbeweging en bij het bewaren van het evenwicht, maar is niet noodzakelijk voor het samentrekken van spieren of voor de waarneming van de stand van het lichaam. Door een beschadiging van de kleine hersenen worden bewegingen veel minder gecoördineerd, de persoon lijkt wel dronken.

Hippocampus



De hippocampus ligt aan de onder/voorkant van de temporaalkwab en maakt onderdeel uit van het limbisch systeem. In beide hersenhelften is een hippocampus aanwezig. De naam komt van het Griekse woord voor zeepaardje, vanwege de gekromde vorm. De hippocampus speelt een belangrijke rol bij de opslag van informatie in het geheugen, de ruimtelijke oriëntatie en het controleren van het gedrag dat van belang is voor overleven.

Thalamus

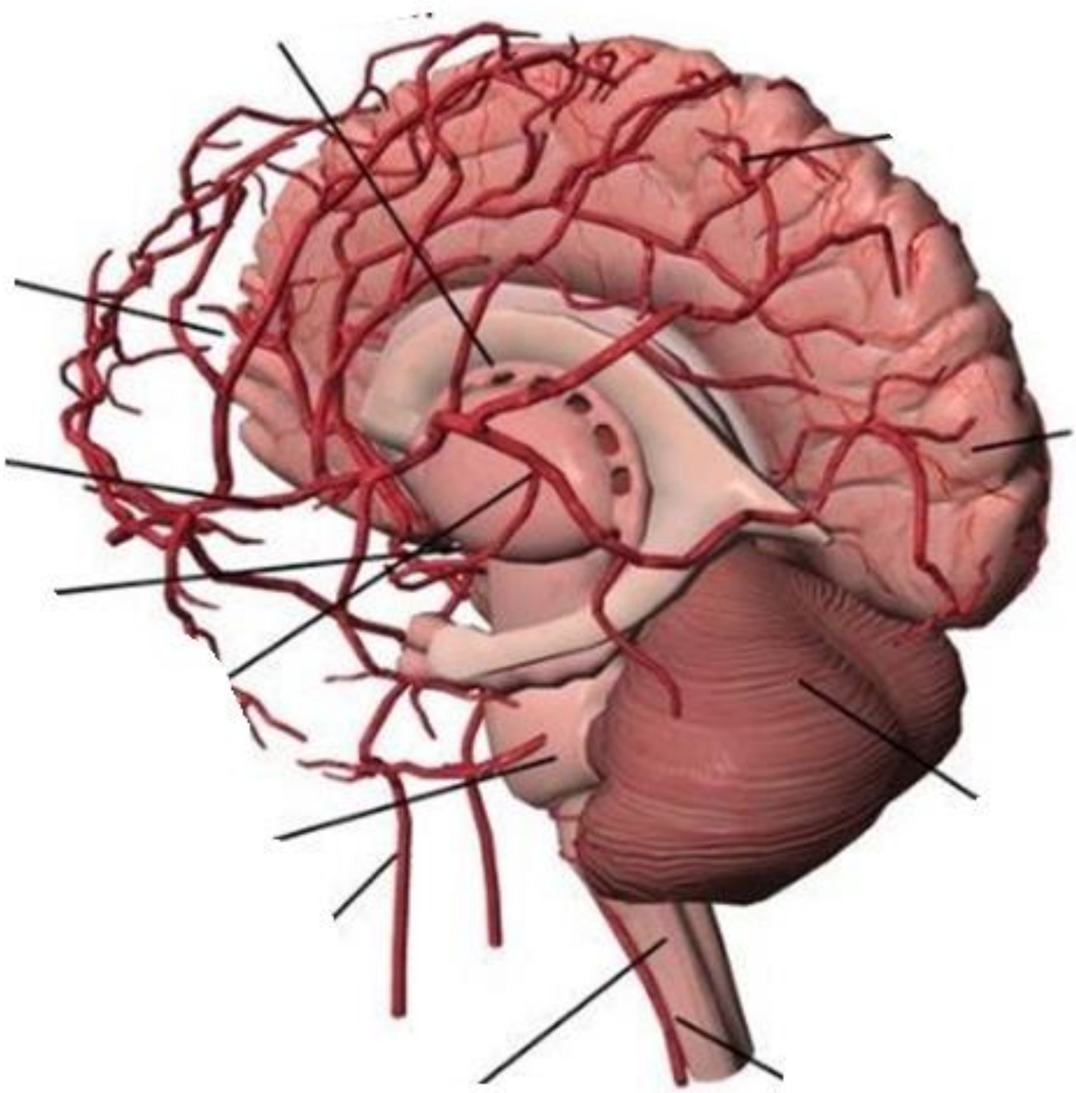


Binnen de hersenen is er een soort centraal punt voor binnenkomende en uitgaande zenuwsignalen: de thalamus. De thalamus speelt een belangrijke rol bij de selectie van prikkels die doorgegeven moeten worden aan de verschillende onderdelen van de hersenschors. Dit maakt dat de thalamus ook wel wordt aangeduid als de 'poort naar de hersenschors'. Alle zintuiglijke informatie, behalve geur, gaat eerst door de thalamus.

Wanneer de hersenschors hier opdracht toe geeft kan de thalamus ook het doorgeven van bepaalde prikkels onderdrukken. Ook is de thalamus betrokken bij de bewustwording van bepaalde prikkels, waaraan de hersenschors een preciezere betekenis hecht. Het gaat hierbij vooral om de emotionele connotaties die een gebeurtenis oproept. Daarnaast speelt de thalamus een rol bij de handhaving van het bewust zijn.

The marker to simulate the AR simulation.

Formulier: Scan Object



Appendix C

Pre- Posttest

The Pretest

Deel 1

Vul in:
Studentnummer:
Leeftijd:
Geslacht: Man / Vrouw / Neutraal

Omcirkel het juiste antwoord, er is steeds één antwoord goed.

1. Kies het antwoord dat de volgende zin correct maakt:
   Het verlengde merg regelt onder andere de …

   a. de ademhaling
   b. het evenwicht
   c. de oogbewegingen

2. Welk onderdeel speelt een belangrijke rol bij het doorgeven van prikkels naar de hersenschors?

   a. De middenhersenen
   b. De hippocampus
   c. De thalamus

3. De middenhersenen zijn betrokken bij:

   a. opslag van informatie in het geheugen
   b. regelen van het bloeddruk
   c. regelen van hormonen

4. Welk onderdeel van de hersenen is betrokken bij het bewaren van het evenwicht?

   a. Hypofyse
   b. Kleine hersenen
   c. Thalamus

5. De frontale kwab is verantwoordelijk voor:

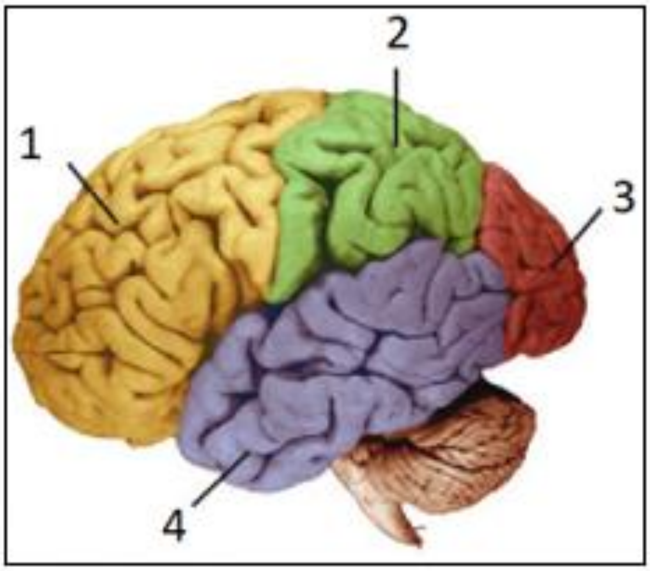
   a. het kijken
   b. zelfbewust zijn
   c. begrijpen van taal

6. Wat zorgt er voor het contact tussen de grote en kleine hersenen?

   a. De hypofyse
   b. Het verlengde merg
   c. De pons

7. Bekijk figuur 1. Op de foto zijn de verschillende hersenenkwabben afgebeeld met verschillende kleuren. Zet de volgende vier begrippen bij de juiste vier nummers:

- **Frontale kwab**
- **Occipitale kwab**
- **Temporale kwab**
- **Pariëtale kwab**



1 : ....

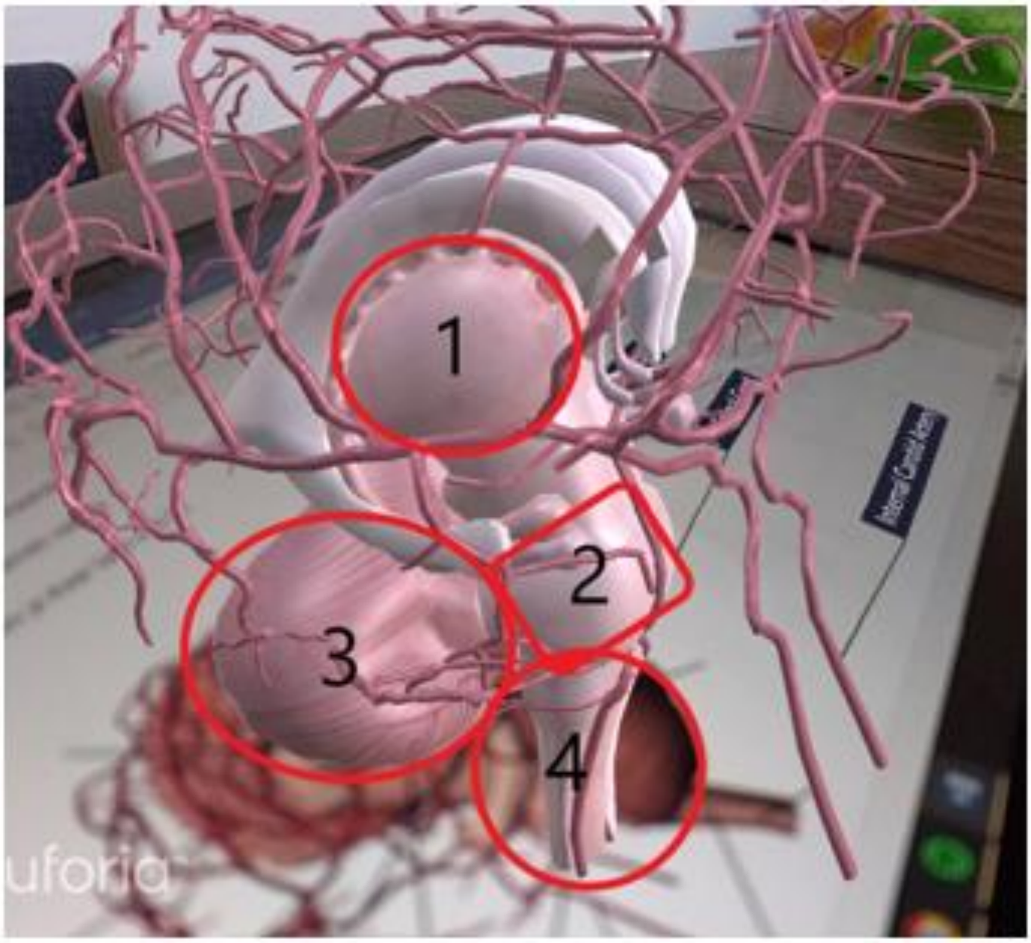
2 : ....

3 : ....

4 : ....

8. Bekijk figuur 2. Op de foto zijn verschillende onderdelen van de hersenen afgebeeld met cirkels. Zet de volgende vier begrippen bij de juiste vier nummers:

- **Verlengde merg**
- **Pons**
- **Kleine hersenen**
- **Thalamus**



1 : ....

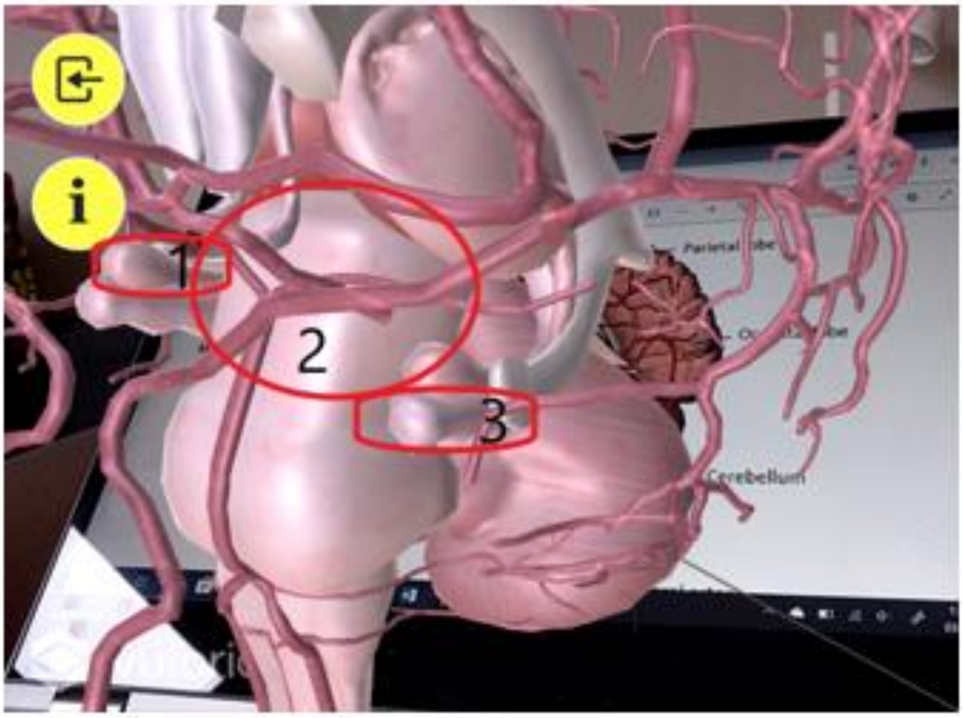
2 : ....

3 : ....

4 : ....

9. Bekijk figuur 3. Op de foto zijn verschillende onderdelen van de hersenen afgebeeld met cirkels. Zet de volgende drie begrippen bij de juiste drie nummers:

    - **Midden hersenen**
    - **Amygdala**
    - **Hippocampus**



1 : ....

2 : ....

3 : ....

Controleer of je studentennummer op de eerste pagina staat. Als je klaar bent mag je het papier omdraaien en wachten op de instructie van de docent

The Posttest

Deel 2

Vul in:
Studentnummer:
Leeftijd:
Geslacht: Man / Vrouw / Neutraal:

Omcirkel het juiste antwoord, er is steeds één antwoord goed.

1. De middenhersenen zijn betrokken bij:

   a. regelen van het bloeddruk
   b. opslag van informatie in het geheugen
   c. regelen van hormonen

2. De frontale kwab is verantwoordelijk voor:

   a. begrijpen van taal
   b. het kijken
   c. zelfbewust zijn

3. Kies het antwoord dat de volgende zin correct maakt:
   Het verlengde merg regelt onder andere de …

   a. de ademhaling
   b. de oogbewegingen
   c. het evenwicht

4. Welk onderdeel van de hersenen is betrokken bij het bewaren van het evenwicht?

   a. Kleine hersenen
   b. Hypofyse
   c. Thalamus

5. Welk onderdeel speelt een belangrijke rol bij het doorgeven van prikkels naar de hersenschors?

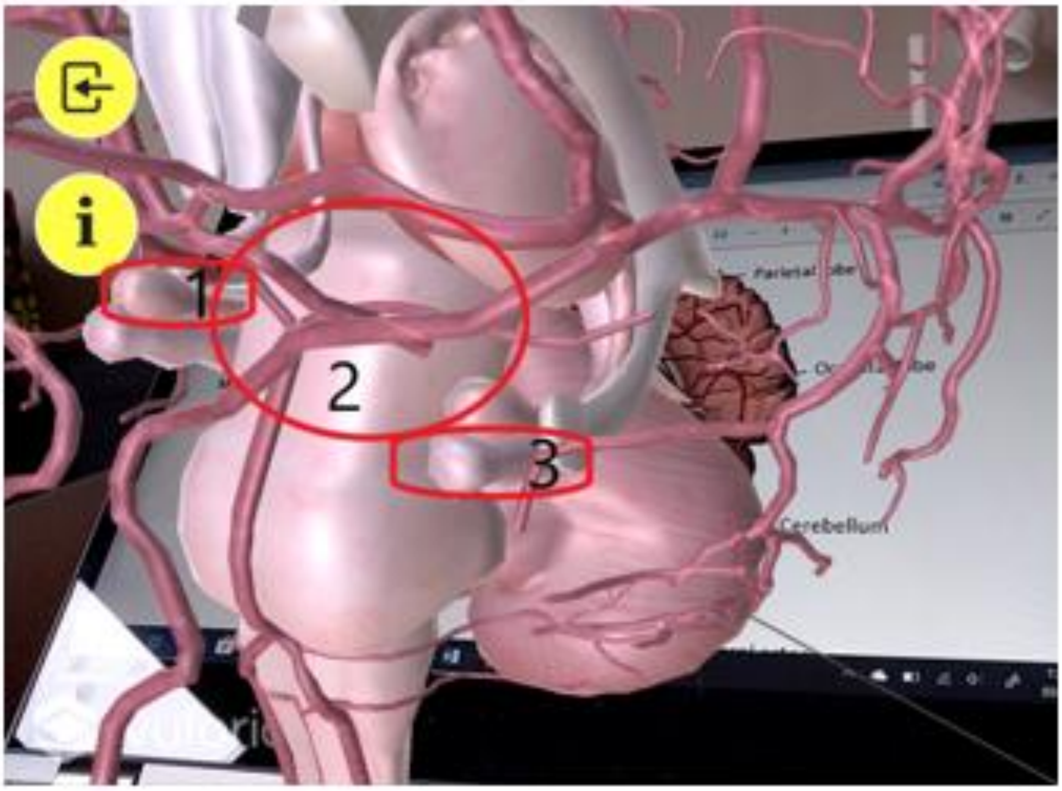
   a. De thalamus
   b. De middenhersenen
   c. De hippocampus

6. Wat zorgt er voor het contact tussen de grote en kleine hersenen?

   a. De hypofyse
   b. De pons
   c. Het verlengde merg

7. Bekijk figuur 3. Op de foto zijn verschillende onderdelen van de hersenen afgebeeld met cirkels. Zet de volgende drie begrippen bij de juiste drie nummers:

- **Amygdala**
- **Hippocampus**
- **Midden hersenen**



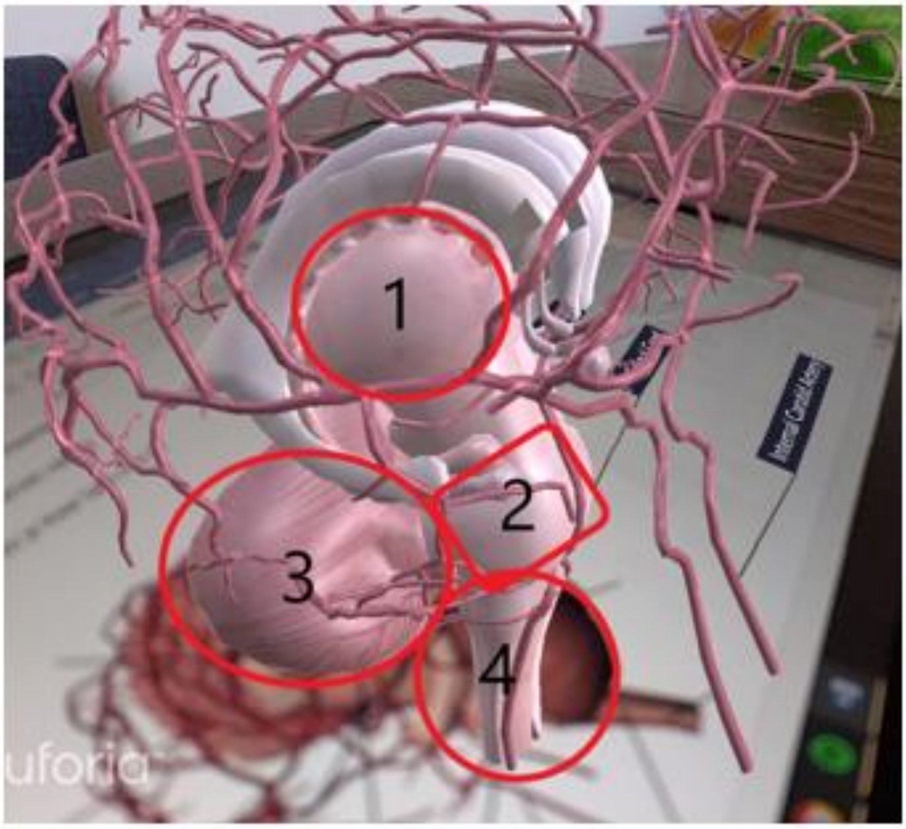
1 : ....

2 : ....

3 : ....

8. Bekijk figuur 2. Op de foto zijn verschillende onderdelen van de hersenen afgebeeld met cirkels. Zet de volgende vier begrippen bij de juiste vier nummers:

    - **Kleine hersenen**
    - **Thalamus**
    - **Pons**
    - **Verlengde merg**



1 : ……………………………………………………………………………………………

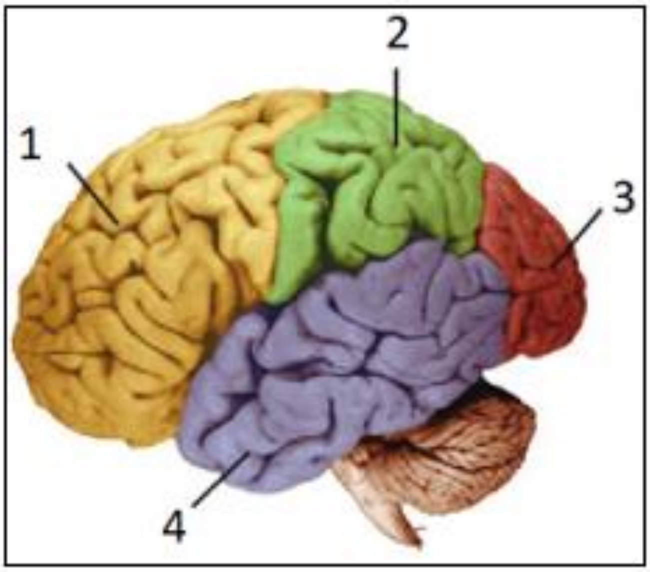
2 : ……………………………………………………………………………………………

3 : ……………………………………………………………………………………………

4 : ……………………………………………………………………………………………

9. Bekijk figuur 1. Op de foto zijn de verschillende hersenenkwabben afgebeeld met verschillende kleuren. Zet de volgende vier begrippen bij de juiste vier nummers:

- **Temporale kwab**
- **Occipitale kwab**
- **Pariëtale kwab**
- **Frontale kwab**



1 : ....

2 : ....

3 : ....

4 : ....

Controleer of je studentennummer op de eerste pagina staat. Als je klaar bent mag je het papier omdraaien en iets voor jezelf gaan doen

Appendix D

Overview of Correspondending Iitems

Question	Item pre	Item post
1	CQ1	CQ 3
2	CQ 2	CQ 5
3	CQ 3	CQ 1
4	CQ 4	CQ 4
5	CQ 5	CQ 2
6	CQ 6	CQ 6
7	SQ 1	SQ 8
8	SQ 2	SQ 9
9	SQ 3	SQ 10
10	SQ 4	SQ 11
11	SQ 5	SQ 4
12	SQ 6	SQ 5
13	SQ 7	SQ 6
14	SQ 8	SQ 7
15	SQ 9	SQ 1
16	SQ 10	SQ 2
17	SQ 11	SQ 3

Appendix E

FERB Form

APPLICATION FORM FOR THE ASSESSMENT OF A RESEARCH PROTOCOL BY THE FACULTY ETHICS REVIEW BOARD (FERB) OF THE FACULTY OF SOCIAL AND BEHAVIOURAL SCIENCES

General guidelines for the use of this form

1. This form can be used for a single research project or a series of related studies (hereinafter referred to as: "research programme"). Researchers are encouraged to apply for the assessment of a research programme if their proposal covers multiple studies with related content, identical procedures (methods and instruments) and contains informed consent forms and participant information, with a similar population. For studies by students, the FERB recommends submitting, in advance, a research programme under which protocol multiple student projects can be conducted so that their execution will not be delayed by the review procedure. The application of such a research programme must include a proper description by the researcher(s) of the programme as a whole in terms of the maximum burden on the participants (e.g. maximum duration, strain/efforts, types of stimuli, strength and frequency, etc.). If it is impossible to describe all the studies within the research programme, it should, in any case, include a description of the most invasive study known so far.
2. Solely the first responsible senior researcher(s) (from post-doctoral level onwards) may submit a protocol.
3. Any approval by the FERB is valid for 5 years or until the information to be provided in the application form below is modified to such an extent that the study becomes more invasive. For a research programme, the term of validity is 2 years and any extension is subject to approval. The researcher(s) and staff below commit themselves to treating the participants in accordance with the principles of the Declaration of Helsinki and the Dutch Code of Conduct for Scientific Practices as determined by the VSNU Association of Universities in the Netherlands (which can both be downloaded from the FERB site on the Intranet[1]) and guarantee that the participants (whether decisionally competent or incompetent and/or in a dependent relationship vis-a-vis the researcher or not) may at all times terminate their participation without any further consequences.
4. The researcher(s) commit themselves to maximising the quality of the study, the statistical analysis and the reports, and to respect the specific regulations and legislation pertaining to the specific methods.
5. The procedure will run more smoothly if the FERB receives all the relevant documents, such as questionnaires and other measurement instruments as well as literature and other sources on studies using similar methods which were found to be ethically acceptable and that testify to the fact that this procedure has no harmful consequences. Examples of studies where the latter will always be an issue are studies into bullying behaviour, sexuality, and parent-child relationships. The FERB asks the researcher(s) to be as specific as possible when they answer the relevant questions while limiting their answers to 500 words maximum per question. It is helpful to the FERB if the answers are brief and to the point.
6. **Our FAQ document that can be accessed through the Intranet provides background information with regards to any questions.**
7. The researcher(s) declare to have described the study truthfully and with a particular focus on its ethical aspects.

Signed for approval[2]:

Date:

[1] See: https://intranet.uu.nl/facultaire-ethische-toetsingscommissie-fetc
[2] The senior researcher (holding at least a doctoral degree) should sign here.

A. GENERAL INFORMATION/PERSONAL DETAILS

1.

a. a. Name(s), position(s) and department(s) of the responsible researcher(s):
Olaf Pijl, Master student, educational sciences

b. Name(s), position(s) and department(s) of the executive researcher(s):
Olaf Pijl, Master student, educational sciences

2. Title of the study or research programme - Does it concern a single study or a research programme? Does it concern a study for the final thesis in a bachelor's or master's degree course?:

The title of study is 'Learning in Education with Augmented Reality on a Smartphone: Individually or Collaborative?'. This study concerns a single study for a final thesis in a master's degree course

3. Type of study (with a brief rationale):

- experimental

4. Grant provider:

- non provider

5. Intended start and end date for the study:

February 2019 – June 2019

6. Research area/discipline:

Cognition & ICT

7. For some (larger) projects it is advisable to appoint an independent contact or expert whom participants can contact in case of questions and/or complaints. Has an independent expert been appointed for this study?[3]:

M.M.H. Schaars

8. Does the study concern a multi-centre project, e.g. in collaboration with other universities, a GGZ mental health care institution, a university medical centre? Where exactly will the study be conducted? By which institute(s) are the executive researcher(s) employed?:
The study will be conducted on a ROC in Hilversum. The executive researcher is employed at the Utrecht University

[3] This contact may, in principle, also be a researcher (within the same department, or not) who is able to respond to the question or complaint in detail. Independent is to say: not involved in the study themselves. The FERB upholds that an independent contact is not obligatory, but will be necessary when the study is more invasive.

9. Is the study related to a prior research project that has been assessed by a recognised Medical Ethics Review Board (MERB) or FERB?

No.

If so, which? Please state the file number:

B. SUMMARY OF THE BACKGROUND AND METHODS

Background

1. What is the study's theoretical and practical relevance? (500 words max.):
The theoretical relevance is that this area is unknow. There has been research on collaboration in AR, reports on time reduction, and on learning outcomes in AR, but not the combination of these above.

The practical relevance is that the findings of this study could make education more efficient and give insight. Teacher can plan their education with AR better. In example, the teachers will know that working together in AR boost the learning outcomes

2. What is the study's objective/central question?:

Does the use of AR-tools which violate the CTML principles create differences in learning outcomes compared to conventional education?'.

3. What are the hypothesis/hypotheses and expectation(s)?:

H0 = There is a non-significant main effect for the learning environment (AR / conventional) on the posttest.

Ha = There is a significant main effect for the learning environment (AR / conventional) on the posttest.

H_0 = There is a non-significant main effect for group composition (individually / collaborative) on the posttest.

H_a = There is a significant main effect for group composition (individually / collaborative) on the posttest.

Design/procedure/invasiveness

4. What is the study's design and procedure? (500 words max.):

This study will examine the learning outcomes of AR tools in education compared to conventional education in a medical domain. The current study is based on a design from a previous study with AR and learning outcomes of Sommerauer and Müller (2014) who used two groups: with AR / without AR. Also, this study is based on the study from Chen (2008) who investigated how the learning outcomes differ between working in dyads or individually with AR. The combination of these previous studies created a quasi-experimental 2x2 factorial design. The factors will be: (1) educational setting (AR/conventional), and (2) group composition (collaborative interdependent dyads or individually). This means that there will be four independend groups: (1) AR dyads, (2) AR individually, (3) conventional dyads, (4) conventional individually.

5.

a. Which measurement instruments, stimuli and/or manipulations will be used?[4]: Pre- and Post-test including questions about the content of the human brain
An AR assignment about the human brain

b. What does the study's burden on the participants comprise in terms of time, frequency and strain/efforts?:
The time that the participants will invest will be one-off of approximately 60 min. They will working on an assignment that is useful for their own knowledge expansion for their study.

c. Will the participants be subjected to interventions or a certain manner of conduct that cannot be considered as part of a normal lifestyle?:
No

d. Will unobtrusive methods be used (e.g. data collection of uninformed subjects by means of observations or video recordings)?:
yes

e. Will the study involve any deception? If so, will there be an adequate debriefing and will the deception hold any potential risks?:
no

6. Will the participants be tested beforehand as to their health condition or according to certain disorders? Are there any inclusion and/or exclusion criteria or specific conditions to be met in order for a participant to take part in this study?: They will not be tested, but the researcher will ask to the participants if they are feeling well and ask the mentors of the participants for important information around health conditions.

7. Risks for the participants -

a. Which risks does the study hold for its participants?:
Non

---

[4] Examples: invasive questionnaires; interviews; physical/psychological examination, inducing stress, pressure to overstep important standards and values; inducing false memories; exposure to aversive materials like a unpleasant film, video clip, photos or electrical stimulus; long-term of very frequent questioning; ambulatory measurements, participation in an intervention, evoking unpleasant psychological or physical symptoms in an experiment, denial, diet, blood sampling, fMRI, TMS, ECG, administering stimuli, showing pictures, etc. In case of the use of a device (apparatus) or administration of a substance, please enclose the CE marking brochure for the relevant apparatus or substance, if possible.

b. To what extent are the risks and objections limited? Are the risks run by the participants similar to those in daily life?:
The risks are similar to those is daily life. The research will not increase any risks

8. How does the burden on the participants compare to the study's potential scientific contribution (theory formation, practical usability)?:

9. Will a method be used that may, by coincidence, lead to a finding of which the participant should be informed?[5] If so, what actions will be taken in the case of a coincidental finding?:
No

Analysis/power

10. How will the researchers analyse the data? Which statistical analyses will be used?:

With an paired T-test and a repeated measures ANOVA in SPSS.

11. What is the number of participants? Provide a power analysis and/or motivation for the number of participants. The current convention is a power of 0.80. If the study deviates from this power, the FERB would like you to justify why this is necessary:
The number of participants will be approximately 60. The reason for this choice is that there are no more participants on the ROC in this specific medical domain that the researchers are interested in.

C. PARTICIPANTS, RECRUITMENT AND INFORMED CONSENT PROCEDURE

1. The nature of the research population (please tick):

1. General population without complaints/symptoms

2. Age category of the participants (please tick):

- 18 years or older
- 16-17 years

3. Does the study require a specific target group? If so, justify why the study cannot be conducted without the participation of this group (e.g. minors):

No, but this target group is interested in the subjects that are in the assignment and they have previously experiences with AR

4. Recruitment of participants -

a. How will the participants be recruited?:
Convenience sample. By a teacher of the ROC

[5] For instance: dementia, dyslexia, giftedness, depression, extremely low heartbeat in an ECG, etc. If coincidental findings may be found, this should be included in the informed consent, including a description of the actions that will be taken in such an event.

b. How much time will the prospective participants have to decide as to whether they will indeed participate in the study?:

Seven days

5. Does the study involve informed consent or mutual consent? Clarify the design of the consent procedure (who gives permission, when and how). Does the study involve active consent or passive consent? If no informed consent will be sought, please clarify the reason:
Informed active consent. The participants are of an age 16+, this means that they can decide for themselves if they would like to participate and agree. The mentor of the participants will provide these informed consults and ask them if they would like to participate and sign the consent a week before the experiment. If they are not sure, they could think about it and sign it later, before the experiment.

6. Are the participants fully free to participate and terminate their participation whenever they want and without stating their grounds for doing so?:

Yes

7. Will the participants be in a dependent relationship with the researcher?:

No

8. Compensation

a. Will the participants be compensated for their efforts? If so, what is included in this recompense (financial reimbursement, travelling expenses, otherwise). What is the amount?
No

b. Will this compensation depend on certain conditions, such as the completion of the study?
No

D. PRIVACY AND INFORMATION

1.

a. Will the study adhere to the requirements for anonymity and privacy, as referred to in the Faculty Protocol for Data Storage[6]?:
   - anonymous processing and confidential storage of data (i.e. storage of raw data separate from identifiable data): yes
   - the participants' rights to inspect their own data: yes
   - access to the data for all the researchers involved in the project: yes

If not, please clarify.

b. **Has a Data Management Plan been designed?**
No

[6] This can be found on the Intranet: https://intranet.uu.nl/wetenschappelijke-integriteit-facultair-protocol-dataopslag

2.

a. Will the participant be offered the opportunity to receive the results (whether or not at the group level)?: no
b. Will the results of the study be fed back to persons other than the participants (e.g. teachers, parents)?: yes
   If so, will this feedback be provided at the group or at the individual level?

   Group level.

3.

a. Will the data be stored on the faculty's data server?: yes

b. Will the data that can be traced back to the individual be stored separately on the other faculty server available for this specific purpose?
   Yes

E. ADDITIONAL INFORMATION

Optional.

F. FORMS TO BE ENCLOSED (CHECKLIST)

- Text (advert) for the recruitment of participants
- Information letter for participant
- Informed consent form for participants
- Written or oral feedback information (debriefing text)
- (Descriptions of) questionnaires
- (Descriptions of) measurement instruments/stimuli/manipulations
- Literature/references

Signature(s):[7] Date and place:

Name, position:

[7] The senior researcher (holding at least a doctoral degree) should sign here.