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# Impacts of cognitive depletion during a school day: research conducted among adolescents in the Dutch secondary education system

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**Abstract**

The relation of academic performance and length of the school day is a central topic . The problems of research is the way that the effects the length of a school day are calculated. Often grades are a central part, these measures can be subjective by nature. The real question should be if adolescents are performing the same throughout the day. Cognitive depletion could lead to worse performances later in the day. Therefore, the main research question: What are the determinants of cognitive depletion among adolescents in the Netherlands? To answer this research question, a 2x2 design is used. Socioeconomic status, length of school day and chronotype are used as main variables. The main conclusion is that explanatory variables Chronotype, socioeconomic class and length of school day do not seem to impact cognitive depletion throughout the school day. Control variables like sleep and academic level seem more impactful in cognitive depletion.

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# Chapter 1: Introduction

Human capital, the knowledge, skills, competencies and attribute embodied in individuals that facilitate the creation of personal, social and economic well-being (OECD, 2001), is an important factor in the (later) life of adolescents. Human capital often determines income and even health prosperity in someone's life (Koch et al., 2015). It is one of the few economic goods that cannot be separated from the person, meaning that in all circumstances human capital stays with a person regardless of time and place (Schultz, 1993). This also indicates the clear relation of human capital and economic growth, higher salaries and more prosperous health are all importance in the growing of our economies. Clearly there is a relation between human capital and economic growth, even though it might not be the sole determinant for economic growth (Mincer, 1984; Wilson & Briscoe, 2004). Therefore, looking at how to improve human capital would result in higher economic growth and a higher quality of life for people with higher amounts of human capital (Altiner & Toktas, 2017).

Human capital is acquired through the education system. Skills, knowledge and competencies are all found and taught in the education system. The main goal of the education system should be to make the acquisition of human capital as high as possible. For the individual adolescent, human capital acquisition starts at the beginning of secondary education. Adolescents are divided within academic levels which determine the practicality of studies and the amount of theoretical knowledge necessary. This is done to make sure that every adolescent can get their maximum of human capital, academic levels make sure that every adolescent gets taught on their own level. If human capital accumulation is important for economic prosperity, what would be the way to maximize this? One turn in this debate is the length of the school day. The logic of longer school days being that more lessons would equal more knowledge transfer, evidence for this argument is also found (Bellei, 2009; van der Aa et al., 2020).  This would then help with the accumulation of human capital.

However the question is if this argument for longer school days is even valid. Even though evidence for longer days is found (Bellei, 2009; van der Aa et al., 2020), it is also shown that diminishing returns are present (Rivkin & Schiman, 2013). There could be an argument made whereby longer school days do not improve educational performance, but even worsen it. From a practical standpoint, everyone has experienced long working days whereafter you actual experience a lack in motivation, lack in 'brain power' and just a general feeling of fatigue. The same argument can be made for adolescents at school, longer days at school could result in the same problems. This can be accredited to a loss in cognitive control, called cognitive depletion. Cognitive control consists of multiple psychological factors, such as willpower, self-control, self-regulation and/or executive control (Spears, 2011). Cognitive depletion in and by itself is not bad, less learning would take place but it would just lead to diminishing returns. However, the problem lies in the education system itself.

Human capital, in a way, is based upon grades achieved. Adolescents have to make tests and make sure that they pass the year by getting average or above average grades. The problem is that a lot of these grades are collected during the school day. Performance differs during the school day, which also influences ones educational achievement (Sievertsen et al., 2016; van der Vinne et al., 2015). This influence on performance is severe and can contribute to adolescents performing on a lower academic level, performing with less effort or even feeling less motivated to stay in the education system after compulsory education (Inzlicht et al., 2006).

The debate therefore continues, are we even doing adolescent a favor by prolonging school days? Wouldn't these longer school days result in cognitive depletion? Evidence is found for both sides of the debate, which brings this research to fruition.

In this research, the argument for cognitive depletion during the school day is discussed. The idea being that the evidence for longer school days is based upon quantity over quality. The problem is also that even on the shorter school days side of the debate, different amounts of evidence are found. For instance, Sievertsen et al. (2016) finding a worsening of academic performance throughout the day while van der Vinne et al. (2015) finds evidence that academic performance stays the same throughout the day but there is a large shift in individual performance. Therefore, it is also necessary to look at what can affect the academic performance and if there is evidence to be found for significant amounts of cognitive depletion throughout the school day.

Determinants of academic performance have been a major topic of research for decades know, but there is no consensus on what the exact causes of academic performance are. For instance, effects like chronotypes (van der Vinne et al., 2015), amount of sleep/quality of sleep (Meijer et al., 2000; Taras, 2005), physical activities (Davranche et al., 2009), breaks (Howie et al., 2015; Sievertsen et al., 2016), effects of different schooling types (Smit et al., 2015), socioeconomic status (Figlio et al., 2017; S. E. Johnson et al., 2011; Suleman et al., 2014; White, 1982), length of the school day (Rivkin & Schiman, 2013; Sievertsen et al., 2016; Smit et al., 2015; van der Vinne et al., 2015) and even the effect of housing equity (Been et al., 2021) have been used as focus for research. The results of some of these researches find conflicting evidence on the matter. One thing that a lot of these researches do have in common is how they measure the effect of these variables on academic performance. Most of these researches are based upon the grades achieved by adolescents. The problem is the subjectivity of these measures. Grades are influenced by the quality of the correction and often even some prejudice by teachers. Therefore, using grades as the determinant of academic performance might not be suited if the goal is to find a clear effect of cognitive depletion. The goal should not be to find evidence of lower grades, but find evidence of a weaker performance of the brain. Grades and performance of the brain are related (Jalava et al., 2014; Murphy & Weinhardt, 2020), but a more objective test which is not based on literacy rate or mathematical skill can only improve the validity of these results. The goal is therefore to check if these variables also cause cognitive depletion. A variable like socioeconomic status is already used in research regarding cognitive depletion (Mani et al., 2013). The other variables mentioned in having influence in academic performance might therefore also result in cognitive depletion. This brings us to the main research question and hypotheses:

**The research question is:** What are the impacts of cognitive depletion among adolescents in the Netherlands? Accompanied by the following three hypothesis:

**Hypothesis 1:** The longer a school day, the greater the drop in cognitive control.

**Hypothesis 2:** Belonging to a lower socioeconomic status has a negative effect on cognitive control throughout the day.

**Hypothesis 3:** Belonging to a late chronotype has a positive effect on cognitive control throughout the day.

To test the hypotheses and to answer the research question, a twofold measure will be used. First, a cognitive task experiment. Second, a survey. We measure cognitive depletion based upon an experimental set-up of (Mani et al., 2013) and van der Vinne et al. (2015). Adolescents of ‘’het Grescollege’’ located in Reuver, the Netherlands will conduct this experiment. This experiment will start with a cognitive test, based on three-dimensional rotation task and progressive matrices (appendix 3 and 4). Participants will make two cognitive tests, one at the beginning of their school day (morning) and one at the end of their school day (afternoon). The idea behind this task is to measure whether students face cognitive control capacity problems at the end of the school day. This cognitive test will result in the main dependent variable for this study, the difference between the scores achieved in the afternoon and the morning cognitive test. After this cognitive test, a survey (appendix 1) will be conducted. The survey helps with finding the main and control variables needed to answer the hypotheses and research question.

# Chapter 2: Literature research

This literature reviews will consists of five different main parts. First, an overview of cognitive theory will be discussed. Second, the ways of measuring cognitive depletion will be discussed. Third, some of the major determinants of academic performance will be discussed. Fourth, the relation between human capital and education is discussed. Finally, a small overview of the Dutch education sector and its place in the global educational sector will be provided.

## 2.1 Cognitive theory

Cognitive control is often defined as ‘’the ability to pursue goal-directed behaviour, in the face of otherwise more habitual or immediately compelling behaviours’’ (J. D. Cohen, 2017, p. 3).

This definition shows clear intent of using dual process theory, the ability to override an automatic response with a more controlled response (Grayot, 2020).. As we see in the next part, dual process theory is dated.. Therefore, using a definition like: ‘’the processes or mechanisms invoked in generating or regulating behavior when that behavior goes beyond the application of learned stimulus-response associations.’’ (Cooper, 2010, p. 588). This definition is broader and does not mention dual process theory, which makes this definition better suited for this research.

### 2.1.1 Dual process theory and its limitations

In cognitive control theory dual process theory is a central construct. Dual process theory refers to two system thinking (Grayot, 2020). These systems are the system one and system two thinking. System one thinking refers to effortless and automatic decision making, while system two refers to effortful and resource dependent decision making (Pocheptsova et al., 2009). The problem with this dual process theory is that it is outdated in neuroeconomic science. The problems lie not only within its implication but also its theoretical foundations (Grayot, 2020). The dual process theory can be divided into two parts of theoretic understanding, namely the default-interventionist model and the parallel competitive model (Evans & Stanovich, 2013; Grayot, 2020). The default-interventionist model interprets the dual process theory strictly, whereby the controlled system two thinking interferes with the automatic response of system one (Evans & Stanovich, 2013). This even goes as far as to argue that the brain is split into two parts, an automatic part and a controlled part. On the other hand there is the parallel competitive model, this model assumes a intertwined system between automatic and controlled decision making (Evans & Stanovich, 2013). Therefore, every decision made would be based on effortful interaction and an initial idea/response. The problem with both of these systems is that they have been shown to be incorrect. Dividing and splitting the brain in two separate parts is questionable, the brain is not hardwired into having an automatic and a controlled response (Grayot, 2020; E. J. Johnson, 2008).

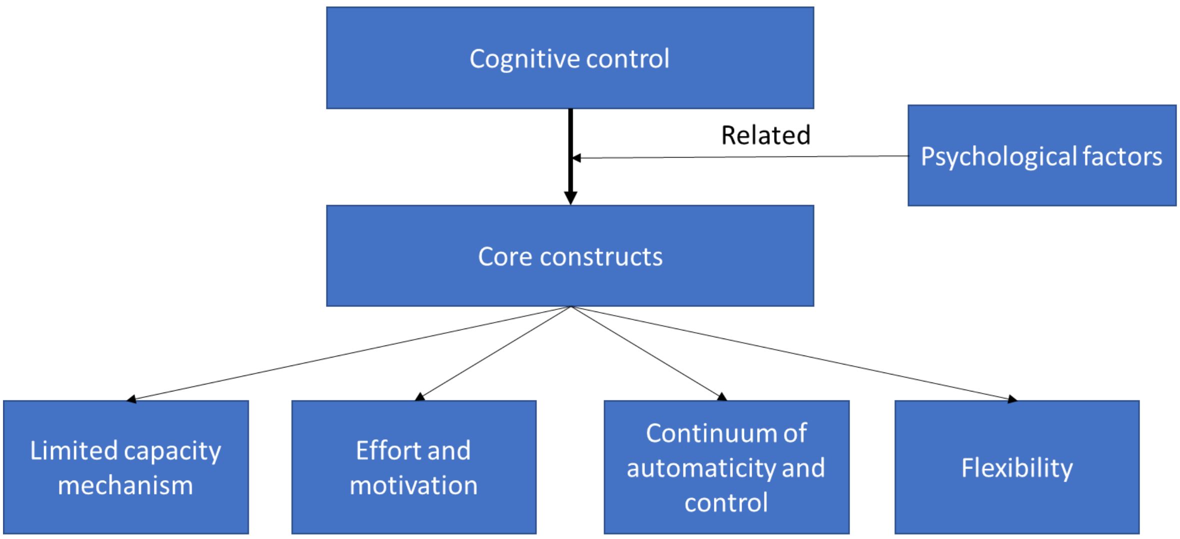



*Figure 1 Overview of cognitive control theory (made by author, based on Cohen (2017))*

### 2.1.2 Core constructs

Now switching to the main part at hand, namely cognitive control theory. According to Cohen (2017) cognitive control consists of four cognitive constructs, namely limited capacity mechanism, effort and motivation, continuum of automaticity and control and lastly flexibility (see figure 1 for schematic overview). Related to these five core constructs are other psychological constructs, like executive function and intelligence, attention, working memory long-term memory, prospective memory and planning and self-control (J. D. Cohen, 2017). First the core constructs will be discussed, after the psychological constructs will be discussed with its relation to cognitive control.

First, the limited capacity mechanism. This limited capacity mechanism shows the problem of the brain only having limited resources to perform well (Baumeister & Vohs, 2007; Healey et al., 2011). The resource, in this case, being a limited amount of working memory. The working memory therefore relates to cognitive control, being limited in your working memory results in worsening of performance when working memory is ‘full’. This means that a worsening of working memory can influence academic performance, think about losing the memory of important test information and therefore performing worse. Having a full working memory results in less accurate performance, therefore this also relates to cognitive control. The cause of these limitations is not yet found, however it could very well be due to physical limitations in our brains. From the 100 billion neurons in our brain, around one third is used for cognitive control (J. D. Cohen, 2017). Also, doing multiple tasks (or multiple actions) can cause depletion of resources (Healey et al., 2011). Research whereby participants had to do multiple unrelated tasks showed that performance went down, especially on tasks that required more cognitive control (J. D. Cohen, 2017). Not only is cognitive control based on the amount of resource dependent tasks, it also shows a clear temporal constraint (J. D. Cohen, 2017). The limited capacity mechanism is closely related to the working memory, which will be discussed in the psychological construct part.

Second, effort and motivation. Effort and motivation can be described as the degree of engagement with any tasks (Westbrook & Braver, 2015). Therefore, effort and motivation can create a higher performance on tasks that require cognitive control. High demanding tasks can improve effort and therefore also improve results (Westbrook & Braver, 2015). As an example, a challenging mathematical problem could increase effort, while easy basic questions are seen as unnecessary and ‘boring’. However, effort does not necessarily imply motivation, one can put in a lot of effort but still be unmotivated. Effort can be improved or reduced whichever way is necessary for that particular task. Still, effort and difficulty are closely related, but not identical (Westbrook & Braver, 2015). The task at hand determines effort and motivation. The definition of cognitive control used shows the importance of behavior that is not learned and regulates ones behavior.  Motivation can compensate for some depletion of cognitive control.. If tasks are resource-limited the performance can be improved if more effort is put into the task (Westbrook & Braver, 2015). Therefore, to increase effort the task should be motivating as to draw in engagement (Westbrook & Braver, 2015). Incentives are therefore a core concept of cognitive control.

Third, the continuum from automaticity to control. The continuum of automaticity and control is related to the dual process theory. In the dual process theory, automaticity and control refer to the brain choosing automatic and controlled responses which divides the brain in two parts (Evans & Stanovich, 2013; Grayot, 2020). The continuum of automaticity and control takes the same principle, but adjust for two factors, namely context dependence and learning (J. D. Cohen, 2017). Context dependence describes how in some cases controlled and automatic processes can switch places. This implies that controlled and automatic processes depend on the context in which they are given (J. D. Cohen, 2017). Learning implies that with practice automatic processes can be replaced with more controlled processes when there is enough practice (J. D. Cohen, 2017). Extensive practice of a task can improve cognitive control (Schneider & Shiffrin, 1977). This develops heuristics, which are decision strategies that save time and effort (Pohl et al., 2013, p. 1).Together this thus forms the continuum of automaticity and control, which implies that cognitive control can be learned and that this is context dependent.  The main difference with automaticity and control in the dual process theory being that the continuum does not divide the brain in two parts, but makes changes and improvements possible. Automatic and controlled responses are therefore not hardwired and can be changed upon the context and the amount of learning (J. D. Cohen, 2017). This gives thought about the psychological construct inhibition. Inhibition refers to controlling ones reaction to its initial response  (Aron, 2007). However, this term inhibition is overrated due to difference in context and learning influencing ones automatic and controlled response. Therefore, using inhibition in and by itself is not useful. This concept of inhibition comes back in other psychological factors like selective attention, emotions and memory (Aron, 2007).

Fourth and finally, flexibility. Flexibility refers to the ability of the brain to change behaviour quickly depending on the situation, even behaviour that has not been seen before (J. D. Cohen, 2017). Flexibility therefore refers to controlling behaviour in a certain context, be it a new behaviour or a behaviour learned through experience. This all spans into the concept of representational code, which is described as the code necessary to use cognitive control (J. D. Cohen, 2017). This representational code looks at the situations in which the brain uses flexibility in cognitive control (J. D. Cohen, 2017). For instance, past experiences can help find a solution/behaviour in a certain new context.

### 2.1.3 Psychological constructs

In total four psychological constructs are related to cognitive control theory, namely executive function and intelligence, attention, working memory and self-control. All these psychological constructs will be discussed individually.

Starting with executive function and intelligence. At this very moment, the difference between executive function and cognitive control is not really well-defined. Often cognitive control and executive control are used as synonyms (Aron, 2007; J. D. Cohen, 2017). It seems that cognitive control capacity is closely related to intelligence (Engle & Kane, 2004). Therefore, having larger intelligence could indicate less cognitive depletion due to the higher cognitive control capacity.

Attention is the base for cognitive control theory. Attention refers to the selection of some processes for engagement over others (J. D. Cohen, 2017, p. 12). Perceptual load and attention are often related, perceptual load referring to the amount of things someone can focus on (Lavie, 2010). This perceptual load improves during childhood, indicating that people can focus on more things at the same time (Lavie, 2010). At older ages, this deteriorates which means that attention gets weaker with age (Cohen-Shikora et al., 2018; Lavie, 2010). Older participants were less likely to ignore irrelevant information and switch to the more relevant information (Cohen-Shikora et al., 2018). Perceptual load also has its thresholds, meaning that it is limited in capacity (Lavie, 2010). Therefore, the brain often activates selective attention, which makes people choose on what to focus on (Lavie, 2010; Lavie et al., 2004). Selective attention can be divided into two mechanisms, a more passive form of attention in which irrelevant distractions get filtered out when there is not capacity left to process them (Lavie et al., 2004). The second mechanism is more active, whereby irrelevant factors need to be dismissed with the working memory (Lavie et al., 2004). This shows that especially when the more active mechanism is used, attention can help improve performance in tasks. Even though often separated, attention and working memory have a lot in common.

Working memory is closely related to cognitive control, because it affects the executive function. Working memory consist of three parts: ‘’(1) short-term storage whereby long term memories are active, (2) rehearsal practices and strategies for achieving and maintaining that activation and (3) executive function’’ (Engle & Kane, 2004, p. 149). It is possible to overload this working memory, which drops performance (Paas et al., 2003). Working memory capacity is all about the ability to keep attention to relevant information and preventing distraction (Engle & Kane, 2004). Working memory also consists of a primary and a secondary knowledge (Wilhelm et al., 2013). In the primary system there are biological components that we learn, for instance to see and to speak. The secondary system consists of thought out processes like reading, which if not taught are not part of a humans skill set. The working memory is closely related to the long term memory. Long-term memory refers to someone’s ability to conjure up memories (J. D. Cohen, 2017). Often these memories are remembered in their setting (Tulving, 2002). This ties long-term memory and cognitive control together, both are context dependent and this long-term memory can therefore help with providing cognitive control in a certain situation (J. D. Cohen, 2017). Prospective memory refers to the idea of remembering to do something in the future, which is closely related to planning. Information can be stored in the short-term and long term memory (Wilhelm et al., 2013).

Information will be stored in either one, but starting in the short term memory (Wilhelm et al., 2013). If the short-term memory is full, information will be stored in the long-term memory, long-term memory being the working memory (Wilhelm et al., 2013). If both systems are full, the person will be overloaded, which causes a drop in performance (Sweller, 2011). Therefore, referring to working memory capacity.

Self-control refers to ‘’the ability to control oneself, in particular his emotions and desires’’ (J. D. Cohen, 2017, p. 14). Self-control is thus clearly related to cognitive control, especially since emotions and desires play a major role in decision making. Self-control can be easily depleted since, just as cognitive control, it has limited resources (Tyler & Burns, 2008). Competition between emotions/desires and controlled processes might invoke intertemporal choice (J. D. Cohen, 2017). The eventual reward can influence a controlled response (waiting) or an immediate response. Self-control has been observed to be an important factor in academic performance, it helps with making the right decision (Baumeister & Vohs, 2007). Because of its limitations in resources, self-control can be an important factor in cognitive depletion at the end of the school day.

All the aforementioned concepts are related to cognitive control. A worsening in one of these systems decreases cognitive control and is called cognitive depletion. Cognitive depletion is also related to these similar psychological factors. For instance, cognitive depletion could also imply a loss of working memory or long-term memory. Both impact cognitive control and therefore also impact performance. Cognitive depletion can occur due to multiple factors like poverty (Mani et al., 2013; Spears, 2011), tiredness (Hodas et al., 2018; Meijer et al., 2000; Taras, 2005), physical fitness (Howie et al., 2015), working memory overload (Sweller, 2011). These factors are important measures when considering adolescents and their performance. Therefore, taking these concepts into account later will be crucial.

To summarize all this information, cognitive control thus consists of four different concepts. These concepts are: the limited capacity mechanism, effort and motivation, continuum of automaticity and control and flexibility. Even though some of the concept like the controlled and automatic processing have been refuted (Buturovic & Tasic, 2015; Grayot, 2020; E. J. Johnson, 2008), the core ideas of having a more automatic and controlled process are still present in human behaviour. The refute being that this dual process system is not as hardwired into our brain as was previously thought. Next to these core concepts are psychological concepts related to cognitive control. For instance, executive function and intelligence, attention, working memory, long-term memory, prospective memory and planning and self-control. These concepts are clearly related to cognitive control, but are not necessarily part of cognitive control. However, a worsening of one of these concepts can results in a depletion of cognitive control, thus creating cognitive depletion. The shows that cognitive depletion does not only have to be from a depletion of the core cognitive control constructs, but can also be due to a worsening of affiliated psychological factors.

## 2.2 How to measure cognitive depletion

Measuring cognitive depletion can be done in a multitude of ways. Four largely used methods are discussed, namely the Stroop task, Eriksen Flanker task, Raven's progressive matrixes and three dimensional rotation exercises.

The Stroop task is used to detect cognitive depletion by virtue of the automatic and controlled processes. The Stroop task has many iterations, in the most traditional Stroop task a word will be displayed to a participant. This word will be written in a different color, the goal of the task is to, as quickly and accurately as possible, state the color of the word (Balota & Marsh, 2004). Therefore the more cognitive control the participant has, the higher the score and/or the faster he/she answers the question. The idea behind this task is that people with more cognitive control are better able to suppress their automatic response (Balota & Marsh, 2004). This is called the Stroop effect, which arises due to three mechanisms. First, the difficulty of this test arises because of competition between the vocal responses to the word and the color. Second of all, words are generally recognized faster by the brain than colors can be named. Finally, due to the similarity of the written color and the 'ink' color the brain has difficulty dividing responses (Balota & Marsh, 2004). The Stroop task is widely used, for instance in the research of Mani et al. (2013). The main reason being its flexibility in the way that the Stroop effect can be generated, the test can be altered whereby literacy rates are unnecessary, for instance by changing out the words and the ink with sets of numbers. Which makes the Stroop task viable for low literacy participants. Mani et al. (2013) therefore altered the Stroop task whereby participants had to mention the amount of numbers displayed, not the actual number itself. For instance, '' 5 5 5'' would be displayed, the goal is to answer ''3'' instead of ''5''.

Another measure of cognitive control would be the Eriksen flanker task. The Eriksen flanker test uses the idea of response time and error finding (Davranche et al., 2009; Eriksen & Eriksen, 1974). The idea behind the most traditional Eriksen flanker task is for the participant to highlight different congruent and incongruent pictures while considering extra noise (Eriksen & Eriksen, 1974). The test shows how extra noise can influence people's decision making and therefore can increase their error rates. Normally the task is performed on a computer. The participant gets images that are congruent and incongruent and has to make a quick decision (Eriksen & Eriksen, 1974). After a certain short amount of time the computer goes on to the next image. Failing to answer in time will result in a faulty answer. The Eriksen flanker test therefore tests reaction time under certain conditions like increased noise.

Problem solving tests are also widely used in determining cognitive control (Lindner et al., 2017; Mani et al., 2013). Problem solving can be defined as ''cognitive processing directed at achieving a goal when no solution is obvious to the problem solver‘’ (Alexander et al., 2006, p. 287). Problem solving test can take all different kinds of forms, from a Raven’s matrices test where the goal is to match graphs and figures (Mani et al., 2013) or a more basic mathematics problem solving test (Lindner et al., 2017). These test can also serve to measure IQ or at least give an indication in the cognitive capabilities of participants. Often these problem solving tests are combined with a Stroop task or an Eriksen flanker task. This gives the possibility of measuring IQ and cognitive depletion at the same time. Problem solving tests are often based on existing knowledge which is needed to answer certain problems, for instance answering mathematics questions requires one to know how to divide and multiply (Alexander et al., 2006). Therefore, problem solving tests need to suited for the participants taking part in the experiment.

Progressive matrices are part of these problem solving tests. Progressive matrices test cognitive control, especially by measuring abstract reasoning which is often dubbed fluid intelligence (Bilker et al., 2012; Evans & Stanovich, 2013). In the most traditional sense, these progressive matrices consist of 60 exercises. These 60 exercises consist of five sets of 12 matrices which measure general intelligence (Bilker et al., 2012). Progressive matrices have been used earlier in educational research and is often used to find especially talented students (Mills et al., 1993). However, it is also necessary to adjust the test based on the target audience, too difficult tests will not give the right results for certain groups of participants (Mills et al., 1993). An advanced form of the progressive matrices is het Advanced progressive matrices, which combines insights from the Stroop task and the matrices from traditional progressive matrices (Bilker et al., 2012). The problem with the traditional and advanced version is the amount of time required to first of all conduct the test and second of all administrate 60 different answers per subject. The big plus of these tests is that they can be performed in larger quantities, participants can all make the test together on a computer or other device (Bilker et al., 2012). Research has shown that decreasing the amount of questions in these progressive matrices does not necessarily remove the legitimacy of the results. Bilker et al. (2012) showed high correlation between only 9 of the answers taken from the progressive matrices and the total 60 exercises. Therefore, Bilker et al. (2012) advocated for a reduced progressive matrices test, with similar amounts of predictive power but with a decreased amount of administrative work.

Three-dimensional rotation exercises are also used to prevent problems with mathematical skill and literacy rate. The goal of three-dimensional cubes is to match the example cube, whereby only three sides are visible, to the answer cubes (for example see appendix 3 and 4). The goal is to make a 3D animation in the brain and to turn the cube, out of the possible answer cubes there is only one which can be the same cube as the example cube. These cubes are often used in intelligence/cognitive ability testing and work similarly compared to the raven’s progressive matrices (Hawes et al., 2015; Holmqvist & Krantz, 2009). It even seems that three-dimensional rotation exercises, when tested on young children, can be a predictor for math and science performance later in their life.(Hawes et al., 2015)

Concluding, in this research the use of the more traditional Stroop task would be best, but might be difficult to execute due to time limitations. The solution to these time limitations could be the progressive matrices. These progressive matrices can be conducted in large quantities and, just like the Stroop task, tests cognitive control. Because of limitations of finding good and statistically verified progressive matrix tests a part of the progressive matrix test will be substituted by three-dimensional rotation exercises. The main goal of this research is to determine cognitive depletion throughout a school day. The Eriksen flanker task is mostly designed to measure reaction time and quick thinking, which is not something of interest in this research. Therefore, using an Eriksen flanker task would not necessarily give the wanted results.

## 2.3 Determinants of depletion of academic performance

In this section, the determinants of a depletion in academic performance are explained. Starting with the expected three most influential effects on academic performance, namely the length of the school day, chronotype and academic performance. After, some related determinants of academic performance will be described, such as sleep, physical exercises and breaks. These are related to the major determinants of academic performance.

### 2.3.1 Major effects of cognitive depletion in academic performance

The length of a school day can have major impacts on academic performance (Sievertsen et al., 2016; van der Vinne et al., 2015), even though there is also evidence that there is no real causal effect between a longer school day and academic performance (Patall et al., 2010). Longer school days could result in problems of cognitive depletion, students might not be able to perform the same after multiple long lessons at school. The working memory could get overloaded which at the very least makes learning less effective and performance worse. Performance throughout the school day has been researched and results have shown a negative relation between the amount of lessons and the performance (Sievertsen et al., 2016). Sievertsen et al. (2016) finds this by looking at national tests and comparing the grades across different times of the day. Students kept performing worse throughout the day (0.9% loss per extra hour in school), the best test scores were achieved in the morning while the worst average test scores were achieved in the afternoon. They described that lessons cause this worsening of test results, while activities like breaks would result in a regain of some of the test results. The amount of breaks was not enough to offset the loss in academic performance through the amount of lessons on a school day. A more in depth explanation of breaks and its effect on cognitive depletion will be given later in this part of the literature research. Van der Vinne et al. (2015) also studied the relation between the duration of the school day and academic performance. They also found some cognitive depletion, but all of this depletion was attributed to the individual biorhythm characteristics, so called chronotypes. Van der Vinne et al. (2015) argue that on average grades stay the same throughout the day, only individual performances related to chronotypes are differing throughout the day.

This brings us to the second concept which can majorly impact ones cognitive depletion, namely ones chronotype. Chronotype refers to someone's biorhythm and circadian clock (Zerbini & Merrow, 2017). The circadian clock referring to how energetic or wakeful someone is at a certain time of the day. Some are therefore more energetic or wakeful in the morning, while some are more energetic or wakeful later in the day (Zerbini & Merrow, 2017). Van der Vinne et al. (2015) find a major difference in academic performance when someone identifies as an early chronotype (morning person) or a late chronotype (evening person). Early chronotypes on average perform better in the morning, but lose performance throughout the day. Late chronotypes on average perform worse in the morning, but gain performance throughout the day. Late chronotypes have difficulties operating early, because their biorhythm is not synced with this time of the day. They do perform better throughout the day, essentially performing better because the time of day fits in better with their biorhythm. Early chronotypes face some loss in academic performance throughout the day, starting off strong but losing some performance. This brings us back to the debate about length of school day and academic performance. Van der Vinne et al. (2015) describe a certain 'sweet spot', where early and late chronotypes perform equal. This sweet spot is just after the lunch break, around 1:00 PM. Early chronotypes have lost their initial advantage, while late chronotypes are starting to pick up their performance. This also brings up the argument that due to how school days are currently used, early chronotypes perform better at school giving a disadvantage to late chronotypes with respect to academic achievement (Goldin et al., 2020). Good characteristics for academic performance, like planning or self-discipline, are positive related towards early chronotypes (Bratko et al., 2006; Randler, 2008). However, this does not entirely explain the difference between morning and afternoon performance, especially if academic level is taken into account. It seems to be mostly based upon a biological process which also seems to be related to other factors like individual characteristics which are relevant for academic performance. This is just one characteristic which adolescents cannot have any control over, the general trend seems to be that with age adolescents switch towards more of a late chronotype (Zerbini & Merrow, 2017).

One other factor which adolescents cannot influence is their socioeconomic status. Socioeconomic status has been shown to influence performance (Banerjee & Duflo, 2007; Carvalho et al., 2016; Haushofer & Fehr, 2014; S. E. Johnson et al., 2011; Mani et al., 2013; Ong et al., 2019; Spears, 2011; Suleman et al., 2014; Vohs, 2013). Socioeconomic status of an adolescent can be determined by combining three measures, parental educational level, parental occupational status and their income level (Suleman et al., 2014). Most of the times, researches show that adolescents with a high socioeconomic status perform relatively better than adolescents with a low socioeconomic status

(S. E. Johnson et al., 2011; Mani et al., 2013; Suleman et al., 2014). The reasoning behind this worsening academic performance is complicated and often attributed to different (psychological) factors, for instance social buffering.

Social buffering is found in highly social animals, like rats, guinea pigs and humans (Kikusui et al., 2006). Social buffering shows how social relationships can reduce the effect of anxiety and stress (Gunnar, 2017; Kikusui et al., 2006). These social relations essentially 'buffer' these problems of anxiety and stress, making well-being higher (S. Cohen & Wills, 1985; Hennessy et al., 2009). This could be related to socioeconomic status, if social relations are not present or people perceive themselves as not belonging to the same socioeconomic status as peers. Therefore, perception of belonging to the same socioeconomic status could be influential in their performance and cognitive control. Essentially showing self-signaling which can be influential in cognitive control theory (Inzlicht et al., 2006).

Adolescents with a lower socioeconomic status could face identity-based concerns, which in turn uses this individuals cognitive resources (S. E. Johnson et al., 2011). Some argue that a low socioeconomic status influences their thinking abilities, therefore not having enough mental power left to perform (Mani et al., 2013). While some others even argue that there is no clear and strong correlation between socioeconomic status and academic performance (White, 1982). The poor often show more signs of cognitive depletion when making decisions, often in all of the factors present in cognitive control (Carvalho et al., 2016; Mani et al., 2013; Vohs, 2013). Poverty does not only contain a measurement of income, but also implies an inability to acquire certain minimum capabilities (Singh & Chudasama, 2020). The problem is that for a long time we did not know the answer to the question if poverty caused cognitive depletion or if cognitive depletion caused poverty. However, even though there is still no conclusive evidence on this phenomena in particular, it seems that poverty causes cognitive depletion (Mani et al., 2013; Spears, 2011). This begs the question of how this cognitive depletion influences the lives of the poor. What causes this exact cognitive depletion among the poor? Often these problems of risk-averse and short sighted decision making stem from stress, depression or social anxiety problems that the poor more often face than the rich (Banerjee & Duflo, 2007; Haushofer & Fehr, 2014; Mani et al., 2013; Ong et al., 2019). This shows that when it comes to tough (economic) decisions, the poor make a worse choice on average. People of the lowest socioeconomic classes are often without any education, without any basic income and without any occupational status. These people might even face exponential effects of cognitive depletion, which might explain some of the difference found in the research of Johnson et al. (2011) and Suleman et al. (2014). In this case, even though most of the research is based on the poorest people in the world, belonging to a relatively lower socioeconomic class in the Netherlands might have a similar effect. Perception of socioeconomic class may therefore also influence results.

### 2.3.2 Related influences on academic performance

Breaks are related to the duration of the school day. In the Dutch secondary schools there is often a similar way of scheduling, even though schools have the freedom to schedule as they wish (Ministerie van Onderwijs, 2016). In the morning there is a break around 10:00 a.m. (often 15 to 20 minutes long), a break in the afternoon at around 12:00 p.m. (often 30 minutes long) and one final break at the end of the afternoon around 15:00 p.m. (often 15 minutes long). Breaks are important since they give adolescents (and teachers) the opportunity to reset or regain some of their cognitive control therefore increasing their academic performance (Howie et al., 2015; Sievertsen et al., 2016). Breaks are therefore fundamental, but as described earlier it could very well be that the breaks are too sporadic in the current schedule to compromise academic performance loss (Sievertsen et al., 2016). Also, in the current Dutch system there is no obligatory amount of breaks or a minimum length of breaks (Ministerie van Onderwijs, 2016). Important in this case is that the length of a break also helps with increasing cognitive control, but the normal lengths of breaks in the education system do not lead to a total reset of cognitive control. This total reset of cognitive control can be achieved with long periods of relaxation and sleep (Tyler & Burns, 2008).

Sleep is a related concept to chronotype. Sleep time and sleep quality are both influential in academic performance (Meijer et al., 2000; van der Vinne et al., 2015). Importantly and understandably, the more sleep someone has gotten the better he/she performs (Meijer et al., 2000; van der Vinne et al., 2015). Sleep quality often refers to the amount of times people get woken up during their sleep. The effects of both of these measures are significant, but it seems that sleep deprivation might be the most important problem when it comes to academic performance (Meijer et al., 2000). Sleep deprivation is often described as having less than five hours of sleep in the past twenty-four hours (Pilcher & Huffcutt, 1996). Losing a lot of sleep can have detrimental effects on performance, losing a whole night of sleep equals an IQ loss of about 13 points which is comparable to living in extreme poverty (Mani et al., 2013). Therefore, controlling for sleep time and especially for sleep deprivation will influence academic performance and therefore possibly also cognitive control.

Physical exercise has been shown to increase the reaction time of people independent of the cognitive control needed for the task (Davranche et al., 2009). Not only does it increase reaction time, physical exercise has also been shown to significantly improve math test results and even academic performance as a whole (Howie et al., 2015). The idea behind physical exercise and an increase in cognitive control is not hard to find. Tons of research has been done regarding the improvement of performance after physical exercising (Taras, 2005). The main idea behind this increase in performance being the increase in blood flow to the brain during exercising, this increased blood flow helps with lowering stress, improve one's mood and give a certain calming effect (Taras, 2005). This in turn frees some of the working memory from the brain, this causes an increase in cognitive control and therefore also an increase in performance. Physical exercise is part of the Dutch secondary education program in the form of PE lessons.

To summarize, length of the school day, chronotype and socioeconomic status have been proved to influence academic performance. Since the assumption is that a loss in academic performance throughout the school day is similar to cognitive depletion, these measures are important to take into account. They also form the bases for answering the three hypotheses. Other closely related factors like breaks, sleep and physical exercise seem to have a positive effect on academic performance, in this case the argument will be that they influence cognitive control positively. An increase in these measures should result in better academic performance. Using these variables is therefore essential in finding the right relation towards cognitive depletion and the school day.

## 2.4 Human Capital in relation to economics

Cognitive control is an important factor in both academics, psychology and behavioral economics. The conditions in which people make a decision and how this affects the decision is a central problem in behavioral economics. Factors like happiness, socioeconomic status, chronotype, sleep quality, ethnicity and many more factors influence performance (Mullainathan & Thaler, 2000). Therefore, if these factors indirectly influence human capital it is important for economic literature.

Not only economic growth is important in economics, one should also consider labor economics. Gender differences are present in the schooling system, women tend to get better grades while men tend to do better on standardized tests (Duckworth & Seligman, 2006). Often this difference being that women tend to have better self-discipline compared to men (Duckworth & Seligman, 2006). Men are often more competitive than women, often because women tend to shy away from competition (Gupta et al., 2013). All these problems can hurt both genders in the labor market. Therefore, the education system also has a big part to play in educating people in the jobs that are heavily needed. The connection between the education system and the labor market seems strong and crucial for economics. This also supports the argument made by the British labour party ("A Longer School Day Will Ready Pupils for Work - Labour," 2012). Only looking at the past has shown how labor market shortages can affect economies and damage human capital as a whole.

On a more macro level of economy higher education causes better innovative research, which in turn is useful in long term economic growth (OECD, 2001). Therefore, an increase in human capital in a certain sector can also cause knowledge spillovers, which in turn helps other sectors or firms also in growing the economy (OECD, 2001). For instance, think about the development of camera technology during the 2000s, this development of smaller and better camera's has given a boost to the smartphone industry whereby a camera is often a unique selling point of a smartphone. Therefore, it seems that human capital is not only necessary on the micro level, whereby employees on average earn more if they have a higher level of education.

As we can see, multiple valid reasons can be used to see the importance of educational oriented research. The effect of the schooling system is so important for the development of human capital. Human capital could potentially be one of the most important resources that comes out of the education system. This research is not designed to change the entire educational system. The goal is to find improvement in the way things are done at educational institutions. Simple solutions that might be fruitful in human capital accumulation. This being in the form of motivation whereby they are willing to increase the amount of time spent in the schooling system or even moving on to a higher level of education because of better circumstances in which they can operate. Grades can be seen as an incentive to perform (Jalava et al., 2014; Murphy & Weinhardt, 2020). If grades are an important measure in education systems, it seems that it can help incentivize or de-incentivize. If it is possible to alter the school day to increase performance, then it can only benefit growth of human capital which, in and by itself, is related to economic growth.

## 2.5 Dutch education system

The Dutch education system works as follows. Children are mandated to start their education at primary school when they become 5 years of age. Children can already start their education at 4 if the school accommodates these lower classes. Children go through 8 groups, which means that most children will finish primary school around their 12th birthday. After primary school, the children go to secondary education. Secondary education consists of three broad levels. The lowest and most practical level is called ''Voorbereidend Middelbaar Beroeps Onderwijs'' (VMBO), this VMBO level can be divided into four different trajectories. VMBO-B (which has low levels of theoretic basis but a lot of practical education), VMBO-K (which has a bit more theoretic basis but a little les practical education), VMBO-G (which has an equal mix of theoretical and practical education) and VMBO-T (which has a higher level of theoretical bases and lower amount of practical education). Finishing a VMBO degree after four years gives these adolescents the possibility to start a ''MBO'' education, which focuses on practical skills and prepares these adolescents for the job market. When someone at the secondary education does the HAVO trajectory, they follow five years of education which on completion grants them access to a university of applied sciences (HBO).

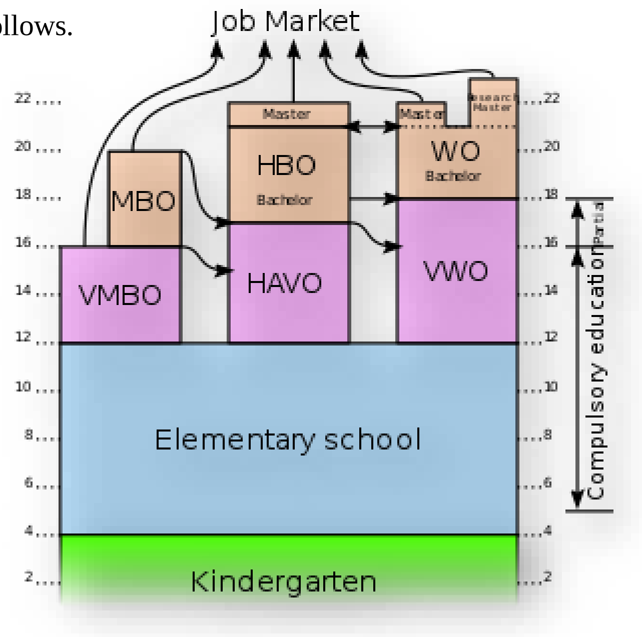



*Figure 2 Overview Dutch education system (''Education in the Netherlands'', 2021)*

Starting and finishing the VWO trajectory at secondary school, gives access to starting a university degree. A global overview can be seen in figure 2 .

The Dutch secondary education system has a compulsory instruction time of 1000 hours (*Instruction Time in Compulsory Education*, n.d.), which puts the Netherlands above average in instructional time. This extra instructional time can be traced back to academic performance, the Netherlands scores 10$^{th}$ best when it comes to education performance (*Education Rankings by Country 2021*, n.d.). The only other European Nation that tops us in this list is Finland, where interestingly the amount of mandatory instructional hours per year is significantly lower. Finnish adolescents have 808 hours of compulsory instructional time (*Instruction Time in Compulsory Education*, n.d.), therefore showing that academic performance is not only related to instructional time. When comparing the average of OESO countries (799 hours) and the EU23 (769 hours) we can conclude that the Netherlands on average has a significant amount of extra educational hours (van der Aa et al., 2020).

# Chapter 3: Methods

To test the hypothesis, a cognitive test and survey will be used to determine the effects of the relevant variables on cognitive depletion among adolescents during a school day. This research will be conducted at ‘’het Grescollege’’, a secondary education institution located in Reuver, the Netherlands. ‘’Het Grescollege’’ offers secondary education to adolescents ranging from 11 years old until about 16 years old. The school provides lessons in all ‘’VMBO’’ trajectories (until graduation) and the ‘’HAVO’’ trajectory for the first three years of secondary education. The school facilitates about four hundred students ranging from 11 to 16 years old. To incentivize student performing well and acting honestly, a gift card of their choice (€10) will be randomly distributed to three participants. Due to budgeting it is not possible to reward every student participating in the experiment.

We implement a 2x2 matrix with within-subject design (see figure 3), each participant makes two cognitive tests at two different moments in a day and a survey. Participants will be tested once at the beginning of their school day and once at the end of their school day. The goal is to find individual differences in cognitive depletion throughout the school day. After the first cognitive test, there is a survey. The survey contributes to some of the major influences of cognitive depletion in academic performance. The survey will ask questions about age, gender, ethnicity, chronotype measures (quality of sleep, sleeping pattern, bed time and wake up time), socio-economic status (based on asset based index FAS), socio-economic perception, duration of lessons, total amount of PE lessons and amounts of breaks (see appendix 1). The cognitive test and survey are supervised. The goal of the survey is to find main and control variables as to make sure to capture the main and major determinants of cognitive depletion better.

| | Cognitive test 1 first | Cognitive test 2 first |
|---|---|---|
| Morning session first | Group 1: 57 participants (28.64%) | Group 2: 34participants (17.09%) |
| Afternoon session first | Group 3: 52 participants (26.13%) | Group 4: 56 participants (28.14%) |

*Figure 3 2x2 Matrix design, actual amount of participants per group*

The reason for implementing this 2x2 matrix design is to combat learning effects during the data collection. Simply due to having the same kind of test again, participants could improve their score due to having already answering these questions. Therefore, it is necessary to divide the participants into four groups, dividing them between morning and afternoon starts and dividing the standard test between the groups. This means that there are four different groups, group 1 which starts with cognitive test 1 and starts in the morning. Group 2 which starts with cognitive test 2 and starts in the morning. Group 3 which starts with cognitive test 1 and starts in the afternoon. Group 4 which starts with cognitive test 2 and starts in the afternoon. The tests were conducted per class, meaning that there are differences in the amount of participants per group.

In total, 199 students participated in the full study. The distribution of participants can be found in figure 3.

## 3.1 Data collection

The data will be collected at ''het Grecollege'' located in the Reuver, a small town in the south of the Netherlands. To collect the data, the researcher visited classes at the beginning and the end of their school day. Beforehand, an appointment with the teacher was be made to ensure that normal education was not be disturbed (which is especially important in these COVID-19 times). The survey and the cognitive test were conducted using Qualtrics, which is an online survey program. The participants in this study made the cognitive tests and the survey on their mobile phones, laptops, tablets or any other device that they wish to use. At every session a short explanation about the experiment was given, participants will be told about the research and a global explanation of the survey and cognitive test was be given. When participants started the cognitive test, a practice example was given. Allocating participants to the different groups was done using their normal in school class.

## 3.2 Cognitive tests

The cognitive tests are the main part of this research, they are necessary to compute the dependent variable of this research. To compute this dependent variable, every subject participates in two test, each compromised of ten questions. The exercises are statistically checked by the ICAR project, both mean (completion rate) and standard deviation are given (*International Cognitive Ability Resource - The ICAR Project*, n.d.). The exercises are tested on a large number of people in previous tests (N >= 3000). The first and second test are both identical in terms of setup. Both tests consist first of six three-dimensional rotation exercises whereafter four progressive matrices need to be answered (see appendix 3 and 4). In total this means that ten exercises are part of the first test. Before the three-dimensional rotation exercises and the progressive matrices there will be a practice question to ensure that students know how to answer and what to answer. Ten exercises are chosen since there is evidence that a full progressive matrices task is unnecessary for statistically sound results (Bilker et al., 2012).

Both progressive matrices and three-dimensional rotation exercises are designed to test abstract reasoning which is a measurement of cognitive control irrespective of literacy or mathematical skills. The figures represented in the two versions of the test have the same success rate (the amount of people that got the question right) with a similar standard deviation (see tables A and B in appendix 2). For instance, the first figure of test 1 and test 2 both have a mean of 0.39 (success rate) and a standard deviation of 0.49. The higher the mean, the easier the question (higher success rate). The lower the mean, the more difficult the question (lower success rate) By making the test comparable there is a greater possibility to find similar effects between the tests. This also ensures that the main research question can be answered as clearly as possible making two tests that are (nearly) identical in terms of mean and standard deviation would help give more validity to the results. All participants get the two designed cognitive tests, this to ensure that there is no possible difference in success rate (the amount of good answers) if multiple different test version were used.

## 3.3 Empirical model

$$\begin{aligned} Y_i = \beta 0 + \beta 1 * X1_{Duration_{lessons_{cent}}} + \beta 2 * X2_{socioeconomicstatusscore} + \beta 3 * X3_{chronotype_{score}} \\ + \beta 4 * X4_{first_{testversion}} + \beta 5 * X5_{afternoon} + \beta 6 * X6_{Female} + \beta 7 * X7_{VMBOB} \\ + \beta 8 * X8_{VMBOKT} + \beta 9 * X9_{VMBO_{GT}} + \beta 10 * X10_{VMBOT} + \beta 11 * X11_{non-dutch} \\ + \beta 12 * X12_{age} + \beta 13 * X13_{Duration_{breaks_{cent}}} + \beta 14 * X14_{Duration_{PE_{lessons}}} \\ + \beta 15 * X15_{Duration_{sleep_{cent}}} + \beta 16 * X16_{Sleep_{inter}} + \beta 17 \\ * X17_{Duration_{sleep\ next\ morning_{cent}}} + \beta 18 * X18_{Sleep_{inter\ next\ morning}} + \varepsilon_i \end{aligned}$$

The dependent variable (Yi) is the difference between cognitive test scores achieved in the afternoon and morning, thus the afternoon performance minus the morning performance. β0 refers to the intercept, the constant of change. X1 until X3 are based on main variables used to answer the hypothesis. X1 refers to the duration of lessons that the participants have had on that particular day. The variable is centered around the mean because no student has zero minutes of lessons that day. Longer than average school days are expected to result in a negative relation with the dependent variable. X2 refers to the asset based wealth index called Family Affluence Scale (FAS) this measure scores socioeconomic status. The higher the score the higher of an socioeconomic status they belong to. Higher socioeconomic status is expected to have a positive relation with the dependent variable. X3 refers to the chronotype score. The higher the score, the more of an early chronotype participants are. A negative relation between Chrono_score and the dependent variable is expected. Higher Chrono_scores indicate an earlier chronotype.

X4 until X18 are control variables. X4 refers to the first test version the player has received. In this case coded as a dichotomous variable whereby test 1 is the default category. X5 refers to the treatment variable afternoon. Which is a dichotomous variable that indicates whether participants have had their first test version in the afternoon or in the morning. The default category being having the test first in the morning. X6 refers to participants being female, in this case being a dichotomous variable whereby the reference category is male. Being or identifying as female results in a 1. A positive relation with the dependent variable is expected. X7 until X10 refers to the academic level of participants. All academic levels are coded as categorical variables, with the academic level ‘’HAVO’’ as reference group. A negative relation between the academic levels and the dependent variable is expected. Lower academic levels compare to the reference category should result in a worse performance throughout the day.

X11 refers to the participant being of non-Dutch decent. This variable is coded as a dichotomous variable, whereby the reference category is being of Dutch decent. Being of non-Dutch decent is expected to have a negative impact on the dependent variable. X12 refers to the participants age. Age is expected to have a positive effect on the dependent variable. X13 refers to the amount of break time the participant is going to have that day, presented in minutes. The variable is centered around the mean since no participants have zero minutes of break on a day. Breaks are expected to have a positive effect on the dependent variable. X14 refers to the amount of minutes of PE lesson that particular day. Minutes of PE lessons are also expected to have a positive relation with the dependent variable. X15 refers to the total amount of sleep the participant has gotten, measured in minutes. The variable is centered around the mean since no participants sleep zero minutes the night prior. Longer than average sleep is expected to have a negative effect on the dependent variable. X16 refers to the quality of sleep, measured by how many times the participant has woken up during the previous night of sleep. More sleep interruptions in a night are expected to have a positive impact on the dependent variable. More sleep interruptions would make morning scores relatively worse. X17 refers to the duration of sleep the next morning, this measure is collected from participants in group 3 and 4 which got their cognitive tests split over 2 days. This measure is expected to have a negative relation with the dependent variable. X18 refers to the amount of sleep interruptions the next morning. This measure is expected to have a positive impact on the dependent variable.

## 3.4 Analysis plan

The hypotheses will be tested using a data from the survey and the cognitive test. The survey and cognitive test are done using online survey program Qualtrics. Participants will be given a QR with which they can conduct the survey on their phones, tablets or Chromebooks.

The dependent variable for this research will be based upon the cognitive test, consisting of three-dimensional rotation exercises and progressive matrices. The dependent variable is constructed using the results of the two cognitive tests. Scores are tallied up, the difference in the score between the afternoon and morning test will be calculated and used as the dependent variable.

Variables from the survey are transformed into usable measurements. The most important measures, chronotype, socioeconomic status and duration of lessons are used and calculated as follows. These are essential for answering the hypothesis. Chronotype is scored following the morningness-eveningness scale (Carskadon et al., 1993, p. 259). The questions will be individually scored, questions without an asterisk will be scored with a = 5, b = 4, c = 3, d = 2, e = 1 while questions with an asterisk will be scored a = 1, b = 2, c = 3, d = 4, e = 5. The higher the score, the more of a morning person the adolescent is. In total 42 points are available. Socioeconomic status follows the Family Affluence Status (FAS) (Currie et al., 2008). Four questions regarding observable assets (Amount of cars, vacation etc.) are asked and scored, for instance a = 0 points, b = 1 point, c = 2 points and d = 3 points. In total, the FAS can give a maximum score of 10 points. The higher the score, the higher the socioeconomic status of the participant. Duration of lessons will be filled in by the participants in the survey, measured and used in minutes. Variables sleep, breaks and PE lessons are also measured and used in minutes. Sleep, breaks and lessons are centered around the mean, since no zero observations are expected. Other variables like, Afternoon, Female, first test version and non-Dutch are transformed into dichotomous variables. Academic level is transformed into a categorical value. Sleep interruptions and age are used as a ratio variable.

After all measurements are defined, the data will be analyzed regarding standard deviation, missing values and regression assumptions will be tested. This is done with STATA. The data will be analyzed regarding three different dependent variables, score achieved in the morning session, score achieved in the afternoon session and the difference between the score achieved in the afternoon and the morning session. After the data will be checked for (auto)correlation. For instance, one could expect a high correlation between chronotype and hours slept (Meijer et al., 2000) and/or socioeconomic status and socioeconomic perception. Therefore, some variables will be excluded or transformed to increase the predictive power of the regression. Missing values will be dropped if they are missing completely at random (Demirtas, 2004), which is what is expected in this research. Some of the values would be missing only if survey questions are left open and/or participants do not return for the second cognitive task. Even though not returning for the second cognitive test would be unlikely, since the participant would need to go home during a school day or not go to the school the very next morning. Missing values are expected for the two variables sleep the next morning and sleep interruptions the next morning. Only 2 out of the 4 groups divide the cognitive test over two days, missing values are filled in with the mean. Outliers are checked, because they can have an influential effect on the eventual outcome of the OLS regression (Alma, 2011). Outliers could be present in the survey part about socioeconomic status. Therefore, isolating this variable would be necessary if it influences the slope of the regression line. To detect these outliers, a robustness check will be performed (Alma, 2011). If the outliers are too influential, they are excluded from the regression, even though this would be the last resort.

# Chapter 4: Data

## 4.1 Importance of main and control variables

Out of all the variables, only the dependent variable is not collected using they survey (see appendix 1). The survey consists of four broad categories: School day related questions, socioeconomic question, sleep/chronotype related questions and general questions. The school day related questions ask about length of school day, amount of PE lessons and amount of breaks. The socioeconomic questions are based on the Family Affluence Scale (FAS), which include measures like amounts of cars owned by parents/caretakers, amount of computers, amount of vacations per year (pre-covid-19), having their own sleeping room and lastly a subjective perception of their own financial situation The sleep/chronotype questions refer questions about the length of their sleep, the sleep quality and the morningness-eveningness scale test to determine chronotype.

The general questions are some of the basic sets of variables for which would want to control, in this case being age, female, non-Dutch and academic level. These variables are important due to a multitude of factors, especially a difference between genders can be interesting regarding the RQ. It could very well be that males suffer higher amount of cognitive depletion throughout the day compared to females, or vice versa. Women tend to get better grades, while men perform better on standardized tests (Duckworth & Seligman, 2006). Asking about the language spoken at home can helps with an indication of socio-economic class. On average minorities are disproportionally represented in lower socio-economic classes(Centraal Bureau voor de Statistiek, n.d.). The language spoken at home can therefore contribute to the determination of socio-economic class if other measures would be insufficient. Also, if another language is spoken at home this could result in lower academic achievements. Since there is evidence for socio-economic class having an impact on cognitive control, this measure of ethnicity can help explain differences in cognitive depletion throughout the school day. Language like Dutch is one of the major subjects in the Dutch education system, which could imply that a different language spoken at home has an influence on academic achievements. To account for overrepresentation of a certain socioeconomic class including language spoken at home would be necessary. The academic level is used as a broad measure of IQ and academic achievement. Even though this measure does not entirely explain IQ, it is at the very least a measure which can indicate the amount of human capital that the participant is expected to achieve at the end of their school career.

Other variables that are added are the first test version that participants received and the first time that participants got their cognitive test (afternoon or morning). Controlling for the experimental design.

## 4.2 Description of variables

**Table 1, Descriptive statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| **Dependent variables:** | | | | | |
| Score morning | 199 | 1.543 | 1.209 | 0 | 5 |
| Score afternoon | 199 | 1.678 | 1.238 | 0 | 6 |
| Score afternoon minus morning (Score_dif) | 199 | .256 | 1.755 | -5 | 5 |
| **Main variables** | | | | | |
| Duration les cent | 199 | 0 | 30.003 | -60.97 | 59.03 |
| Soc eco class | 199 | 7.92 | 1.542 | 3 | 10 |
| Soc perc | 199 | 8.54 | 1.546 | 1 | 10 |
| Chrono score | 199 | 25.065 | 5.355 | 10 | 38 |
| **Control variables** | | | | | |
| Age | 199 | 13.764 | 1.025 | 12 | 16 |
| Duration break | 199 | 46.809 | 12.206 | 15 | 90 |
| Duration break cent | 199 | 0 | 12.206 | -32.847 | 42.153 |
| Duration PE les | 199 | 20.503 | 26.719 | 0 | 60 |
| Duration sleep | 199 | 470.23 | 83.179 | 60 | 630 |
| Duration sleep cent | 199 | 0 | 83.179 | -410.792 | 159.208 |
| Sleep inter | 199 | .753 | 1.165 | 0 | 6 |
| Duration sleep next_morning | 199 | 476.529 | 57.711 | 180 | 615 |
| Duration sleep next_morning_cent | 199 | 0 | 57.711 | -296.529 | 138.471 |
| Sleep inter next morning | 199 | .783 | .932 | 0 | 6 |

Table 1 shows the descriptive statistics for the dependent, explanatory and control variables. In total 199 observations are made. Starting with the dependent variables used, the score achieved in the morning is on average lower than the score achieved in the afternoon (1.543 vs 1.678). This also shows that average difference between the scores achieved in the afternoon and morning, which is shown by Score afternoon minus morning (In regressions used as variable Score_dif). The average difference in score is 0.256.

The duration of lessons centered, this variable is centered around the mean of 470.23 lessons per school day. The minimum value for this variable being -60.97 with a maximum value of 59.03. On average, Soc_eco_class has a score of 7.92 out of the possible 10 points. The lowest socioeconomic class score achieved was 3. Soc_perc scores on average 8.54 out of 10. This shows that, on average, adolescents perceive their socioeconomic status higher than it objectively is. Lastly, Chrono_score has an average score of 25.065 out of the possible 42. Scores range from 10 (lowest possible score) to 38. The standard deviation of chrono score is 5.355.

On average participants are 13.764 years old with a standard deviation of 1.025. Observations range from 12 to 16 years old. Duration of breaks shows an average of 46.809 minutes of break on a school day. The minimum duration of breaks was 15 minutes with a maximum of 90 minutes. Duration_breaks_cent is centered around this average with a standard deviation of 12.206. On average participants had 20.503 minutes of PE lessons on their school day with a standard deviation of 26.719. Observations range from 0 minutes of PE lessons to 60 minutes of PE lessons.

On average participants slept 470.23 minutes, which is just shy of 8 hours of sleep. The standard deviation being 83.179 minutes. The duration of sleep is centered because no 0 observations have taken place. The amount of sleep differs from 60 to 630 minutes of sleep. On average participants have woken up 0.753 times with a standard deviation of 1.165. Sleep interruptions range from 0 to 6 or more times.

For participants that participated in the cognitive test over two days, the duration of sleep the next morning was on average 476.529 minutes with a standard deviation of 57.711 minutes. The minimum amount of sleep was 180 minutes with a maximum of 615 minutes. This variable was also centered around the mean. This second morning, participants on average woke up 0.783 times with a standard deviation of 0.932. Sleep interruptions range from 0 to 6 or more times.

**Table 2, Tabulations of dichotomous/categorical variables**

| Variable | Frequency | Percent | Cum |
|---|---|---|---|
| **First_test_version** | 199 | | |
| Cognitive test 1 = 0 | 109 | 54.77 | 54.77 |
| Cognitive test 2 = 1 | 90 | 45.23 | 100 |
| **Female** | 199 | | |
| Male = 0 | 93 | 46.73 | 46.73 |
| Female = 1 | 104 | 52.26 | 98.99 |
| Other = 2 | 2 | 1.01 | 100 |
| **Non-Dutch** | 199 | | |
| Dutch = 0 | 184 | 92.46 | 92.46 |
| Non-Dutch = 1 | 13 | 6.53 | 98.99 |
| Do not want to say = 2 | 2 | 1.01 | 100 |
| **Afternoon** | 199 | | |
| Morning first = 0 | 91 | 45.73 | 45.73 |
| Afternoon first = 1 | 108 | 54.27 | 100 |
| **Group_number** | 199 | | |
| Group 1 = 1 | 57 | 28.64 | 28.64 |
| Group 2 = 2 | 34 | 17.09 | 45.74 |
| Group 3 = 3 | 52 | 26.13 | 71.86 |

| | | | |
|---|---|---|---|
| Group 4 = 4 | 56 | 28.14 | 100 |
| **Academic level** | 199 | | . |
| HAVO = 0 | 38 | 19.1 | 19.1 |
| VMBO-B = 1 | 24 | 12.06 | 31.16 |
| VMBO-K = 2 | 44 | 22.11 | 53.27 |
| VMBO-GT = 3 | 63 | 31.66 | 84.92 |
| VMBO-T = 4 | 30 | 15.08 | 100 |

Table 2 shows the dichotomous and categorical variables. All variables have 199 total observations. The first_test_version made was mostly cognitive test 1, with 109 out of 199 participants starting with cognitive test 1. 90 out of 199 participants started with cognitive test 2. In total, more females have participated in this research. 104 out of 199 participants was or identified as female, 93 out of 199 identified as male with 2 out of 199 not specifying or wanting to share their gender. In total 13 out of the 199 participants are of non-Dutch decent, 2 out of the 199 participants did not want to specify while 184 out of 199 participants were of Dutch decent. Afternoon refers to the first time they have received the cognitive test. In total, 108 out of 199 participants started in the afternoon, while 91 out of 199 participants started in the morning.

The amount of participants per group (see figure 3) is not equally balanced. Group 1 has the most participant with 57 while group 2 has the lowest amount of participants with 34. Group 3 and 4 have 52 and 56 participants respectively. The other categorical value, academic level, is divided into five groups. HAVO is the reference category with in total 38 participants, VMBO-B has 24 participants, VMBO-K has 44 participants, VMBO-GT has the most participant with 63 and VMBO-T has 30 participants in total.

No measures are too strongly correlated. For an overview of correlations see appendix 5. The highest influential correlation being between chrono_score and duration_sleep, however this correlation is still below 0.5.

## 4.3 Inspecting the dependent variable

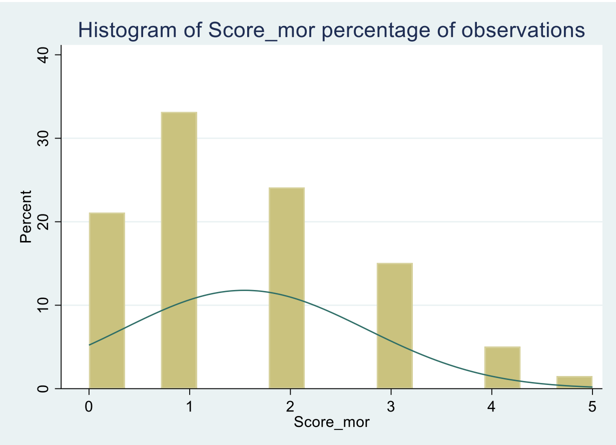



*Figure 4 Histogram of Scrore_mor percentage of observations*

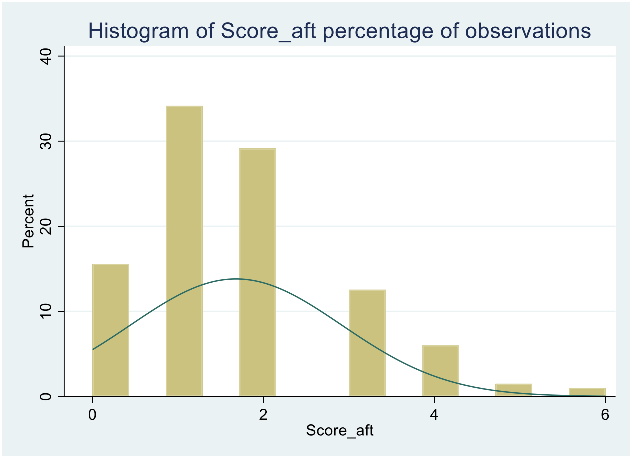



*Figure 5 Historgram of Score_aft percentage of observations*

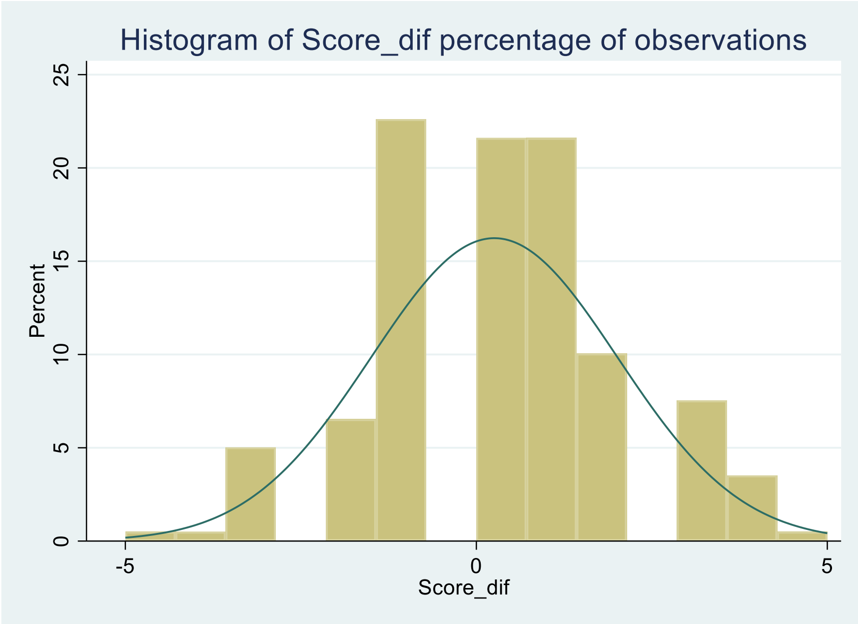



*Figure 6 Histogram of Score_dif percentage of observations*

To inspect the dependent variable, first histograms are used (see figures 4, 5 and 6). As can be observed, all measures of the dependent variable are normally distributed. Because of the normal distribution, an OLS regression is used. The dependent variable complies with all seven theoretical assumptions of the Gauss-Markov theorem. This implies that using a OLS is BLUE, the best linear unbiased estimator. All variables are checked for correlation, multicollinearity and their residuals.

When looking at the distribution of the scores, just as was described in the summary of the statistics (table 3), the mean score of participants was slightly higher at the afternoon session compared to the morning session (1.678 vs 1.543 respectively). Looking at the minimum and maximum scores, the afternoon session ranges from 0 to 6 points scored (out of 10) while the morning session ranges from 0 to 5 points scored (out of 10). Relatively speaking, there are more 0 results in the morning compared to the afternoon. This could point towards lower concentration/working capacity for participants in the morning compared to the afternoon. However, the general trend seems to be similar with no major deviations between the morning and afternoon session.

Looking at the difference in test scores between the afternoon and the morning (figures 4 and 5), there is a clear normal distribution present. In this case, most of the participants are competing similar in the morning and afternoon session, with only a couple of large deviations from 0. The general trend seems to be that students score better in the afternoon session compared to the morning session, which is also supported by the mean (0.256) of the Score_dif variable. However, there could still be differences in the average score achieved in the different treatment groups.

**Table 3 Tabulation of score distribution by Group number**

| Score_dif | Group_number | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | Total |
| -5 | 1 | 0 | 0 | 0 | 1 |
| -4 | 0 | 0 | 0 | 1 | 1 |
| -3 | 4 | 3 | 3 | 0 | 10 |
| -2 | 2 | 5 | 2 | 4 | 13 |
| -1 | 10 | 7 | 12 | 16 | 45 |
| 0 | 11 | 8 | 13 | 11 | 43 |
| 1 | 13 | 7 | 11 | 12 | 43 |
| 2 | 7 | 2 | 4 | 7 | 20 |
| 3 | 6 | 2 | 5 | 2 | 15 |
| 4 | 3 | 0 | 1 | 3 | 7 |
| 5 | 0 | 0 | 1 | 0 | 1 |
| Total | 57 | 34 | 52 | 56 | 199 |

Since the dependent variable can also be influenced by the way that the research was designed, it is also necessary to look at the results regarding the different result per group. Instead of reiterating the groups and their meaning, I refer back to figure 3. As can be seen in table 3, there is no clear difference in distribution between the four groups. As for the number of observations, group 2 has relatively less observations because of participants dropping out of the research (see excluded participants). Out of all the 199 observations, 131 are between a score difference of -1 and 1. On average, the groups seem equal in their distribution of results, which suggests that this design has worked to prevent learning effects and other externalities.

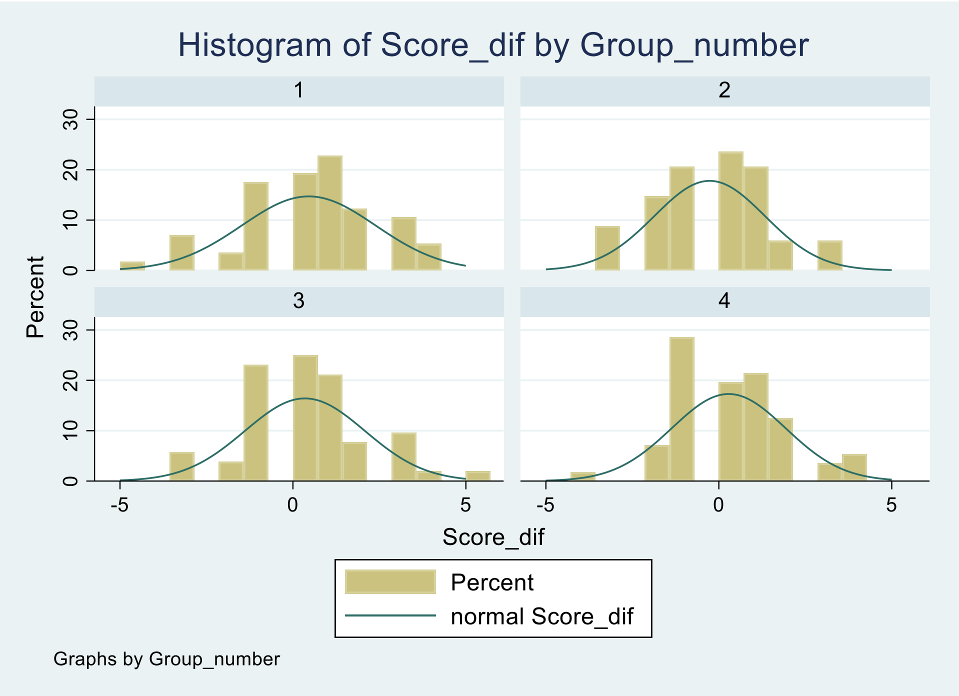



*Figure 7 Histogram of Score_dif by Group_number*

Looking at the normal distributions of figure 7, a generally same distribution can be observed. There are no major differences in the distribution of Score_dif, which suggests that all groups performed similarly. The difference that are present can be attributed to difference in participant per group or other externalities which will become clear in the regressions.

## 4.4 Excluded participants

Participants of the study are adolescents studying at ‘’het Grescollege’’ in the Netherlands. In total around four hundred students are studying at this secondary education institution. In this research, all students from the first, second and third year of education were supposed to participate in the research. Normally, there is also a fourth year of education, but these students had their national exams which made them absent at school. Therefore, these participants had to be excluded from the research, purely based on the normal national school planning.

From the first three years, all classes were participating except one class. This class did the morning session of the experiment, but when returning in the afternoon, the group was not controllable and the decision was made to abandon the second cognitive test. Pushing on with these results would give unusable results, students were not quiet which would influence their concentration and working memory for the cognitive test. Also, because of the class not being quiet it would have been impossible to give clear instructions to the group.

All other classes were participating. However, some students did not participate because of a multitude of reasons. First of all, some students were not present at school that day, that being late for the lessons, sick at home or to another appointment. Second of all, some students did not have a device with them to conduct the research online. Last of all, some students were only present at the morning or afternoon session, giving incomplete results. In total, around 20 percent of students faced these problems, although some were more class specific. Therefore, the originally planned 270 participants were not reached.

## 4.5 Research ethics

In this research informed consent was asked from the participants. To make sure that it was technically possible to link the morning and afternoon tests to the right person, the participants had to fill in their name. However, since their name is of no real importance in this research participants could, if they wanted to, fill in a different name, their initials or even a nickname as long as they did the same at the second cognitive test. The students were promised anonymity in the final research, so after the data collection was complete the names were taken out of the results which makes it impossible to relink them. One other reason to ask for a ‘name’ is to make it possible to reward three of the participants with a ten euro gift card.

When looking at the questions asked in the survey, a lot of questions might be very personal. Especially questions about socioeconomic status of parents and participants were seen as a bit intrusive. A lot of participants felt that these questions were not necessary to ask with this research and were vocal about the questions intrusiveness. At the beginning of every sessions, participants were told that if they did not want to answer a question, that they could leave the question blank. Some participants used this option, but most participants filled all the questions. One could agree that these questions are a bit intrusive. However, the question is all based on countable property which could be discussed in a normal day conversation. The question might be interpreted as 'rude', but as mentioned in the literature research, the measure is of utmost importance for measuring cognitive depletion.

Questions about amount of sleep, sleep interruptions and chronotype could also violate ethics. It asks about day experiences, which is a private matter. Participants did not raise concern about these questions, but were mostly curious about the link of these questions to academic performance. When time permitted, the reason for including these measures was explained to the participants.

Lastly, the data was stored on a protected server using the Qualtrics survey software. This means that the data is secure and encrypted. Names are only collected to link the morning and afternoon tests. Names are deleted immediately after linking the data, which results in an anonymous string of data. To add to this, students were promised at the beginning of the survey that their data would be used only for this research. Teachers, parents or other participants were not informed about any of the answers given.

# Chapter 5: Results

In this chapter, the results of the experiment will be discussed to answer the hypothesis and main research question. First, the results regarding the hypotheses are presented using simple models. After this, three more elaborate models are presented, one with dependent variable Score_mor, one with Score_aft and finally, the most important one, Score_dif. These elaborate models consists of all explanatory and all control variables that are present in this model.

## 5.1 Hypothesis 1: The longer a school day, the greater the drop in cognitive control

**Table 4 Regression of dependent variables and Duration_les_cent**

| | (1) Score_aft + controls | (2) Score_dif + controls |
|---|---|---|
| | b/t | b/t |
| Duration_les_cent | -0.0048 | 0.0027 |
| | (-1.60) | (0.62) |
| Afternoon | 0.11 | 0.17 |
| | (0.65) | (0.68) |
| First_test_version | -0.25 | -0.39 |
| | (-1.36) | (-1.50) |
| Constant | **1.73*** | 0.34 |
| | (11.77) | (1.62) |
| Observations | 199 | 199 |
| Adjusted $R^2$ | 0.015 | -0.002 |
| Log lik | -321.4 | -392.5 |
| | . | . |

**** p<.001, ** p<.01, * p<.05*

To know what the effect is of the duration of lessons on the dependent variable, we run two regressions (see table 4). Since the duration of lessons only affect the score in the afternoon, only the effect on Score_aft and Score_dif is taken into account. The variable used, Duration_les_cent, is centered around the mean. This implies that an extra minute of lessons is an extra minute away compared to the average minutes of lessons. To control for learning effects, control variables first_test_version and Afternoon are used.

Duration_les_cent shows a negative relation with Score_aft. This implies that the longer the school day than average, the more mistakes a participant will make in the afternoon test. The negative relation was expected. Longer than average school days were expected to negatively influence the scores achieved in the afternoon.

Duration_les_cent shows a positive relation with Score_dif. This implies that the longer the school day compared to the average, the more of a difference in score between the afternoon and morning session. In this case, a positive deviation from the average amount of lessons would lead to an increase in the relative test scores in the afternoon by 0.0012 compared to the morning score. This relation was unexpected. Longer than average school days were expected to decrease the gap between afternoon scores achieved and morning scores achieved. The same relation is found in the full model, shown in table 9.

## 5.2 Hypothesis 2: Belonging to a lower socioeconomic status has a negative effect on cognitive control throughout the day.

**Table 5 Regression of dependent variables and Soc_eco_class**

| | (1)<br>Score_mor<br>b/t | (2)<br>Score_aft<br>b/t | (3)<br>Score_dif<br>b/t |
|---|---|---|---|
| Soc_eco_class | -0.00067 | 0.053 | 0.053 |
| | (-0.01) | (0.93) | (0.66) |
| Constant | **1.55**$^{***}$ | **1.26**$^{**}$ | -0.17 |
| | (3.43) | (2.74) | (-0.25) |
| Observations | 199 | 199 | 199 |
| $R^2$ | 0.00 | 0.0043 | 0.0022 |
| Log lik | -319.6 | -323.9 | -393.6 |
| | . | . | . |

**** p<.001, ** p<.01, * p<.05*

Table 5 shows the regression of the dependent variables and Soc_eco_class. Looking purely at the effect of Soc_eco_class on the performance in this study, there seems to be little to no effect on the dependent variables. In this case thus indicating that socioeconomic status does not have a statistical impact on performance in both the morning and afternoon session. The same relation is found in the full models (table 7, 8 and 9). Also, there is no effect of socioeconomic status on the difference between the afternoon and morning results. Lastly, there is a difference in the expected direction of the variables. According to the hypothesis, a positive coefficient was expected. The results show this expected direction for the scored achieved in the afternoon and the difference in scores. However, the effect on morning scores achieved an unexpected negative relation.

## 5.3 Hypothesis 3: Belonging to a late chronotype has a positive effect on cognitive control throughout the day.

**Table 6 Regression of dependent variables and Chrono_score**

| | (1)<br>Score_mor<br>b/t | (2)<br>Score_aft<br>b/t | (3)<br>Score_dif<br>b/t |
|---|---|---|---|
| Chrono_score | -0.023 | -0.030 | 0.017 |
| | (-1.43) | (-1.85) | (0.71) |
| Constant | **2.12***** | **2.44***** | -0.16 |
| | (5.16) | (5.82) | (-0.27) |
| Observations | 199 | 199 | 199 |
| $R^2$ | 0.0103 | 0.0171 | 0.0026 |
| Log lik | -318.6 | -322.6 | -393.6 |
| | . | . | . |

**** p<.001, ** p<.01, * p<.05*

To answer hypothesis 3, again three regressions are made to find the effect of chronotype on the difference in scores achieved between the afternoon and morning (table 6). Regression (1) shows dependent variable Score_mor with independent variable Chrono_score. Regression (2) shows dependent variable Score_aft with independent variable Chrono_score. Regression (3) shows dependent variable Score_dif with independent variable Chrono_score. Looking at the distribution of Chrono_scores, it seems that out of the total 42 points most participants score around 25 points. In this case, it seems that most participants identify somewhere between an early and late chronotype. This would suggest that most participant are ‘afternoon’ chronotypes. However, one other relation can be noted. It seems that late chronotypes are more explicit in their opinion, since the lowest score has been reached multiple times. Early chronotypes seem to not be so explicit in their opinion, nobody reaching the maximum score of 42.

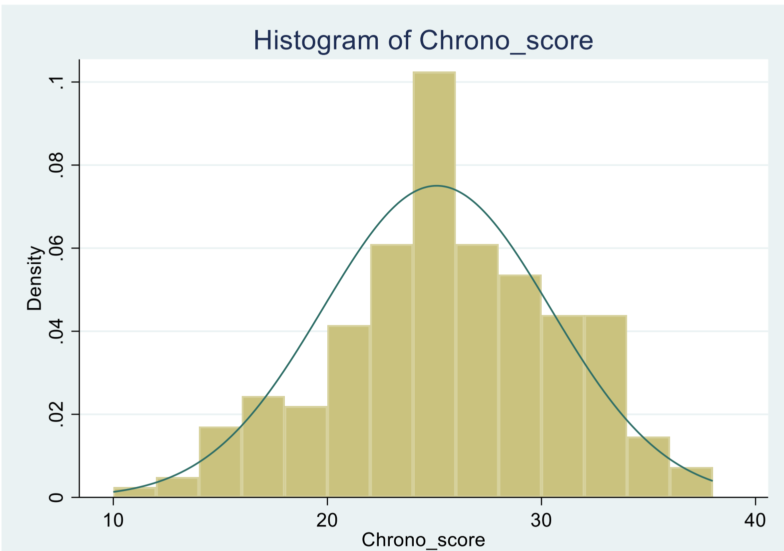



*Figure 8 Histogram of Chrono_score*

Based upon the interaction between just Chrono_score and the dependent variables,there seems to be no real effect. In this case, the expected relation between Chrono_score and the dependent variables would have been positive for the morning score and negative for the scores achieved in the afternoon and the difference in scores between the afternoon and morning. In this case, an unexpected relation between chrono_score and morning performance was found. Early chronotypes seem to perform worse in the morning compared to later chronotypes. The variable is not significant at the 5% level. There is an expected relation between the scores achieved Chrono_score and scores achieved in the afternoon. In this case a higher Chrono_Score (which would indicate being more of an early chronotype) would result in a lower score in the afternoon. Lastly, the relation between Chrono_score and the difference in scores achieved is unexpected. According to the results, early chronotypes perform relatively better than late chronotypes. The measure is statistically insignificant at the 5% level.  In the full models (tables 7, 8 and 9) the relation between chronotype and stays the same. In the full models with dependent variables Score_mor and Score_aft, the relation even becomes significant at the 5% level.

## 5.4 Regression Morning results

**<u>Table 7 OLS regression of morning scores.</u>**

| | (1)<br>Score_mor<br>expl var | (2)<br>Score_mor<br>expl var<br>Soc_perc | (3)<br>Score_mor<br>expl var<br>Soc_perc<br>Soc_eco_cl<br>ass | (4)<br>Score_mor<br>expl var<br>+ control | (5)<br>Score_mor<br>expl var<br>Soc_perc +<br>Soc_eco_cl<br>ass +<br>control |
|---|---|---|---|---|---|
| | b/t | b/t | b/t | b/t | b/t |
| Soc_eco_class | 0.0066 | | 0.013 | 0.029 | 0.038 |
| | (0.12) | | (0.22) | (0.53) | (0.65) |
| Chrono_score | -0.023 | -0.022 | -0.022 | **-0.038*** | **-0.037*** |
| | (-1.43) | (-1.36) | (-1.37) | (-2.08) | (-2.03) |
| Soc_perc | | -0.015 | -0.020 | | -0.028 |
| | | (-0.27) | (-0.33) | | (-0.46) |
| First_test_version | | | | -0.14 | -0.14 |
| | | | | (-0.56) | (-0.57) |
| Afternoon | | | | 0.15 | 0.15 |
| | | | | (0.64) | (0.66) |
| Female | | | | 0.13 | 0.14 |
| | | | | (0.82) | (0.82) |
| Academic level: | | | | | |
| VMBO-B | | | | 0.21 | 0.22 |
| | | | | (0.58) | (0.61) |
| VMBO-K | | | | -0.52 | -0.51 |
| | | | | (-1.33) | (-1.30) |
| VMBO-GT | | | | **-0.61*** | **-0.61*** |

| | | | | | |
|---|---|---|---|---|---|
| | | | | (-2.20) | (-2.20) |
| VMBO-T | | | | -0.45 | -0.44 |
| | | | | (-1.50) | (-1.46) |
| Non-Dutch | | | | -0.35 | -0.34 |
| | | | | (-1.22) | (-1.19) |
| Age | | | | **0.23*** | **0.23*** |
| | | | | (2.39) | (2.38) |
| Duration_sleep_cent | | | | **0.0027*** | **0.0028*** |
| | | | | (2.16) | (2.20) |
| Sleep_inter | | | | 0.14 | 0.14 |
| | | | | (1.72) | (1.62) |
| Duration_sleep_next_ morning_cent | | | | -0.0027 | -0.0027 |
| | | | | (-1.57) | (-1.60) |
| Sleep_inter_next_mor ning | | | | -0.094 | -0.095 |
| | | | | (-0.89) | (-0.90) |
| Constant | **2.07***** | **2.23***** | **2.16**** | -0.60 | -0.44 |
| | (3.58) | (3.83) | (3.33) | (-0.40) | (-0.29) |
| Observations | 199 | 199 | 199 | 199 | 199 |
| Adjusted $R^2$ | 0.000 | 0.001 | -0.004 | 0.068 | 0.064 |
| Log lik | -318.6 | -318.6 | -318.5 | -304.8 | -304.7 |

**** p<.001, ** p<.01, * p<.05*

Regression table 7 shows five regressions of the dependent variable Score_more. Score_mor refers to the total score that participants got when they performed one of the two cognitive tests in the morning. The regression is split between 5 different regressions, regression (1) regresses Score_mor with the explanatory variables Chrono_score, Soc_eco_class and Duration_les_cent. Regression (2) regresses Score_mor with the explanatory variables Chrono_score, Soc_perc and Duration_les_cent, this is done to see if ones Socioeconomic perception has a greater effect on the dependent variable than the more objective variable Soc_eco_class. Regression (3) includes all explanatory variables, which means Soc_eco_class Chrono_score and Soc_perc. Regression (4) includes all explanatory variables, with the exception of Socioeconomic perception, including all the control variables. Important to note is that not all control variables and explanatory variables are included. Regression (5) includes all explanatory and control variables, this time including Soc_eco_class and Soc_perc. Not all control and explanatory variables are present in these regression. This is due to the fact that in the morning session, participants have not had any lessons, breaks, or gym lessons yet. The beta-coefficients are displayed first, with their respective t-value in brackets.

First of all, just looking at the regressions, it is clear that when it comes to explaining the dependent variable the addition of control variables gives a higher adjusted R-squared variable. This indicates that regression (4) is best for interpreting and predicting the dependent variable. However, according to the log likelihood, regression 5 would be most suited. Since some correlation is expected between the variables Soc_eco_class and Soc_perc, regression (4) will mostly be used.

Soc_eco_class shows a positive relation with the score achieved in the morning, which was an expected result. The relation is not significant with the dependent variable, which was unexpected. The chronotype score shows a negative relation with the score achieved in the morning. This indicates that the more of an early chronotype you are, the less points you score in the morning test. This result is unexpected, early chronotypes were expected to perform relatively well in the morning. However, the measure is significant at the 5% level. Indicating an influential effect on the score achieved in the morning.

Three control variables show significance in regression (4). First, the academic level shows a significant difference from the performance of the participants following the HAVO academic level (the reference category). The relation is expected, even though the cognitive tests are not based on mathematical skills or literacy skills, intuitively one would expect higher academic levels to perform relatively better. Age also shows an expected relation, the older the participant the better he/she performs in the morning session. Lastly, Duration_sleep_cent shows the expected relation with the dependent variable. Longer than average sleep results in better performance. Importantly, control variables First_test_version and Afternoon together control for all groups of the 2x2 design.

## 5.5 Afternoon cognitive test results

**Table 8 OLS regression of scores achieved in the afternoon**

| | (1)<br>Score_aft<br>expl var | (2)<br>Score_aft<br>expl var<br>Soc_perc | (3)<br>Score_aft<br>expl var<br>Soc_perc<br>Soc_eco_c<br>lass | (4)<br>Score_aft<br>expl var +<br>control | (5)<br>Score_aft<br>expl var<br>+<br>Soc_eco_<br>class +<br>Soc_perc |
|---|---|---|---|---|---|
| | b/t | b/t | b/t | b/t | b/t |
| Soc_eco_class | 0.079 | | 0.090 | 0.089 | 0.096 |
| | (1.38) | | (1.49) | (1.57) | (1.59) |
| Chrono_score | -0.031 | -0.029 | -0.029 | **-0.043*** | **-0.043*** |
| | (-1.89) | (-1.74) | (-1.79) | (-2.38) | (-2.34) |
| Duration_les_cent | **-0.0060*** | -0.0055 | **-0.0061*** | 0.00044 | 0.00044 |
| | (-2.06) | (-1.88) | (-2.08) | (0.12) | (0.12) |
| Soc_perc | | -0.0030 | -0.033 | | -0.021 |
| | | (-0.05) | (-0.55) | | (-0.34) |
| First_test_version | | | | -0.24 | -0.23 |
| | | | | (-0.70) | (-0.68) |
| Afternoon | | | | 0.12 | 0.13 |
| | | | | (0.53) | (0.55) |
| Female | | | | 0.25 | 0.25 |
| | | | | (1.52) | (1.52) |

| | | | | | |
|---|---|---|---|---|---|
| Academic level: | | | | | |
| VMBO-B | | | | -0.76 | -0.76 |
| | | | | (-1.87) | (-1.86) |
| VMBO-K | | | | -0.57 | -0.57 |
| | | | | (-1.30) | (-1.30) |
| VMBO-GT | | | | -0.23 | -0.23 |
| | | | | (-0.79) | (-0.79) |
| VMBO-T | | | | **-0.66**$^{*}$ | **-0.66**$^{*}$ |
| | | | | (-2.17) | (-2.14) |
| Non-Dutch | | | | 0.41 | 0.41 |
| | | | | (1.41) | (1.42) |
| Age | | | | -0.090 | -0.089 |
| | | | | (-0.86) | (-0.85) |
| Duration_break_cent | | | | **-0.024**$^{*}$ | **-0.024**$^{*}$ |
| | | | | (-2.43) | (-2.45) |
| Duration_PE_les | | | | 0.0053 | 0.0052 |
| | | | | (1.19) | (1.16) |
| Duration_sleep_cent | | | | 0.0012 | 0.0012 |
| | | | | (1.01) | (1.03) |
| Sleep_inter | | | | **0.18**$^{*}$ | 0.17$^{*}$ |
| | | | | (2.43) | (2.31) |
| Constant | **1.83**$^{**}$ | **2.42**$^{***}$ | **1.99**$^{**}$ | **3.29**$^{*}$ | **3.38**$^{*}$ |
| | (3.11) | (4.10) | (3.02) | (2.00) | (2.02) |
| Observations | 199 | 199 | 199 | 199 | 199 |
| Adjusted $R^2$ | 0.029 | 0.020 | 0.026 | 0.096 | 0.091 |
| Log lik | -319.9 | -320.8 | -319.7 | -306.0 | -305.9 |

**** p<.001, ** p<.01, * p<.05*

Regression table 8 shows the regressions of the dependent variable Score_aft. This variable shows the score the participant got in the cognitive test that they achieved in the afternoon session. This could be the first or the second time that they made the cognitive test, all dependent on which group they belong to. The regressions are in the same order as the regression for the morning score. Regression (1) has all the explanatory variables, excluding Soc_perc. Regression (2) has all the explanatory variables, excluding Soc_eco_class. Regression (3) has all the explanatory variables. Regression (4) has all the explanatory variables, excluding Soc_perc. Also, all control variables are added. Regression (5) has all the explanatory variables including all the relevant control variables. This time, Duration_Sleep_next_morning_cent and Sleep_inter_next morning are excluded, since these variables should not affect the dependent variable based on the way the research was designed and conducted. Lastly, the control variables Duration_break_cent and Duration_PE_les are added, since they should affect the test scores in the afternoon.

Out of the three variables related to the hypothesis. Only the relation of scores achieved in the afternoon and Chrono_score is significant. The negative relation between Chrono_score and Score_aft was expected. Early chronotypes are performing relatively worse in the afternoon test compared to participants that identify as late chronotypes. As for soc_eco_class the result is insignificant, but the relation towards the dependent variable is expected. Belonging to a higher socioeconomic status increases the test scores achieved in the afternoon. Lastly, Duration_les_cent shift its relation with the dependent variable when control variables are added to the model. Based upon the model with control variables (regression (4)) there is a positive relation towards the dependent variable. This is an unexpected result. Looking at models without the control variables (regressions (1), (2) and (3)), there is a negative relation with the dependent variable which is what was expected.

Three control variables are significant at the 5% level, academic level VMBO-T, Duration_break_cent and Sleep_inter. VMBO-T shows the expected relation with the dependent variable. In comparison to academic level HAVO, participants of academic level VMBO-T perform relatively worse on the test. Duration_break_cent has a negative impact on the test scores achieved in the afternoon, which is an unexpected result. Longer than average breaks should lead to higher scores achieved in the afternoon. Sleep_inter is positively related to the scores achieved in the afternoon. This result was expected, more sleep interruptions would indicate worse morning results, but the afternoon results should be relatively better.

## 5.6 Difference between afternoon and morning cognitive test scores

**Table 9 Regressions of Score_dif, explanatory and control variables**

| | (1) Score_dif expl var | (2) Score_dif expl var Soc_perc | (3) Score_dif expl var Soc_perc Soc_eco_class | (4) Score_dif expl var Soc_eco_class + Control | (5) Score_dif expl var Soc_eco_class + Soc_perc + control |
|---|---|---|---|---|---|
| | b/t | b/t | b/t | b/t | b/t |
| Soc_eco_class | 0.046 | | 0.054 | 0.036 | 0.036 |
| | (0.56) | | (0.61) | (0.44) | (0.41) |
| Chrono_score | 0.015 | 0.017 | 0.016 | 0.0079 | 0.0079 |
| | (0.65) | (0.70) | (0.68) | (0.30) | (0.30) |
| Duration_les_cent | 0.00078 | 0.0011 | 0.00074 | 0.0093 | 0.0093 |
| | (0.18) | (0.26) | (0.17) | (1.80) | (1.79) |
| Soc_perc | | -0.0041 | -0.022 | | -0.00085 |
| | | (-0.05) | (-0.25) | | (-0.01) |
| First_test_version | | | | -0.54 | -0.54 |
| | | | | (-1.11) | (-1.10) |
| Afternoon | | | | 0.070 | 0.070 |
| | | | | (0.21) | (0.21) |
| Female | | | | -0.044 | -0.044 |
| | | | | (-0.18) | (-0.18) |
| Academic level: | | | | | |
| VMBO-B | | | | **-1.36*** | **-1.36*** |

| | | | | | |
|---|---|---|---|---|---|
| | | | | (-2.32) | (-2.32) |
| VMBO-K | | | | -0.30 | -0.30 |
| | | | | (-0.48) | (-0.48) |
| VMBO-GT | | | | -0.31 | -0.31 |
| | | | | (-0.75) | (-0.75) |
| VMBO-T | | | | -0.73 | -0.73 |
| | | | | (-1.63) | (-1.62) |
| Non-Dutch | | | | **0.94*** | **0.94*** |
| | | | | (2.26) | (2.25) |
| Age | | | | **-0.31*** | **-0.31*** |
| | | | | (-2.08) | (-2.07) |
| Duration_break_cent | | | | -0.025 | -0.025 |
| | | | | (-1.82) | (-1.80) |
| Duration_PE_les | | | | 0.0025 | 0.0025 |
| | | | | (0.39) | (0.38) |
| Duration_sleep_cent | | | | -0.0020 | -0.0020 |
| | | | | (-1.10) | (-1.09) |
| Sleep_inter | | | | 0.014 | 0.014 |
| | | | | (0.12) | (0.11) |
| Duration_sleep_next_ morning_cent | | | | **0.0062*** | **0.0062*** |
| | | | | (2.49) | (2.47) |
| Sleep_inter_next_morn ing | | | | 0.12 | 0.12 |
| | | | | (0.80) | (0.80) |
| Constant | -0.49 | -0.12 | -0.39 | 4.49 | 4.49 |
| | (-0.58) | (-0.15) | (-0.41) | (1.89) | (1.86) |
| Observations | 199 | 199 | 199 | 199 | 199 |
| Adjusted $R^2$ | -0.011 | -0.012 | -0.016 | 0.072 | 0.067 |
| Log lik | -393.4 | -393.5 | -393.3 | -376.9 | -376.9 |

**** p<.001, ** p<.01, * p<.05*

Regression table 9 shows the dependent variable, Score_dif, and differing amounts of explanatory and control variables. Score_dif refers to the amount of difference between the scores in the afternoon and the morning. The higher the variable, the higher the score participants got in the afternoon compared to the morning. The table is divided in 5 separate regressions. Regression (1) consists of the three explanatory variables, Soc_eco_class, Chrono_score and Duration_les_cent. Regression (2) consists of explanatory variables, Soc_perc, Chrono_score and Duration_les_cent. Regression (3) consists of all the explanatory variables, Soc_eco_class, Chrono_score, Duration_les_cent and Soc_perc. Regression (4) consists of the explanatory variables, Soc_eco_class, Chrono_score and Duration_les _cent plus all control variables. Regression (5) consists of explanatory variables, Soc_eco_class, Chrono_score, Duration_les_cent and Soc_perc plus all control variables. Regression (1), (2) and (3) are shown to view the relation of the explanatory variables towards the dependent variables without any control variables interfering. Regressions (4) and (5) show the 'real' effect of the explanatory variables when the control variables are added.

Looking at the explanatory variables it seems that in all regressions there is a positive relation between the main variables (Chrono_score, Duration_les_cent and Soc_eco_class). Looking at the expected relationships, it seems that Soc_eco_class shows an expected result, higher socioeconomic class results in higher afternoon scores compared to the morning scores. Chrono_score shows an unexpected result, higher Chrono_score (which indicates belonging to an early chronotype) increases scores achieved in the afternoon compared to the morning. Duration_les_cent also shows an unexpected result, longer than average school days result in better performance in the afternoon compared to the morning.

Four control variables are significant at the 5% level. First, the effect of the academic level VMBO-B compared to the reference category HAVO. Again, having an expected effect on the dependent variable. This indicates that participants belonging to academic level VMBO-B perform worse compared to participants following academic level HAVO. Being of non-Dutch decent has a positive relation with the dependent variable, which is an unexpected result. Being of non-Dutch decent increase the difference between scores achieved in the afternoon and morning. Age shows a negative relation with the dependent variable. This, again, is an unexpected result. According to the results, being older causes the scores in the afternoon to drop relative to the scores achieved in the morning. Expected was that the relation between Score_dif and age was positive, just like the effect found in table 9. Lastly, Duration_sleep_next_morning has a significant effect on the dependent variable. Sleeping longer than average the second morning results in a bigger difference between the score achieved in the afternoon versus the score achieved in the morning. This is an unexpected result. Longer than average sleep was expected to positively influence the morning scores achieved, while the afternoon would relatively suffer. Finally, the constant is a positive value. Which indicates that if all other variables are zero, the difference between the afternoon and morning scores gets bigger.

# Chapter 6: Discussion and conclusion

## 6.1 Hypothesis and main research question

On to the conclusion of the hypotheses and research question. First starting with the hypotheses which will aid in answering the research question.

**Hypothesis 1:** The longer a school day, the greater the drop in cognitive control.

Based on the results, it is hard to determine what the real relation of longer school days on cognitive control is. Looking at the results for the score achieved in the afternoon, longer than average school days should decrease the scores achieved in the afternoon. However, looking at the difference between afternoon and morning scores longer than average lessons result in a relatively better score. Therefore, making a conclusive verdict is impossible. On this bases, the hypothesis cannot be rejected nor accepted.

Even though the results for more than average minutes of lessons in a day are not significant, it seems that longer than average school days have a positive effect on cognitive control. Participants would perform better when their school day is longer than the average 180.6 minutes. Looking at past research, it seems that the relation found in this research is both coherent and incoherent with previous findings. Longer school days affect the average score achieved in the afternoon negatively, but the difference between the afternoon and morning scores is affected positively. Sievertsen et al. (2016) shows that longer school day should result in lower academic performance in the afternoon, which would be incoherent with the results in this research. According to van der Vinne et al. (2015), the average amount of academic performance does not differ a lot throughout the school day. Which might be coherent with the findings of this research. Since no statistical significant relation is found, this could imply that there are no major differences between performance in the morning and afternoon. However, from the perspective of cognitive depletion, longer school days should result in more cognitive depletion. Even if the measure was significant, the relation would be reversed compared to what was expected. This suggests that duration of lessons might not have an influence on cognitive depletion as tested in this research.

The better explanation for the counterintuitive result would be the limitations of this research to test the participants. Participant only had a lessons of 30 minutes compared to the normal 45 minutes. Therefore, participants were tested around 08:30 am and most of the time around 12:00 am. This is not a normal school day, but because of the COVID-19 pandemic this was the 'normal' school day for the participants. This might give problems with determining the cognitive depletion across the school day, since it might be possible that there are no significant differences in cognitive depletion around 12:00 am for participants.

**Hypothesis 2:** Belonging to a lower socioeconomic status has a negative effect on cognitive control throughout the day.

Interestingly, socioeconomic status seems to have a positive effect on cognitive control. In this case indicating that participants from a higher socioeconomic status performed better in the afternoon sessions compared to the morning sessions. This thus indicates that participants belonging to a lower socioeconomic status would suffer relatively more cognitive depletion compared to participants belonging to a higher socioeconomic status. This supports research like Mani et al. (2013), Suleman et al. (2014), S.E. Johnson et al. (2011), Carvalho et al. (2016) and Vohs (2013) showed that socioeconomic class could have an effect on performance. These measures all show that lower socioeconomic status should result in more cognitive depletion throughout the day. It therefore seems that higher socioeconomic status leads to a bigger difference in score between the afternoon and morning session. Thus indicating that cognitive depletion is relatively less present in individuals that have a higher socioeconomic status.

To give another perspective on this hypothesis, a participants socioeconomic perception was also used. This measure of socioeconomic perception has a negative coefficient. This thus indicates that socioeconomic perception has a negative effect on the dependent variable. In this case one could say that the higher someone perceives their own socioeconomic status, the worse they do in the afternoon session relative to the morning session. This would contradict the previous research since self-signaling has been found to influence cognitive control (Inzlicht et al., 2006). Therefore, looking at both the significance of this measure and previous research, it would be better and more accurate to look at the more objective measure socioeconomic class.

Using these measures, it seems that the hypothesis could be accepted based upon the more objective measure of socioeconomic status. However, fully accepting this hypothesis would be unjustified, since the measure only has a small effect and is statistically insignificant. Therefore, the conclusion with regard to this hypothesis could be that it is inconclusive. The reasoning behind this result can be found in previous research. Higher socioeconomic status helps with keeping the working memory of the brain clear. This results in a better ability to think, concentrate and perform when it matters. Having more capacity left means that performance would be relatively better in the afternoon compared to others that do not have this free space in their working memory.

**Hypothesis 3:** Belonging to a late chronotype has a positive effect on cognitive control throughout the day.

Based on the data acquired, this hypothesis can be rejected. Being more of an early chronotype has a negative effect on the scores achieved in the morning test. The same is effect is also found in the scores achieved in the afternoon. Interestingly, this is counterintuitive to the results found by van der Vinne et al. (2015). They show that belonging to an early chronotype should increase performance in the morning relative to late chronotypes. Based on the negative relation between Chrono_Score and Score_mor, this is incoherent with previous literature. However, the negative relation with Chrono_score and Score_aft is somewhat coherent with the research of van der Vinne et al. (2015). Early chronotypes should lose their advantage and perform relatively worse on these cognitive test.

The real problem with the results shows when looking at the relation between chronotype and difference in score between the afternoon and morning. According to the results, belonging to an early chronotype has a positive effect in the difference of scores achieved made between the afternoon and morning session(see table 11, regression 4). This, again, is incoherent with prior research, whereby late chronotypes should catch up relatively more in the afternoon compared to the early chronotypes. In this case, it seems that this effect is not present. An explanation for this could be that due to the shorter school day, late chronotypes do not have the ability to catch up just yet. Early chronotypes could therefore still perform relatively well in the afternoon session, since their amounts of cognitive control has not depleted enough to make a significant difference. The afternoon test was taken at the 'sweet spot' where the difference between early and late chronotype performance could be negligible, at least in the findings of Van der Vinne et al. (2015). Also, there might be reversed reasoning in the sense that late chronotypes have to start their day early, while early chronotypes start their day normally. This could also influence the main result, early chronotypes do not recover in the afternoon because they started too early for their circadian clock. Lastly, it seems that most participants identify somewhere between an early and late chronotype. This could therefore also explain the results, these 'middle' chronotypes could potentially perform well all around the day. However, just by looking at the average score achieved in the morning session (1.543) and the average scored achieved in the afternoon (1.678) this would be questionable. Therefore, it seems that the answer, based on the data available, would be to reject the hypothesis. Belonging to a late chronotype does not seem to have a positive effect on cognitive control throughout the day.

**Main research question:** What are the impacts of cognitive depletion among adolescents in the Netherlands?

According to the three hypothesis the main determinants of cognitive depletion were expected to length of the school day, socioeconomic status and chronotype. However the three hypothesis do not give any conclusive evidence for answering the research question. Therefore, it is necessary to look at other variables that have an effect on the difference in score achieved between the afternoon and the morning.

Looking at previous research, variables like socioeconomic class, chronotype, duration of the school day, duration of sleep, duration of breaks, duration of PE lessons and quality of sleep should all influence academic performance. Longer school day should result in higher amounts of cognitive depletion. The results show that longer than average school days have a positive effect on cognitive control, which is counterintuitive to previous research by van der Vinne (2015) and Sievertsen (2016). Higher socioeconomic status should cause less cognitive depletion throughout the day. Results have shown that this is the case, even though this measure is statistically insignificant. Even if the insignificance of this variable is ignored, the main effect is relatively small. Researchers like Mani et al. (2013), Suleman et al.(2014) and Carvalho et al. (2016) all find a more significant effect of cognitive depletion with respect to socioeconomic status. Therefore, taking this variable as a real predictor of cognitive depletion seems ungrounded. Belonging to an early chronotype should result in relatively better academic performance in the morning compared to the afternoon (van der Vinne et al., 2015). In this case, results show that belonging or identifying as an early chronotype has a negative effect on the test scores achieved in the morning. Which is counterintuitive. The same negative relation is found in the achieved afternoon scores. However, this could be explained as in line with prior research. In this case, the negative relation between chronotype and the score in the afternoon seems to be bigger compared to chronotype and the score achieved in the morning. Looking purely at the difference between the scores in the afternoon and the morning, there is a positive relation. This indicates that, early chronotypes perform relatively better in the afternoon test compared to the morning test. This result, again, is counterintuitive with prior research. Early chronotypes should perform relatively worse later in the day, late chronotypes should catch up after they have 'woken up' in the afternoon. According to this measure, it seems that early chronotypes would perform relatively better in the afternoon than in the morning. Therefore, higher chronotype scores should lead to an increase in cognitive control.

Duration of sleep has also been shown to affect performance. Shorter nights should influence academic performance (Meijer et al., 2000; van der Vinne et al., 2015) and therefore also cognitive depletion . Results show an incoherent relation with the dependent variable. In the main model, duration of sleep on the first day and duration of sleep on the second day show an opposite relation. Duration of sleep on the first day having a negative impact on the difference in afternoon and morning scores while duration of sleep on the second day positively influences this measure and shows statistical significance at the 5% level. This result is counterintuitive, both should show a lower amount of academic performance when comparing afternoon and morning results. Longer than average duration of sleep should positively influence the morning test while the effects fade when participating in the afternoon cognitive test. In this case, one could argue that the duration of sleep on the second day only affects the morning test, which could cause some overrepresentation of the scores achieved in the morning. However, even if that is the case, the expected relation should have been negative. Longer than average sleep should result in worse academic performance throughout the day. The results show incoherent and inconclusive evidence in that case. Even just looking at the performance in the morning and afternoon separately does not give any conclusive support for sleep influencing academic performance. This is incoherent with previous research regarding sleep and its effect in the education system, In this case, it seems that the effect of sleep on cognitive depletion is unclear. Not having a significant effect on the scores achieved in the morning or afternoon and finding an incoherent result in the difference between the afternoon and morning scores achieved.

Duration of breaks and PE lessons do not seem to have statistically influenced cognitive depletion. Breaks should, according to previous research, lead to a higher amount of academic performance (less cognitive depletion) (Howie et al., 2015; Sievertsen et al., 2016). This would mean that the relation between breaks and the difference in score achieved in the afternoon and morning should be positive. Longer amounts of breaks should lead to a positive effect on the dependent variable. In this case, in the full model longer than average breaks result in a lower score achieved, which is incoherent with previous research. This could be explained by the fact that having longer breaks also means that a participant has a longer school day (since breaks are fixed). Therefore, this measure might indicate a negative relation between longer school days and the difference between the afternoon and morning scores. Thus, possibly showing an argument for the fact that longer school days cause cognitive depletion. However, this explanation is not verifiable, thus an incoherent result must be assumed. PE lessons should have a positive effect on the difference between the afternoon and morning scores (Davranche et al., 2009). This positive relation is found, however also statistically insignificant. The explanation for this insignificant effect is hard to find, physical exercise has been shown to positively influence cognitive control. Finding an insignificant relation in that sense is unexplainable.

Sleep interruptions do not show a significant relation with the difference in score achieves in the afternoon and morning. A positive impact on this difference was expected and also found. Even though statistical significance is absent, it seems that more sleep interruptions positively affect the scores achieved in the afternoon compared to the morning. Which was also what was found and expected based on previous research (Meijer et al., 2000; van der Vinne et al., 2015).

Lastly, it seems that more basic control variables, like academic level and age, cause the most significant change in the difference between afternoon and morning scores. These measures were not explicitly researched in the literature research. However, what can be concluded from these measures is that lower academic level face more cognitive depletion throughout the day compared to the higher academic level ''HAVO''. Also, the older one gets, the more cognitive depletion is present throughout the day. The reasoning behind is could be that lower academic levels fail to keep motivated throughout the day, which is one of the major determinants of cognitive depletion. With respects to age, the relation seems more unclear.

To conclude, the general theme seems to be that on average participant perform better in the afternoon session than in the morning session. Looking at the mean of the dependent variable (0.256), participants perform relatively better in the afternoon than in de morning. This gives evidence to believe that adolescents should be tested later in the day. Even though the research was initiated under the assumption that cognitive depletion would be a significant factor in academic performance throughout the school day, it seems that the school day improves cognitive control. However, it has to be noted the data collection might not find the right relation. The data collection shows that there might be a sweet spot around 12:00 AM to 1:00 PM. Therefore, academic performance could be increased if tests and other forms of grading are done around these times. This would not only increase average academic performance, but in turn also help with human capital accumulation. The effects might not be large, but every little bit could help in the improvement of academic performance.

## 6.2 Limitations of this research

Statistical significance is one of the big limitations in this research. Statistical significance is not reached for lots of the variables used in the hypothesis testing. The reason for the lack of statistical significance can be of differing natures. The amount of participants was lower than originally planned. Even though this estimate was already based on lower amounts of significance (namely a 90% confidence interval) only 199 of the originally planned 270 were able to participate. Also, all participants went to the same school and live in a similar rural area, creating the possibility for selection bias. Participants were tested during their normal school day, therefore the normal difficulties involving a school day are present. This is good for some external validity, but comes at the costs of internal validity. External effect might have had too much of an influence on the results.

Second of all, the amount of cognitive test exercises were limited. Every participant made 20 cognitive questions in total (10 in the morning, 10 in the afternoon). With these relatively few questions, the full effect of cognitive depletion might not have been portraited. Therefore, to improve a similar research one should look at scaling up the amount of cognitive questions. Even though research suggested that 9 figures of ravens progressive matrixes were enough to establish a similar result as the full test (Bilker et al., 2012), there could be dissimilarities with the lower number of participants. Increasing the amount of cognitive questions asked might improve results and establish clearer trends.

Third of all, a limitation of this research was the amount of participants per academic level. Not all academic levels of the secondary education system in the Netherlands were present. The highest academic level, VWO, is not present at ‘’het Grescollege’’ and even the amount of ‘’HAVO’’ students are not large. Therefore, repeating this research on a multitude of schools whereby all academic levels are present should increase the validity.

Fourth and finally, there is an outside effect of the COVID-19 pandemic on the participants tested at this very moment. Participants followed lectures online for multiple months, and still now some lectures are only given online. Looking at the average effect of the COVID-19 pandemic there seems to be a dissimilarity in the way that COVID-19 has affected some adolescents. Therefore, the timing of this research might not have been perfect to legitimize a research of cognitive control throughout the school day.

## 6.3 Recommendations for further research

As already mentioned in the limitations part of this research, there are a couple of noteworthy recommendations for future research. First of all, research could continue using the same frameworks as mentioned in this paper. The first improvements could be in the form of more participants, more cognitive tests and even a controlled experiment environment to increase (internal) validity of the results and increase statistical significance. Conventional Raven’s progressive matrixes consist of around 60 questions (Bilker et al., 2012), which could give more accurate results. Also, a variation whereby the explanatory variables are tested one by one would be interesting since the effects of some of these variables with respect to cognitive depletion seem unclear. For instance, a bigger research purely regarding socioeconomic status and cognitive depletion could result in interesting results for the education system.

Second of all, research about the effect of COVID-19 pandemic on cognitive depletion could be a useful and interesting topic regarding the future of human capital. A lot of schools in the Netherlands were closed for longer amounts of times and the effects of this pandemic on future human capital are not entirely clear as of yet.

Third and finally, a qualitative research about student motivation might prove useful. Student motivation might be an important measure in performance and therefore also human capital accumulation. Not only student preference about their school day could be interesting, but also questions about the effect of the COVID-19 pandemic. Questions about the importance of social interactions with peers might be valuable in the importance of full school days. Not only can increased performance be an outcome of this research, but also an increase in social performance could be a valuable lessons from this research. Students view about cognitive depletion throughout the school day could also prove valuable for secondary education institutions.

# Bibliography

A longer school day will ready pupils for work—Labour. (2012, January 5). *BBC News*. https://www.bbc.com/news/education-16427941

Alexander, P. A., Winne, P. H., Winne, Anderman, E., & Corno, L. (2006). *Handbook of Educational Psychology*. Psychology Press.

Alma, Ö. G. (2011). Comparison of Robust Regression Methods in Linear Regression. *Int. J. Contemp. Math. Sciences*, *9*(6), 13.

Altiner, A., & Toktas, Y. (2017). Relationship Between Human Capital And Economic Growth: An Application To Developing Countries. *Eurasian Journal of Economics and Finance*, *5*(3), 87–98.

Aron, A. R. (2007). The Neural Basis of Inhibition in Cognitive Control. *The Neuroscientist*, *13*(3), 214–228. https://doi.org/10.1177/1073858407299288

Balota, D. A., & Marsh, E. (2004). *Cognitive Psychology: Key Readings*. Psychology Press.

Banerjee, A. V., & Duflo, E. (2007). The Economic Lives of the Poor. *Journal of Economic Perspectives*, *21*(1), 141–168. https://doi.org/10.1257/jep.21.1.141

Baumeister, R. F., & Vohs, K. D. (2007). Self-Regulation, Ego Depletion, and Motivation. *Social and Personality Psychology Compass*, *1*(1), 115–128. https://doi.org/10.1111/j.1751-9004.2007.00001.x

Been, V., Ellen, I., Figlio, D. N., Nelson, A., Ross, S., Schwartz, A. E., & Stiefel, L. (2021). *The Effects of Negative Equity on Children's Educational Outcomes* (No. w28428). National Bureau of Economic Research. https://doi.org/10.3386/w28428

Bellei, C. (2009). Does lengthening the school day increase students' academic achievement? Results from a natural experiment in Chile. *Economics of Education Review*, *28*(5), 629–640. https://doi.org/10.1016/j.econedurev.2009.01.008

Bilker, W. B., Hansen, J. A., Brensinger, C. M., Richard, J., Gur, R. E., & Gur, R. C. (2012). Development of Abbreviated Nine-Item Forms of the Raven's Standard Progressive Matrices Test. *Assessment*, *19*(3), 354–369. https://doi.org/10.1177/1073191112446655

Bratko, D., Chamorro-Premuzic, T., & Saks, Z. (2006). Personality and school performance: Incremental validity of self- and peer-ratings over intelligence. *Personality and Individual Differences*, *41*(1), 131–142. https://doi.org/10.1016/j.paid.2005.12.015

Buturovic, Z., & Tasic, S. (2015). Kahneman's Failed Revolution Against Economic Orthodoxy. *Critical Review*, *27*(2), 127–145. https://doi.org/10.1080/08913811.2015.1068512

Carskadon, M. A., Vieira, C., & Acebo, C. (1993). Association between Puberty and Delayed Phase Preference. *Sleep*, *16*(3), 258–262. https://doi.org/10.1093/sleep/16.3.258

Carvalho, L. S., Meier, S., & Wang, S. W. (2016). Poverty and Economic Decision-Making: Evidence from Changes in Financial Resources at Payday. *The American Economic Review*, *106*(2), 260–284. https://doi.org/10.1257/aer.20140481

Centraal Bureau voor de Statistiek. (n.d.). *Sociaaleconomische positie*. Centraal Bureau voor de Statistiek. Retrieved May 6, 2021, from https://www.cbs.nl/nl-nl/achtergrond/2018/47/sociaaleconomische-positie

Cohen, J. D. (2017). *Chapter 1: Cognitive Control Core Constructs and Current Considerations. In: The Wiley Handbook of Cognitive Control, edited by Tobias Egner, John Wiley & Sons, Incorporated* (T. Egner, Ed.; 1st ed.). Wiley.

Cohen, S., & Wills, T. A. (1985). Stress, Social Support, and the Buffering Hypothesis. *Psychological Bulletin*, *98*(2), 48. https://doi.org/10.1037/0033-2909.98.2.310

Cohen-Shikora, E. R., Diede, N. T., & Bugg, J. M. (2018). The flexibility of cognitive control: Age equivalence with experience guiding the way. *Psychology and Aging*, *33*(6), 924–939. https://doi.org/10.1037/pag0000280

Cooper, R. P. (2010). Cognitive Control: Componential or Emergent?: Topics in Cognitive Science(2010). *Topics in Cognitive Science*, *2*(4), 598–613. https://doi.org/10.1111/j.1756-8765.2010.01110.x

Currie, C., Molcho, M., Boyce, W., Holstein, B., Torsheim, T., & Richter, M. (2008). Researching health inequalities in adolescents: The development of the Health Behaviour in School-Aged Children (HBSC) Family Affluence Scale. *Social Science*, 8.

Davranche, K., Hall, B., & McMorris, T. (2009). Effect of Acute Exercise on Cognitive Control Required during an Eriksen Flanker Task. *Journal of Sport and Exercise Psychology*, *31*(5), 628–639. https://doi.org/10.1123/jsep.31.5.628

Demirtas, H. (2004). Modeling Incomplete Longitudinal Data. *Journal of Modern Applied Statistical Methods*, *3*. https://doi.org/10.22237/jmasm/1099267500

Duckworth, A. L., & Seligman, M. E. P. (2006). Self-Discipline Gives Girls the Edge: Gender in Self-Discipline, Grades, and Achievement Test Scores. *Journal of Educational Psychology*, *98*(1), 198–208.

*Education Rankings by Country 2021*. (n.d.). Retrieved March 25, 2021, from https://worldpopulationreview.com/country-rankings/education-rankings-by-country

Engle, R. W., & Kane, M. J. (2004). Executive Attention, Working Memory Capacity, and a Two-Factor Theory of Cognitive Control. In *The psychology of learning and motivation: Advances in research and theory, Vol. 44* (pp. 145–199). Elsevier Science.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*(1), 143–149. https://doi.org/10.3758/BF03203267

Evans, J. St. B. T., & Stanovich, K. E. (2013). Dual-Process Theories of Higher Cognition: Advancing the Debate. *Perspectives on Psychological Science*, *8*(3), 223–241. https://doi.org/10.1177/1745691612460685

Figlio, D. N., Freese, J., Karbownik, K., & Roth, J. (2017). Socioeconomic status and genetic influences on cognitive development. *Proceedings of the National Academy of Sciences*, *114*(51), 13441–13446. https://doi.org/10.1073/pnas.1708491114

Goldin, A. P., Sigman, M., Braier, G., Golombek, D. A., & Leone, M. J. (2020). Interplay of chronotype and school timing predicts school performance. *Nature Human Behaviour*, *4*(4), 387–396. https://doi.org/10.1038/s41562-020-0820-2

Grayot, J. D. (2020). Dual Process Theories in Behavioral Economics and Neuroeconomics: A Critical Review. *Review of Philosophy and Psychology*, *11*(1), 105–136. https://doi.org/10.1007/s13164-019-00446-9

Gunnar, M. R. (2017). Social Buffering of Stress in Development: A Career Perspective. *Perspectives on Psychological Science*, *12*(3), 355–373. https://doi.org/10.1177/1745691616680612

Gupta, N. D., Poulsen, A., & Villeval, M. C. (2013). Gender Matching and Competitiveness: Experimental Evidence. *Economic Inquiry*, *51*(1), 816–835. https://doi.org/10.1111/j.1465-7295.2011.00378.x

Haushofer, J., & Fehr, E. (2014). On the psychology of poverty. *Science*, *344*(6186), 862–867. https://doi.org/10.1126/science.1232491

Hawes, Z., LeFevre, J.-A., Xu, C., & Bruce, C. D. (2015). Mental Rotation With Tangible Three-Dimensional Objects: A New Measure Sensitive to Developmental Differences in 4- to 8-Year-Old Children: 3D Mental Rotation in Young Children. *Mind, Brain, and Education*, *9*(1), 10–18. https://doi.org/10.1111/mbe.12051

Healey, M. K., Hasher, L., & Danilova, E. (2011). The stability of working memory: Do previous tasks influence complex span? *Journal of Experimental Psychology: General*, *140*(4), 573–585. https://doi.org/10.1037/a0024587

Hennessy, M. B., Kaiser, S., & Sachser, N. (2009). Social buffering of the stress response: Diversity, mechanisms, and functions. *Frontiers in Neuroendocrinology*, *30*(4), 470–482. https://doi.org/10.1016/j.yfrne.2009.06.001

Hodas, N. O., Hunter, J., Young, S. J., & Lerman, K. (2018). Model of cognitive dynamics predicts performance on standardized tests. *Journal of Computational Social Science*, *1*(2), 295–312.

Holmqvist, B., & Krantz, J. H. (2009). *Division of Engineering Psychology, Department of Human Work Sciences, Luleå University of Technology, 97187 Luleå, Sweden*. 6.

Howie, E. K., Schatz, J., & Pate, R. R. (2015). Acute Effects of Classroom Exercise Breaks on Executive Function and Math Performance: A Dose–Response Study. *Research Quarterly for Exercise and Sport*, *86*(3), 217–224. https://doi.org/10.1080/02701367.2015.1039892

*Instruction time in compulsory education*. (n.d.). Retrieved March 25, 2021, from https://stats.oecd.org/Index.aspx?DataSetCode=EAG_IT_ALL

*International Cognitive Ability Resource—The ICAR Project*. (n.d.). Retrieved May 6, 2021, from https://icar-project.com/

Inzlicht, M., McKay, L., & Aronson, J. (2006). Stigma as Ego Depletion: How Being the Target of Prejudice Affects Self-Control. *Psychological Science*, *17*(3), 262–269. https://doi.org/10.1111/j.1467-9280.2006.01695.x

Jalava, N., Joensen, J. S., & Pellas, E. (2014). *Grades and Rank: Impacts of Non-Financial Incentives on Test Performance*. *no. 8412*, 70.

Johnson, E. J. (2008). Man, my brain is tired: Linking depletion and cognitive effort in choice. *Journal of Consumer Psychology*, *18*(1), 14–16. https://doi.org/10.1016/j.jcps.2007.10.003

Johnson, S. E., Richeson, J. A., & Finkel, E. J. (2011). Middle class and marginal? Socioeconomic status, stigma, and self-regulation at an elite university. *Journal of Personality and Social Psychology*, *100*(5), 838–852. https://doi.org/10.1037/a0021956

Kikusui, T., Winslow, J. T., & Mori, Y. (2006). Social buffering: Relief from stress and anxiety. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *361*(1476), 2215–2228. https://doi.org/10.1098/rstb.2006.1941

Koch, A., Nafziger, J., & Nielsen, H. S. (2015). Behavioral economics of education. *Journal of Economic Behavior & Organization*, *115*, 3–17. https://doi.org/10.1016/j.jebo.2014.09.005

Lavie, N. (2010). Attention, Distraction, and Cognitive Control Under Load. *Current Directions in Psychological Science*, *19*(3), 143–148. https://doi.org/10.1177/0963721410370295

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load Theory of Selective Attention and Cognitive Control. *Journal of Experimental Psychology: General*, *133*(3), 339–354. https://doi.org/10.1037/0096-3445.133.3.339

Lindner, C., Nagy, G., Arhuis, W. A. R., & Retelsdorf, J. (2017). A new perspective on the interplay between self-control and cognitive performance: Modeling progressive depletion patterns. *PLOS ONE*, *12*(6), 1–22. https://doi.org/10.1371/journal.pone.0180149

Mani, A., Mullainathan, S., Shafir, E., & Zhao, J. (2013). Poverty impedes cognitive function. *Science (New York, N.Y.)*, *341*(6149), 976–980. https://doi.org/10.1126/science.1238041

Meijer, A. M., Habekothé, H., & Wittenboer, G. (2000). Time in bed, quality of sleep and school functioning of children. *Journal of Sleep Research*, *9*, 145–153. https://doi.org/10.1046/j.1365-2869.2000.00198.x

Mills, C. J., Ablard, K. E., & Brody, L. E. (1993). The raven's progressive matrices: *Its usefulness for identifying gifted/talented students*. *Roeper Review*, *15*(3), 183–186. https://doi.org/10.1080/02783199309553500

Mincer, J. (1984). Human capital and economic growth. *Economics of Education Review*, *3*(3), 195–205. https://doi.org/10.1016/0272-7757(84)90032-3

Ministerie van Onderwijs, C. en W. (2016, August 18). *Lunchtijd en onderwijstijd—Onderwijstijd—Inspectie van het onderwijs*. Ministerie van Onderwijs, Cultuur en Wetenschap. https://www.onderwijsinspectie.nl/onderwerpen/onderwijstijd/onderwijstijd-in-het-basisonderwijs/lunchtijd-en-onderwijstijd

Mullainathan, S., & Thaler, R. H. (2000). *Behavioral Economics* (Working Paper No. 7948; Working Paper Series). National Bureau of Economic Research. https://doi.org/10.3386/w7948

Murphy, R., & Weinhardt, F. (2020). Top of the Class: The Importance of Ordinal Rank. *The Review of Economic Studies*, *87*(6), 2777–2826. https://doi.org/10.1093/restud/rdaa020

OECD. (2001). *The Well-being of Nations: The Role of Human and Social Capital*. OECD. https://doi.org/10.1787/9789264189515-en

Ong, Q., Theseira, W., & Ng, I. Y. H. (2019). Reducing debt improves psychological functioning and changes decision-making in the poor. *Proceedings of the National Academy of Sciences*, *116*(15), 7244–7249. https://doi.org/10.1073/pnas.1810901116

Paas, F., Tuovinen, J. E., Tabbers, H., & Gerven, P. W. M. V. (2003). Cognitive Load Measurement as a Means to Advance Cognitive Load Theory. *Educational Psychologist*, *38*(1), 63–71. https://doi.org/10.1207/S15326985EP3801_8

Patall, E. A., Cooper, H., & Allen, A. B. (2010). Extending the School Day or School Year: A Systematic Review of Research (1985–2009). *Review of Educational Research*, *80*(3), 401–436. https://doi.org/10.3102/0034654310377086

Pilcher, J. J., & Huffcutt, A. I. (1996). Effects of Sleep Deprivation on Performance: A Meta-Analysis. *Sleep*, *19*(4), 318–326. https://doi.org/10.1093/sleep/19.4.318

Pocheptsova, A., Amir, O., Dhar, R., & Baumeister, R. F. (2009). Deciding without Resources: Resource Depletion and Choice in Context. *Journal of Marketing Research*, *46*(3), 344–355.

Pohl, R. F., Erdfelder, E., Hilbig, B. E., Liebke, L., & Stahlberg, D. (2013). Effort reduction after self-control depletion: The role of cognitive resources in use of simple heuristics. *Journal of Cognitive Psychology*, *25*(3), 267–276. https://doi.org/10.1080/20445911.2012.758101

Randler, C. (2008). Morningness–eveningness, sleep–wake variables and big five personality factors. *Personality and Individual Differences*, *45*(2), 191–196. https://doi.org/10.1016/j.paid.2008.03.007

Rivkin, S. G., & Schiman, J. C. (2013). *Instruction Time, Classroom Quality, and Academic Achievement* (No. w19464). National Bureau of Economic Research. https://doi.org/10.3386/w19464

Schneider, W., & Shiffrin, R. M. (1977). *Controlled and Automatic Human Information Processing: I. Detection, Search, and Attention*. *1*(84), 66.

Schultz, T. W. (1993). The Economic Importance of Human Capital in Modernization. *Education Economics*, *1*(1), 13–19. https://doi.org/10.1080/09645299300000003

Sievertsen, H. H., Gino, F., & Piovesan, M. (2016). Cognitive fatigue influences students' performance on standardized tests. *Proceedings of the National Academy of Sciences*, *113*(10), 2621–2624. https://doi.org/10.1073/pnas.1516947113

Singh, P. K., & Chudasama, H. (2020). Evaluating poverty alleviation strategies in a developing country. *PLOS ONE*, *15*(1), e0227176. https://doi.org/10.1371/journal.pone.0227176

Smit, F., Driessen, G., & van Kuijk, J. (2015). *Variatie in schooltijd en onderwijskwaliteit*. 57.

Spears, D. (2011). Economic Decision-Making in Poverty Depletes Behavioral Control. *The B.E. Journal of Economic Analysis & Policy*, *11*(1). https://doi.org/10.2202/1935-1682.2973

Suleman, Q., Hussain, I., & Nisa, Z.-. (2014). Effects of Parental Socioeconomic Status on the Academic Achievement of Secondary School Students in District Karak (Pakistan). *International Journal of Human Resource Studies*, *2*(4), 14. https://doi.org/10.5296/ijhrs.v2i4.2511

Sweller, J. (2011). CHAPTER TWO - Cognitive Load Theory. In J. P. Mestre & B. H. Ross (Eds.), *Psychology of Learning and Motivation* (Vol. 55, pp. 37–76). Academic Press. https://doi.org/10.1016/B978-0-12-387691-1.00002-8

Taras, H. (2005). Physical Activity and Student Performance at School. *Journal of School Health*, *75*(6), 214–218. https://doi.org/10.1111/j.1746-1561.2005.tb06675.x

Tulving, E. (2002). Episodic Memory: From Mind to Brain. *Annual Review of Psychology*, *53*(1), 1–25. https://doi.org/10.1146/annurev.psych.53.100901.135114

Tyler, J. M., & Burns, K. C. (2008). After Depletion: The Replenishment of the Self's Regulatory Resources. *Self and Identity*, *7*(3), 305–321. https://doi.org/10.1080/15298860701799997

van der Aa, R., van den Bergh, D., Scheeren, J., Stevenson, S., Vermeulen, M., Vrielink, S., & van Zijtveld, S. (2020). *Onderwijstijd: Meer of minder?* (p. 117). https://www.rijksoverheid.nl/documenten/kamerstukken/2020/06/01/internationaal-vergelijkend-onderzoek-naar-de-urennorm-en-onderwijstijd-in-het-primair-onderwijs

van der Vinne, V., Zerbini, G., Siersema, A., Pieper, A., Merrow, M., Hut, R. A., Roenneberg, T., & Kantermann, T. (2015). Timing of Examinations Affects School Performance Differently in Early and Late Chronotypes. *Journal of Biological Rhythms*, *30*(1), 53–60. https://doi.org/10.1177/0748730414564786

Vohs, K. D. (2013). The Poor's Poor Mental Power. *Science*, *341*(6149), 969–970. https://doi.org/10.1126/science.1244172

Westbrook, A., & Braver, T. S. (2015). Cognitive effort: A neuroeconomic approach. *Cognitive, Affective & Behavioral Neuroscience*, *15*(2), 395–415. https://doi.org/10.3758/s13415-015-0334-y

White, K. R. (1982). The relation between socioeconomic status and academic achievement. *Psychological Bulletin*, *91*(3), 461–481. https://doi.org/10.1037/0033-2909.91.3.461

Wilhelm, O., Hildebrandt, A., & Oberauer, K. (2013). What is working memory capacity, and how can we measure it? *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00433

Wilson, R. A., & Briscoe, G. (2004). *The impact of human capital on economic growth: A review* (Cedefop Reference Series, p. 64).

Zerbini, G., & Merrow, M. (2017). Time to learn: How chronotype impacts education. *PsyCh Journal*, *6*(4), 263–276. https://doi.org/10.1002/pchj.178

# Appendix 1: Survey

Survey **Name:** **Participant number:**

In this survey broad questions about your daily life will be asked. The survey answers will not be published online with your name attached. The survey will not be completely anonymous, because of the necessity to compare results. However, The only person reviewing this information will be me, the researcher. All questionnaires will be stored in an AVG proof data storage. All documents will be made completely anonymous before sharing any data. At random, three participants will win a €10 gift card of their choice. Winners will be announced at the end of the process. If you have any questions feel free to contact me, Peter Vermeulen (peter.vermeulen@student.ru.nl).

By filling in this form I consent to the researcher using this data as long as the data will not be published online with my name attached.

**General questions**

**My age:**

12 13 14 15 16 17 18

**I am:**

A Man

A Woman

Other/Do not want to share

**What language do you mostly speak at home?**

Dutch (or Dutch dialect)

Moroccan

Turkish

Polish

Arabic

Chinese

Other, namely: ________________________________________

**What academic level are you currently following?**

VMBO-B (VMBO-BK)

VMBO-K

VMBO-GT

VMBO-T

HAVO

**How many hours of lecturing have you had today?**

_________________________________________________________________

**How many PE lessons have you had today?**

0 1 2 3

**What is the total length of the break you had today?**

______________________________________________________________________________

**<u>Questions about economic status (FAS)</u>** (Currie et al., 2008)**<u>:</u>**

**How many cars do your parents own?**

0 1 2 or more

**Which of the following statements applies to you**

I have my own room

I share a room with 1 person

I share a room with more than 1 person

**How many computers (including iPads and tablets) does your family own?**

0 1 2 3 or more

**How many times would you normally (pre-covid times) go on vacation per year?**

0 1 2 3 or more

**See the ladder depicted to the right. How satisfied are you with the financial situation of your household? If 1 indicates that you are completely dissatisfied and 10 means that you are completely satisfied.**

1 2 3 4 5 6 7 8 9 10

**<u>Questions about sleep (Gets repeated for groups 2 and 4)</u>**

**At what time did you go to bed last night?**

______________________________________________________________________________

**At what time did you turn of the lights?**

______________________________________________________________________________

**At what time did you wake up?**

______________________________________________________________________________

**How many times did you wake up during the night?**

0 (I slept through)

1

2

3

**Questions about chronotype** (Carskadon et al., 1993, p. 259) **:**

***Imagine: School is canceled! You can get up whenever you want to. When would you get out of bed? Between:**

a. 5:00 and 6:30 am
b. 6:30 and 7:45 am
c. 7:45 and 9:45 am
d. 9:45 and 11:00 am
e. 11:00 am and noon

**Is it easy for you to get up in the morning?**

a. No way!
b. Sort of
c. Pretty easy
d. It's a cinch

***Gym class is set for 7:00 in the morning. How do you think you'll do?**

a. My best
b. Okay
c. Worse than usual
d. Awful

***The bad news: you have to take a two-hour test. The good news: You can take it when you think you'll do your best. What time is that?**

a. 8:00 to 10:00 am
b. 11:00 to 1:00 pm
c. 3:00 to 5:00 pm
d. 7:00 to 9:00 pm

***When do you have the most energy to do your favorite things?**

a. Morning! I'm tired in the evening
b. Morning more than evening
c. Evening more than morning
d. Evening! I'm tired in the morning.

***Guess what? Your parents have decided to let you set your own bedtime. What time would you pick? Between…**

a. 8:00 and 9:00 pm
b. 9:00 and 10:15 pm
c. 10:15 pm and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

**How alert are you in the first half hour you're up?**

a. Out of it
b. A little dazed
c. Okay
d. Ready to take on the world

***When does your body start to tell you it's time for bed (even if you ignore it)? Between**

a. 8:00 and 9:00 pm

b. 9:00 and 10:15 pm
c. 10:15 pm and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

**Say you had to get up at 6:00 am every morning: what would it be like**

a. Awful
b. Not so great
c. Okay (if I have to)
d. Fine, no problem

***When you wake up in the morning how long does it take for you to be totally ‘’with it’’?**

a. 0 to 10 minutes
b. 11 to 20 minutes
c. 21 to 40 minutes
d. More than 40 minutes

**Point scoring: A = 1 B =2 C =3 D = 4 E=5. For questions with * the scoring is reversed. In total 42 points can be scored. The higher the score, the more of a morning person someone is.**

**<u>Questions that the school is interested in:</u>**

**If you would have to choose, which of the following school times would be your preference?**

a. 08:00 – 14:00
b. 08:30 – 14:30
c. 09:00 – 15:00
d. 09:30 – 15:30
e. 10:00 – 16:00

**The perfect length for the morning break (around 10:15) would be:**

____________________________________________________________

**The perfect length for the lunch break (around 12:15) would be:**

____________________________________________________________

**The perfect length for the afternoon break (around 14:30) would be:**

____________________________________________________________

**How long should one lesson be in your opinion? Keep in mind that a shorter lesson does not mean that you are home earlier!**

____________________________________________________________

# Appendix 2: Cognitive tests exercise statistics

**Table A (cognitive test 1):**

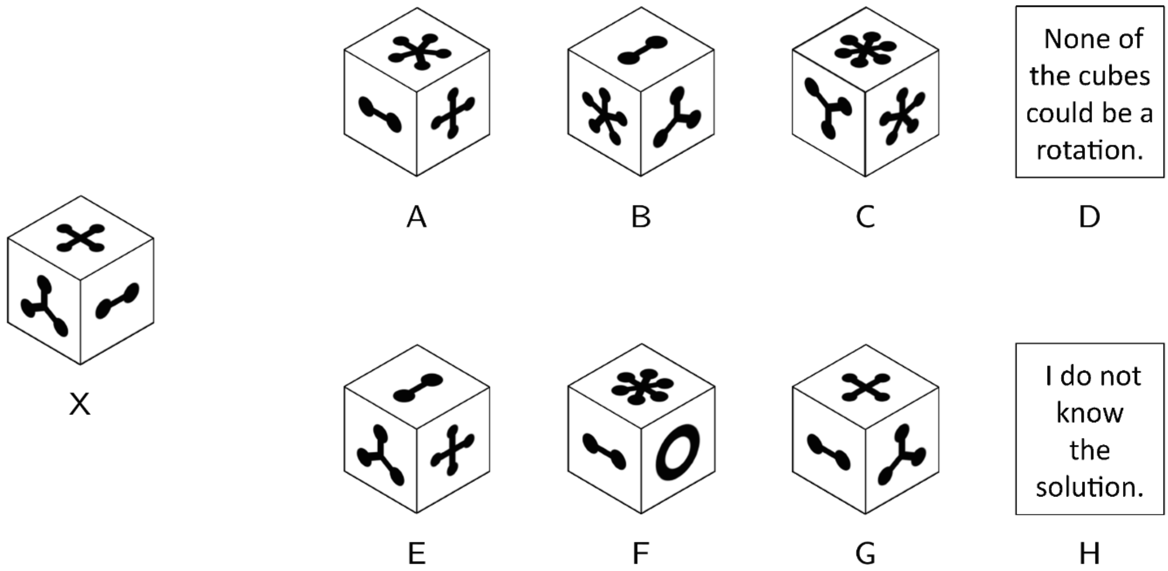
| **Figure number** (from ICAR project) | Mean | Standard deviation | Answer |
|---|---|---|---|
| 20 | 0.39 | 0.49 | F |
| 25 | 0.38 | 0.49 | A |
| 64 | 0.25 | 0.43 | E |
| 62 | 0.22 | 0.41 | A |
| 03 | 0.18 | 0.38 | C |
| 50 | 0.21 | 0.41 | G |
| **Matrix** | | | |
| 46 | 0.56 | 0.5 | B |
| 54 | 0.40 | 0.49 | A |
| 55 | 0.27 | 0.45 | D |
| 45 | 0.49 | 0.5 | E |

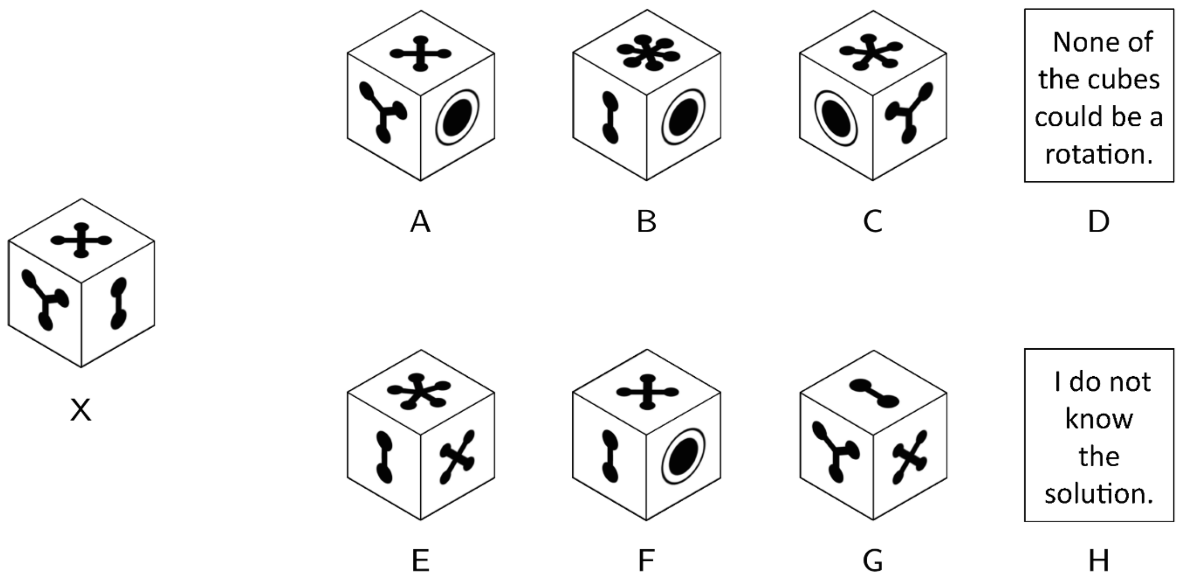
**Table B (cognitive test 2):**

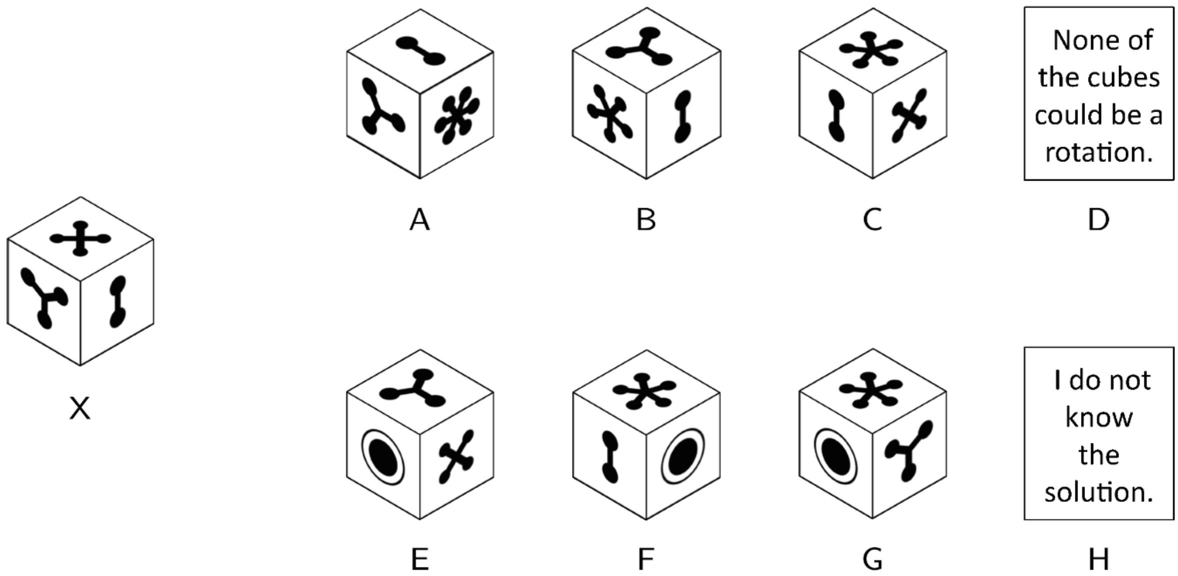
| **Figure number** (from ICAR project) | Mean | Standard Deviation | Answer |
|---|---|---|---|
| 44 | 0.39 | 0.49 | B |
| 29 | 0.37 | 0.48 | F |
| 06 | 0.31 | 0.46 | F |
| 63 | 0.22 | 0.41 | A |
| 34 | 0.18 | 0.39 | A |
| 54 | 0.21 | 0.40 | B |
| **Matrix** | | | |
| 47 | 0.56 | 0.5 | B |
| 48 | 0.41 | 0.49 | D |
| 56 | 0.29 | 0.45 | E |
| 53 | 0.54 | 0.5 | C |

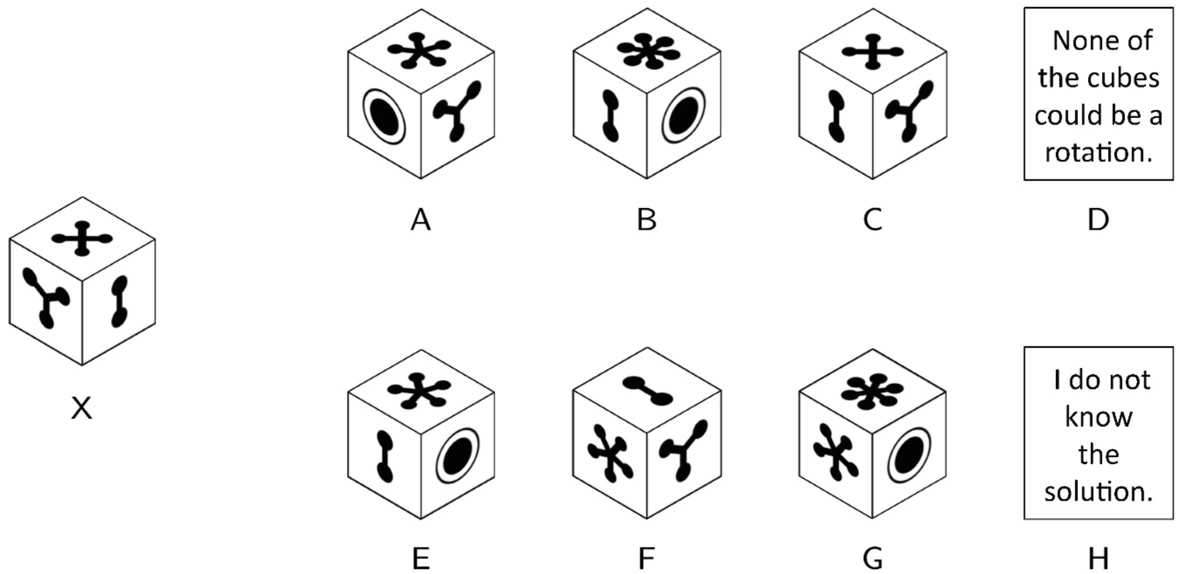
# Appendix 3: Cognitive test 1

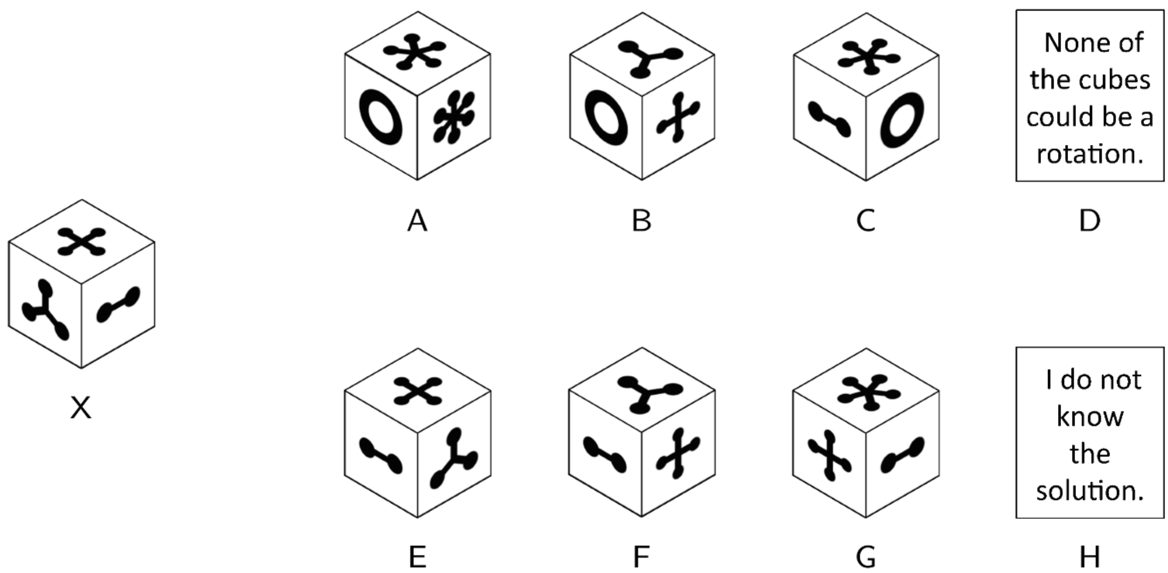
Figures are in order figure: 20, 25, 64, 62, 63, 50, 46, 54, 55, 45.

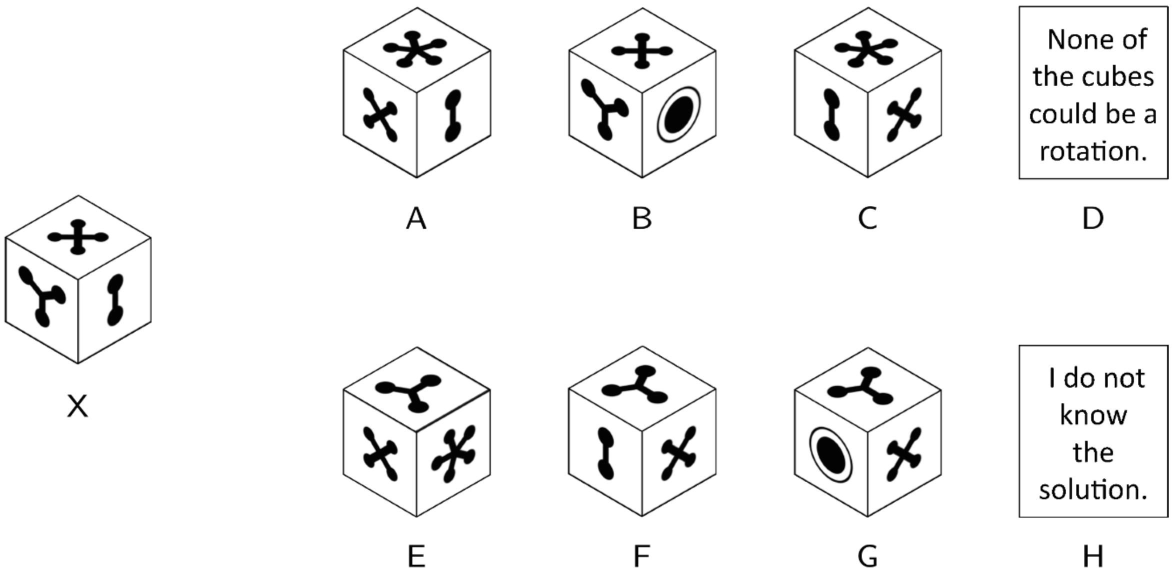


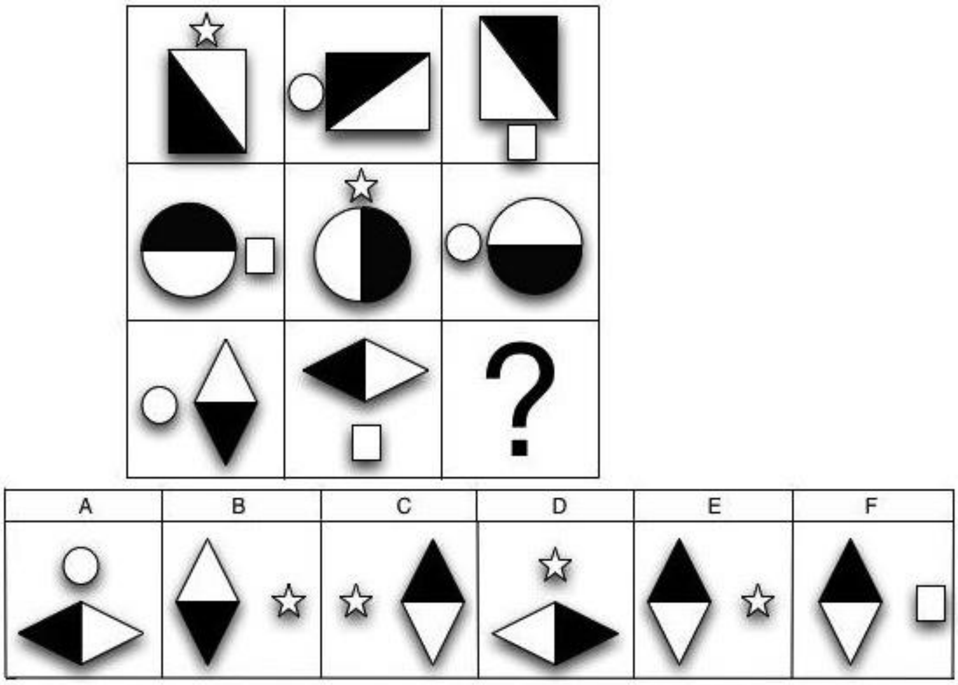



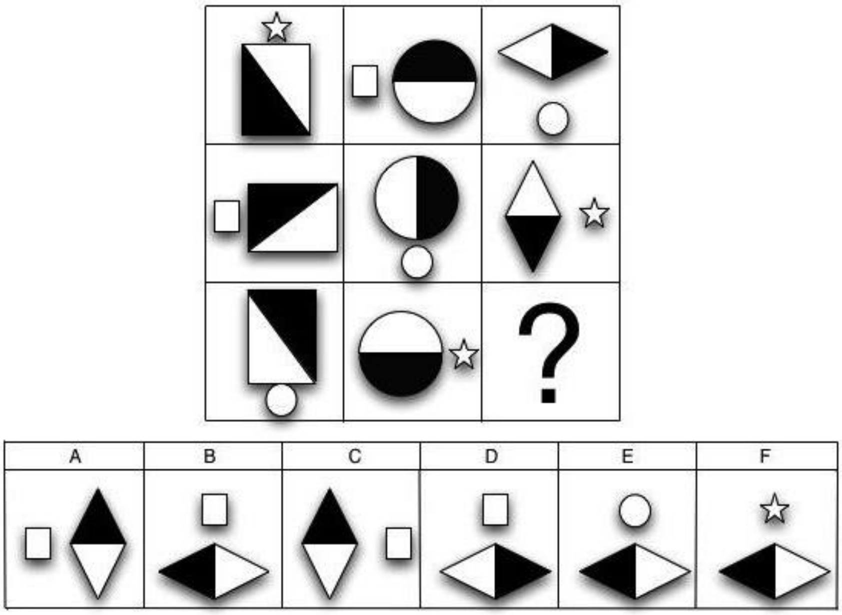

A
B
C
None of the cubes could be a rotation.
D
X
E
F
G
I do not know the solution.
H


A
B
C
None of the cubes could be a rotation.
D
X
E
F
G
I do not know the solution.
H


A
B
C
None of the cubes could be a rotation.
D
X
E
F
G
I do not know the solution.
H


None of the cubes could be a rotation.
I do not know the solution.
A
B
C
D
X
E
F
G
H


A
B
C
D
E
F


?
A
B
C
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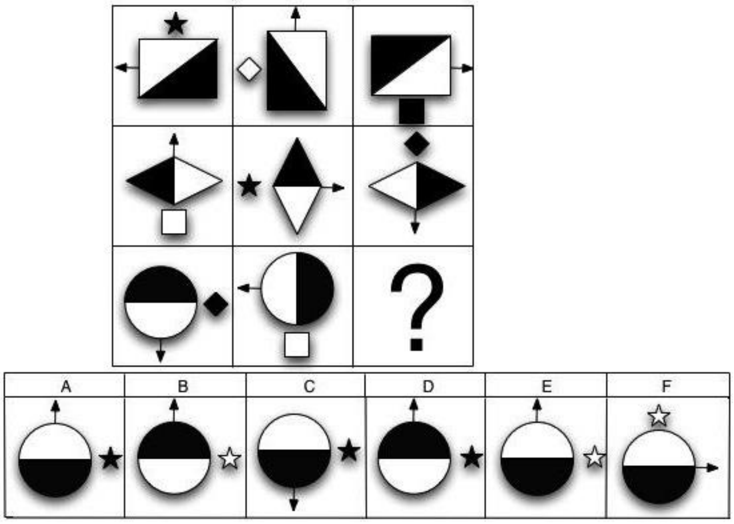
E
F


?
A
B
C
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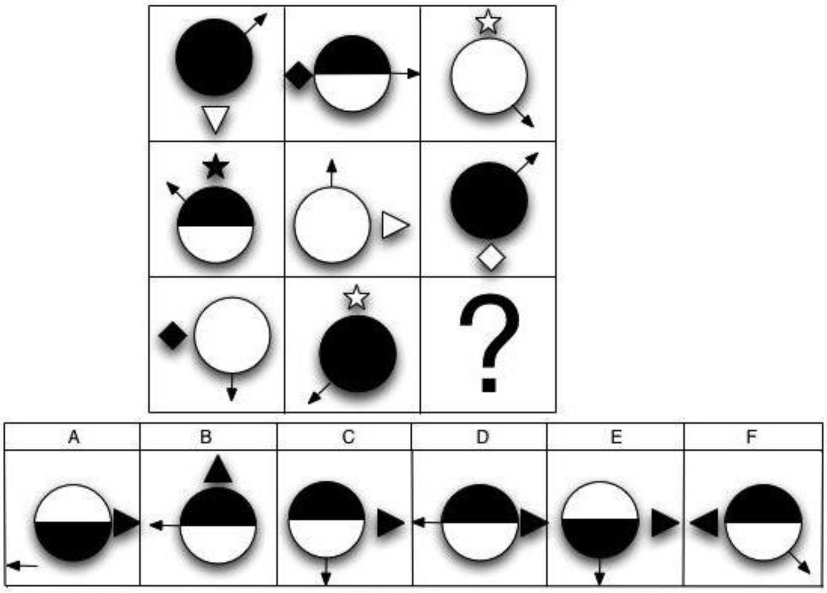
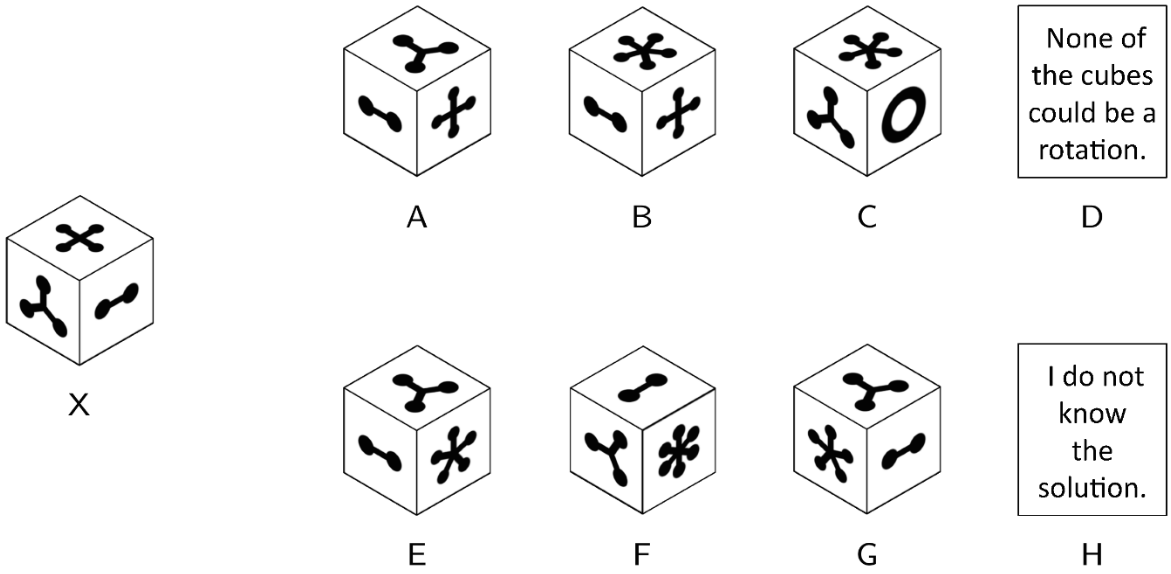
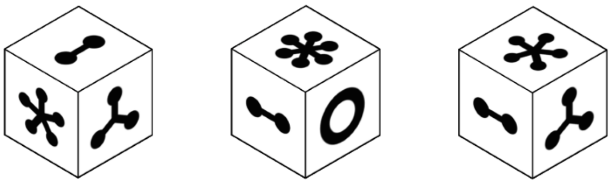
E
F


?
A
B
C
D
E
F

# Appendix 4: Cognitive test 2

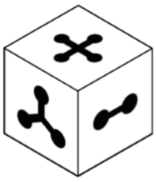
The figures are in order numbers: 44, 29, 06, 63, 34, 54,47, 48, 56 and 53.



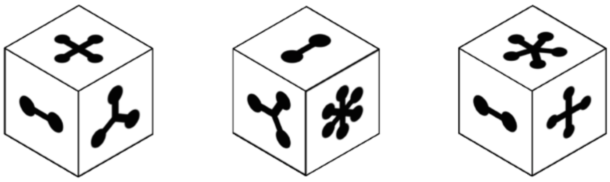


None of the cubes could be a rotation.

A B C D

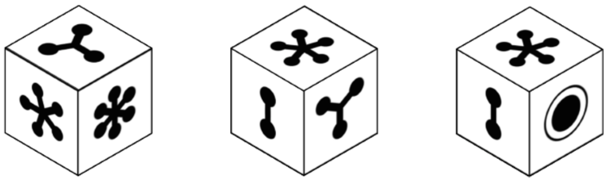


X



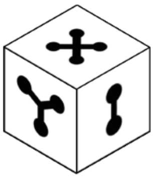
I do not know the solution.

E F G H



None of the cubes could be a rotation.

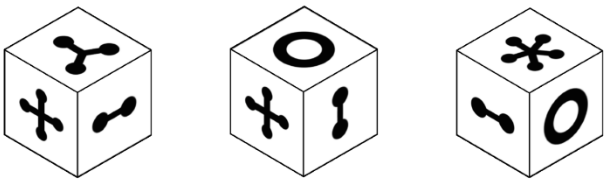
A B C D



X

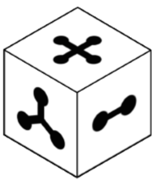
I do not know the solution.

E F G H



None of the cubes could be a rotation.

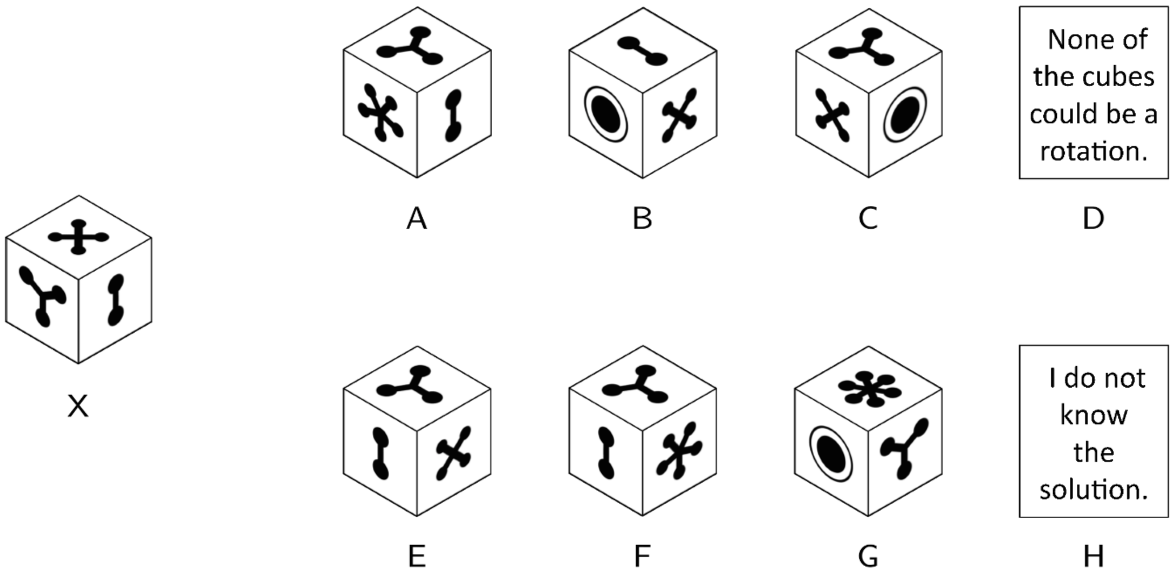
A B C D

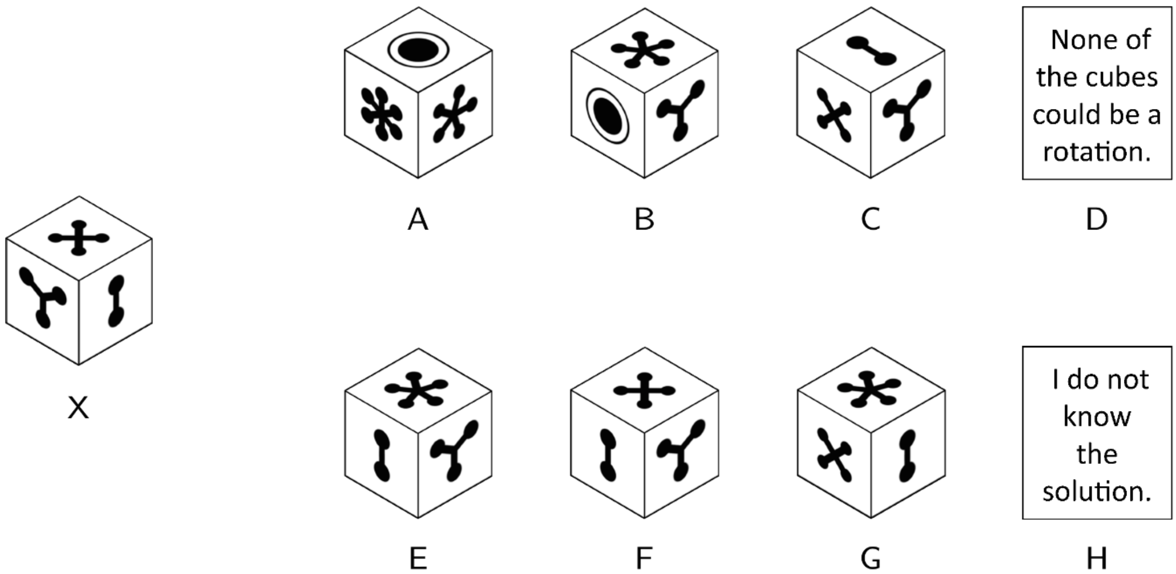


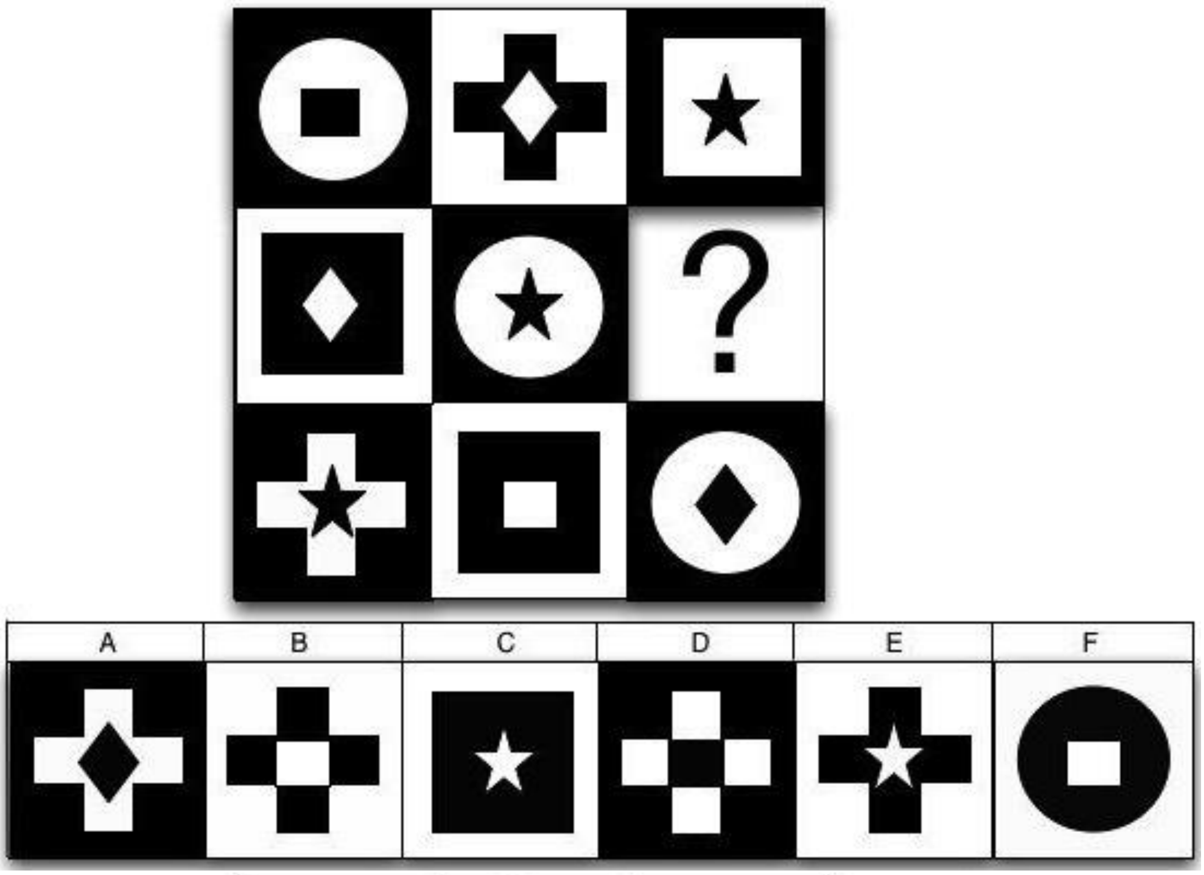
X

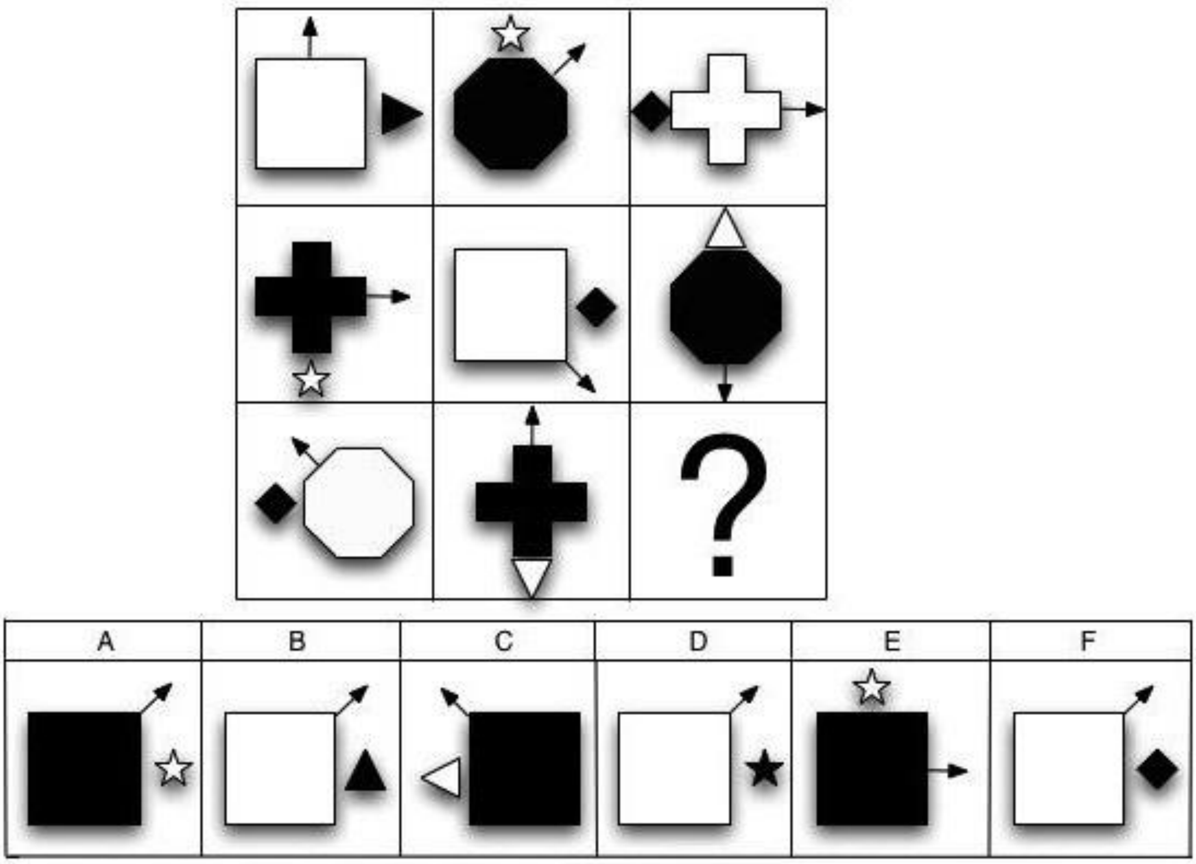
I do not know the solution.

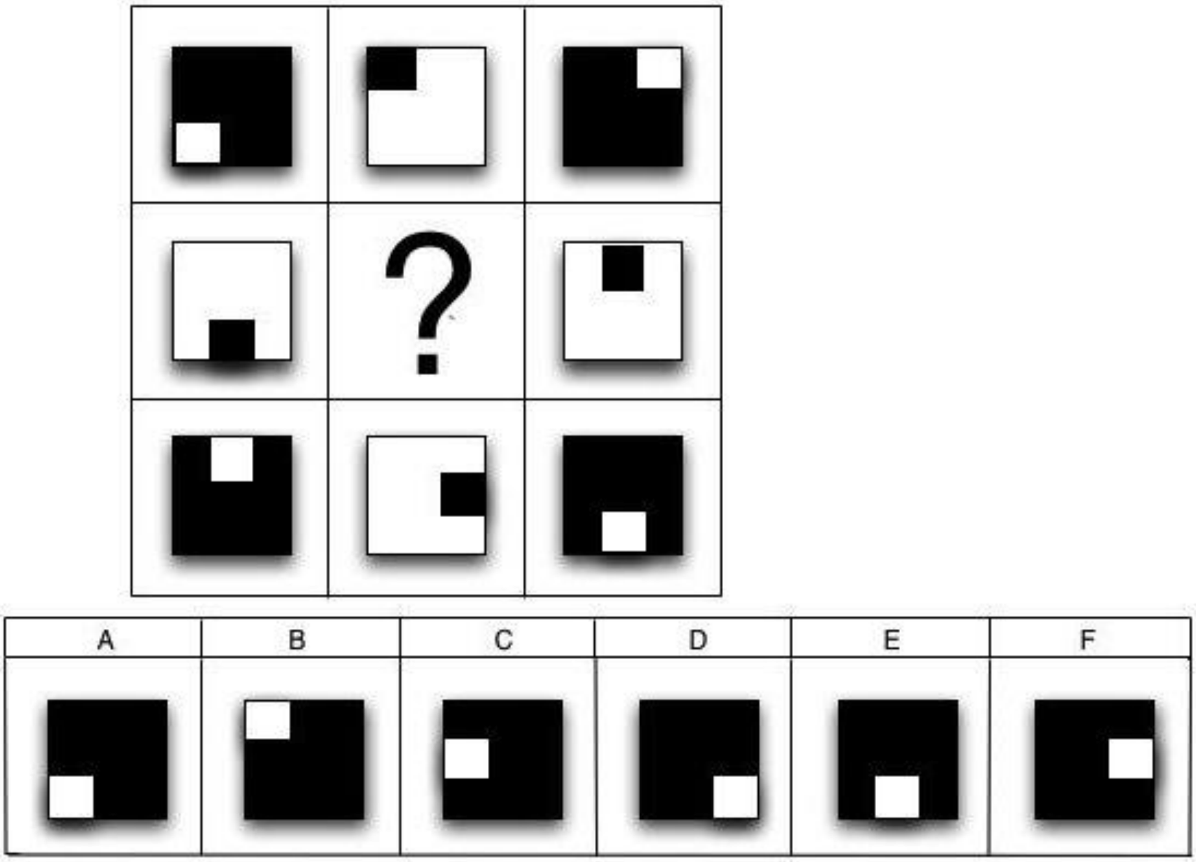
E F G H

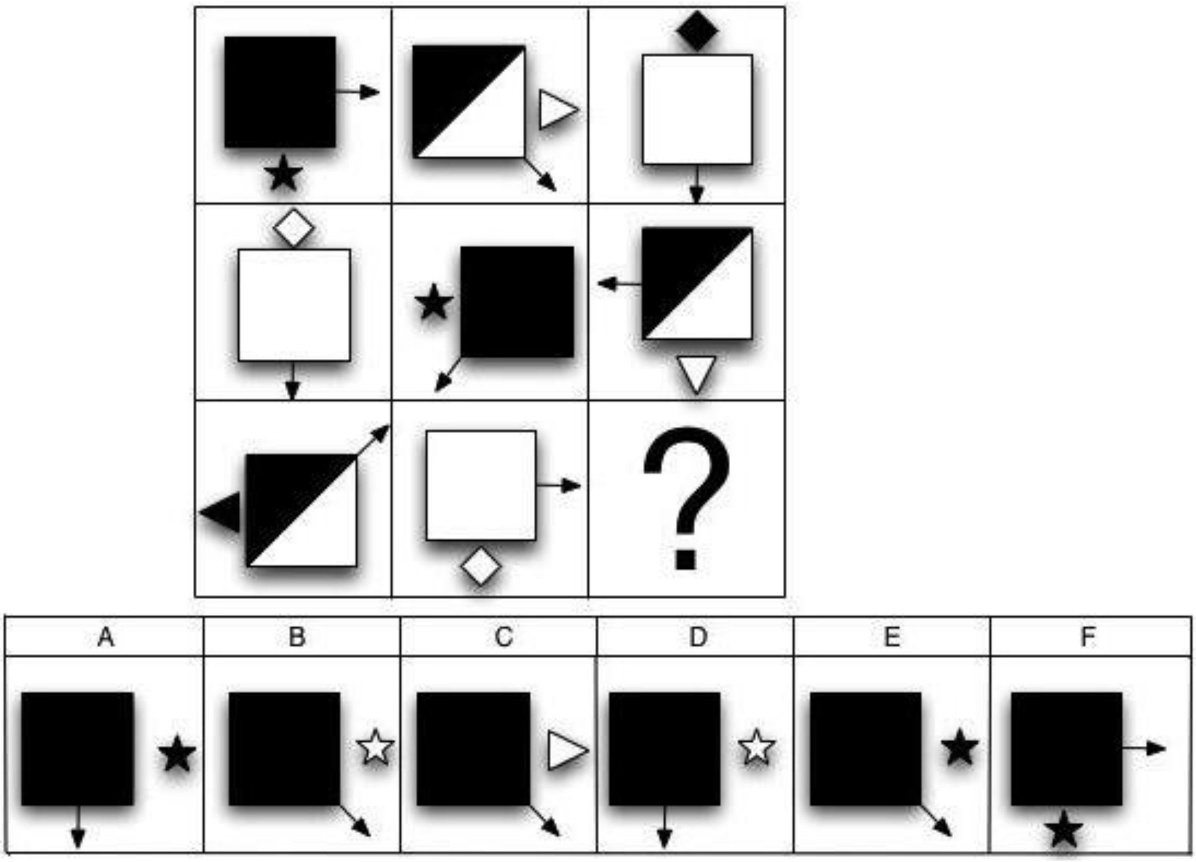

A
B
C
None of the cubes could be a rotation.
D
X
E
F
G
I do not know the solution.
H


A
B
C
None of the cubes could be a rotation.
D
X
E
F
G
I do not know the solution.
H


?
A
B
C
D
E
F


?
A
B
C
D
E
F


?
A
B
C
D
E
F


?
A
B
C
D
E
F

# Appendix 5: Correlation matrix

**Matrix of correlations**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Score_mor | 1.000 | | | | | | | | | | | | | | | | |
| (2) Score_aft | -0.045 | 1.000 | | | | | | | | | | | | | | | |
| (3) Score_dif | -0.613 | 0.675 | 1.000 | | | | | | | | | | | | | | |
| (4) Duration_les_c~t | -0.100 | -0.138 | 0.021 | 1.000 | | | | | | | | | | | | | |
| (5) Soc_eco_class | -0.001 | 0.066 | 0.047 | 0.139 | 1.000 | | | | | | | | | | | | |
| (6) Soc_perc | -0.036 | -0.027 | 0.005 | 0.019 | 0.344 | 1.000 | | | | | | | | | | | |
| (7) Chrono_score | -0.101 | -0.131 | 0.051 | 0.045 | 0.091 | 0.170 | 1.000 | | | | | | | | | | |
| (8) Age | 0.165 | -0.088 | -0.149 | 0.168 | -0.098 | -0.083 | -0.169 | 1.000 | | | | | | | | | |
| (9) Duration_break | -0.036 | -0.167 | -0.075 | 0.510 | 0.100 | -0.078 | 0.016 | 0.065 | 1.000 | | | | | | | | |
| (10) Duration_brea~t | -0.036 | -0.167 | -0.075 | 0.510 | 0.100 | -0.078 | 0.016 | 0.065 | 1.000 | 1.000 | | | | | | | |
| (11) Duration_PE_les | -0.032 | -0.001 | -0.032 | 0.003 | 0.014 | 0.002 | 0.003 | -0.010 | -0.010 | -0.010 | 1.000 | | | | | | |
| (12) Duration_sleep | 0.038 | 0.020 | 0.042 | -0.030 | 0.003 | 0.151 | 0.427 | -0.245 | 0.001 | 0.001 | -0.136 | 1.000 | | | | | |
| (13) Duration_slee~t | 0.038 | 0.020 | 0.042 | -0.030 | 0.003 | 0.151 | 0.427 | -0.245 | 0.001 | 0.001 | -0.136 | 1.000 | 1.000 | | | | |
| (14) Sleep_inter | 0.093 | 0.148 | 0.016 | -0.035 | -0.072 | -0.223 | -0.078 | 0.103 | 0.046 | 0.046 | 0.037 | -0.129 | -0.129 | 1.000 | | | |
| (15) Duration_sleep_next_mor | -0.107 | 0.090 | 0.192 | -0.005 | -0.007 | -0.020 | 0.255 | -0.197 | -0.042 | -0.042 | 0.158 | 0.409 | 0.409 | 0.025 | 1.000 | | |
| (16) Duration_sleep_next_ mor_cent | -0.107 | 0.090 | 0.192 | -0.005 | -0.007 | -0.020 | 0.255 | -0.197 | -0.042 | -0.042 | 0.158 | 0.409 | 0.409 | 0.025 | 1.000 | 1.000 | |
| (17) Sleep_inter_n~g | 0.053 | 0.152 | 0.033 | -0.139 | -0.043 | -0.107 | -0.188 | 0.045 | -0.015 | -0.015 | -0.100 | -0.040 | -0.040 | 0.425 | -0.180 | -0.180 | 1.000 |