MASTER'S THESIS

How Does a Growth Mindset Affect Cognitive Load and Learning Performance?

Koorn, P.

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Hoe Beïnvloedt een Groeimindset Cognitieve Belasting en Leerprestaties?

P.M.D. Koorn

Master Educational science

Open University

Date: November 11th, 2019

Name supervisor: Kate Xu, PhD

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Summary

The merit of promoting a growth mindset in order to improve students' academic performance has been proclaimed by many researchers and practitioners in the educational context. The social-cognitive model of achievement motivation postulates that learners with a growth mindset perceive their intelligence as malleable, making them motivated to learn and demonstrate intrinsic academic achievement strivings. However, empirical support for mindset interventions remains inconsistent, which may be due to the fact that learning process-related variables such as cognitive load are not yet considered and incorporated. It is possible that motivational factors may facilitate learning by investing cognitive effort in meaningful learning processes.

The current study aimed to expand the existing body of research on mindset in that it examined the effect of a growth mindset on learners' motivation, perceived cognitive load and subsequent performance.

In this double blind, lab-controlled 'between-subjects' design experiment, a total of 138 10th grade students in higher secondary education were recruited from two comparable comprehensive public high schools in the Netherlands through the electronic learning environment of the schools, and an oral invitation by the experimenter. The participants were randomly assigned to either the experimental condition ($n = 69$) or the active control condition ($n = 69$).

During the experiment, all participants answered questions regarding their level of prior knowledge on the Doppler effect, which was the subject of the multimedia reading task during the learning phase. Next, participants in the growth mindset condition read about brain functions and malleability of intelligence, then wrote a short letter to a student who struggles with learning a difficult subject. Participants in the control condition only read about brain functions, then wrote a summary of the reading. The experimental phase was followed by questionnaires on mindset, achievement goal orientations, and situational interest. Then, all participants performed the multimedia reading task to learn about the Doppler effect, and rated their perceived cognitive load. Finally, they performed comprehension and transfer tests.

The key variables were measured by the Implicit Beliefs of Intelligence Scale (Dweck, 2000), the Achievement Goal Questionnaire-Revised (Elliot & Murayama, 2008), the Situational Interest Scale (Linnenbrink-Garcia et al., 2010), and the Cognitive Load Index (Leppink, Paas, Van der Vleuten, Van Gog & Van Merriënboer, 2013). Additionally, learning performance was measured by scoring four open-ended questions on comprehension and transfer.

The experimental group reported a significantly higher growth mindset than the control group, indicating a successful experimental manipulation. Furthermore, the growth mindset group reported significantly higher mastery goal orientation, situational interest related to feeling, and lower perceived intrinsic and extraneous cognitive load. They also scored significantly higher on learning performance.

The current research confirms that inducing a growth mindset prior to learning, leads to a stronger mastery-goal orientation, more feeling related situational interest, and lower perception of cognitive load, ultimately resulting in a positive impact on learning performance. Additional research is required to further examine how to incorporate motivational and cognitive process aspects identified in the present research, in order to maximize the effect of a growth mindset on learning performance.

1. Introduction

For decades scientists have been studying why some people succeed whereas people who are equally intelligent, do not. Must we believe that our intellectual ability to accomplish goals is written in the stars, or that it is something that can be improved upon with hard work and learning the right strategies? The academic literature on beliefs of intelligence is extensive and goes back to 1988 when Dweck and Leggett (Dweck & Leggett, 1988) conceptualized implicit beliefs of intelligence based on the social-cognitive model of achievement motivation. This model proposes that individuals can either perceive intelligence as congenital and unchangeable -also known as an entity belief or a fixed mindset-, or as amendable to change and prone to development. The belief that intelligence can grow is called an incremental belief or a growth mindset (Costa & Faria, 2018). Ever since, a large body of research in educational contexts has indicated that adopting a growth mindset reinforces mastery-oriented learning goals, promotes motivated learning and leads to better academic achievement (e.g., Costa & Faria, 2015; Tirri & Kujala, 2016; Zeng, Hou & Peng, 2016). However, in which manner this process occurs in context specific learning activities is less explored. To date, no previous research has examined the effect of implicit beliefs on learners' self-perceived cognitive processes, such as invested mental effort or perceived task difficulty portrayed in learning theories (e.g., cognitive load theory (Sweller, 1994, 1999; Sweller & Chandler, 1994)). It could be possible that students who hold a growth mindset are more likely to embrace a more favourable perception on task difficulties in the learning environment and therefore maintain cognitive engagement as measured by mental effort. As a result, these students may experience less cognitive overload, invest more mental effort and achieve better learning performances.

By assessing the effect of implicit beliefs on achievement and cognitive load, the present study aims to gain a better understanding of how the effect of a growth mindset facilitates effective learning.

In the following sections, the theoretical frameworks on implicit beliefs of intelligence and its relationship with motivation (i.e., achievement goals, situational interest), cognitive load perceptions, and learning performances will be further elaborated upon.

1.1 Theoretical Framework

1.1.1 Implicit Beliefs of Intelligence and the Social-Cognitive Model of Achievement

Individuals' belief that their general intelligence is a malleable or a fixed unchangeable characteristic can have a significant influence on their academic and motivational outcomes (Aronson, 2002; Burnette, O'Boyle, Van Epps, Pollack & Finkel, 2013; Costa & Faria, 2018; Romero, Master, Paunesku, Dweck & Gross, 2014). As stated by Dweck and her colleagues (Diener & Dweck, 1978;

Dweck, 2006; Dweck & Leggett, 1988; Dweck & Reppuci, 1973; Elliott & Dweck 1988) the implicit beliefs of intelligence are crucially related to achievement and have an impact on the learning process of students, especially when facing difficulties or challenges. According to the social-cognitive model of achievement, students holding a fixed mindset experience difficulties as negative and demotivating failures, leading to a helpless response and decreasing motivation. They tend to avoid challenges and effort when engaged in an academic learning task, because they believe that their failures could reveal their deficiencies or low ability. These students demonstrate low academic achievement strivings and give up easily, blaming their failures or deficiencies on uncontrollable circumstances such as congenital intelligence. Students holding a growth mindset on the other hand, are motivated to learn and demonstrate high academic achievement strivings. They experience difficulties as interesting learning opportunities, leading to a mastery-oriented response. These students remain involved in their learning and persist when the going gets tough, because they believe that their intellectual ability can grow overtime and that outcomes can be influenced by how hard they work. They tend to blame their failures to insufficient effort (Blackwell, Trzesniewski & Dweck, 2007; Butler, 2000; Dweck, 2006; Hong, Chiu, Dweck, Lin & Wan, 1999; Hong & Lin-Siegler, 2012; Lin-Siegler, Ahn, Chen, Fang & Luna-Lucero, 2016; Rattan, Savani, Chugh & Dweck, 2015; Robins & Pals, 2002).

1.1.2 Effect of Implicit Beliefs of Intelligence Interventions on Academic Achievement

Since the eighties, numerous studies have tested the theoretical predictions based on the implicit beliefs of intelligence. The assumption that both a growth and a fixed mindset can be altered for shorter periods of time, or changed more permanently, have led researchers to design interventions that change students' perception of intelligence (Burnette et al., 2013; Costa & Faria, 2018; Sisk, Burgoyne, Sun, Butler & Macnamara, 2018; Vella, Braithewaite, Gardner & Spray, 2016).
For instance, Blackwell and her colleagues (2007, study 2) conducted growth mindset interventions for adolescents, a "Vulnerable age at which declines in achievement are common and can have important consequences for future life success" (Dweck & Yeager, 2019, p. 7). The researchers divided 548 seventh grade students from a public secondary school located in New York City, who were relatively low-achieving, into an intervention group and an active control group for a weekly intervention of 25 minutes over a period of eight weeks. The intervention group read an article about the malleability of intelligence called "You can grow your intelligence". They learned that the brain can grow new connections and gets smarter overtime when working on difficult or challenging tasks. The control group attained lessons on memory reading and mnemonics. The results of this study showed that participants in the control group displayed a continuing decline of math grades, whereas the participants in the intervention group were able to even reverse this downward trajectory in grades ($d = 0.62$). Additionally, results showed that holding a growth mindset was also positively correlated

with mastery goals (r = .34). More recent research (e.g., Burnette, Russell, Hoyt, Orvidas & Widman, 2018; Paunesku et al., 2015; Yeager et al., 2016) investigated the potential of online growth mindset interventions in order to help improve students' academic achievement. For example, Burnette et al. (2018) examined whether an online growth mindset intervention could be leveraged to promote academic outcomes in a sample of 222 tenth grade adolescent girls living within the rural areas of the South-eastern United States. Burnette and her colleagues tested the efficacy of an implicit belief intervention, relative to a sexual health program by randomly assigning the girls in either an implicit belief intervention group or an attention-matched control group. The girls in the intervention group first were taught about research related to a growth mindset. Second, they read the same article about the malleability of intelligence as used by Blackwell et al. (2007) and Paunesku et al. (2015). Finally, the students participated in a "saying-is-believing" exercise (see e.g., Aronson et al., 2002; Burnette & Finkel, 2012) to encourage them to adopt the growth mindset message. This exercise is a self-persuasion strategy which fosters participants to embrace a growth mindset (Yeager et al., 2016). At the four month follow up after the immediate post-test, the girls who were assigned to the intervention group showed an indirect and modest increase in motivation to learn, efficacy and grades.

Although many researchers have claimed that implicit beliefs interventions are of a revolutionary kind and can lead to large gains and striking effects on academic achievement (e.g. Yeager & Walton, 2011), there are also contradicting findings (Devers, 2015; Dommett, Devonshire, Sewter & Greenfield, 2013; Rheinschmidt & Mendoza-Denton, 2014; Sisk et al. 2018). Several recent meta-analyses have reported inconsistent findings with effect sizes on academic performance in interventional studies ranging from small (d = 0.08) (Sisk et al. 2018) to large (d = 0.56) (Lazowski & Hulleman, 2016). Costa and Faria (2018) conducted a meta-analysis of 46 studies from 2002 to 2017 to examine the relationship between implicit beliefs of intelligence and students' academic achievement. The mean weighted effect size of these studies indicated that implicit beliefs were, in general, positively related to academic achievement, though at a low magnitude (r = .07). However, in this study, only gender, academic grades, measurements of implicit beliefs and culture were investigated as potential moderators. In a more comprehensive meta-analysis (k = 43; N = 57,16) Sisk et al. (2018) examined the impact of implicit belief interventions on academic achievement (d = 0.08) and considered numerous potential moderating factors which might identify the factors influencing the effectiveness of the interventions. These potential moderators are of particular interest to the current study, because these results were used for the design of the current experiment. Sisk and her colleagues (2018) reported that studies using an active control group (i.e., placebo control) had a significant intervention effect, d = 0.08, 95% CI = [0.01, 0.16], p = .034. The effectiveness of a growth mindset intervention on academic achievement was significant when the intervention was interactive (e.g., reading about a growth mindset and then actively discussing or writing a reflection) d = 0.09,

95% CI = [0.02, 0.16], p = .011. Furthermore, interventions were effective when students read growth mindset materials d = 0.20, 95% CI = [0.09, 0.30], p < .001. The mode of intervention was also significant. Interventions which were administered via paper-based growth mindset reading materials were significantly effective, d = 0.20, 95% CI = [0.09, 0.30], p < .001. When the interventions were administered outside regular classroom activities, the effect was also significant, d = 0.09, 95% CI = [0.03, 0.16], p = .003. Surprisingly, the authors found that the effect of implicit beliefs on academic achievement was significant when manipulation checks failed, but null when manipulation checks succeeded. The effect of growth mindset interventions was moderate in most studies, however, Sisk et al. (2018) suggest that it is possible that imperfect control of the intervention in the classroom or unmeasured factors could have buffered the effects. The current investigation addressed this issue by investigating the effect of a growth mindset intervention during a single learning session, in a lab-controlled setting.

1.1.3 Implicit Beliefs of Intelligence and Achievement Goals

Closely related to implicit beliefs and academic achievement are achievement goals. Cury, Elliot, Da Fonseca and Moller (2006) state that "Implicit beliefs are predictors of achievement goals, which, in turn, predict outcomes in achievement settings" (p. 667). According to the authors, achievement goals can be characterised as mastery goals and performance goals. Learners can either focus on developing a skill, which is a mastery goal orientation, or they can focus on demonstrating a skill, which is a performance goal orientation. Cury et al. (2006) base their findings on the achievement goal theory (see Elliott & Dweck, 1988) which postulates that students can pursue either performance or mastery goals for their course or academic task. According to this theory, students who believe that their intelligence is malleable are more likely to pursue mastery goals, which reflect a desire in students to *improve* their ability by learning and improving their skills and competences. These students are task oriented and mostly concerned with learning and mastering, resulting in positive affect, intrinsic motivation and use of deep processing strategies when they face difficulties. Students who believe that their intelligence is fixed and unchangeable are likely to pursue performance goals. Performance goals reflect a desire in students to *prove* their ability by outperforming peers or matching their peers' success with less effort, gaining positive feedback or looking good in the eyes of others (Dweck & Leggett, 1988; Ingebrigtsen, 2018; Senko, 2016). To comprise valence, both mastery and performance goals have been conceptually separated into approach and avoidance sub-goals, resulting in a 2 x 2 model of achievement goals (Elliott, 1999; Elliott & Mc Gregor, 2001; Harackiewicz, Barron, Pintrich, Elliot & Thrash, 2002; Korn, Elliot & Daumiller, 2019; Pintrich, 2000). In particular, students who pursue mastery-approach goals focus on developing competence with an emphasis on learning and self-improvement, whereas students who pursue mastery-avoidance goals are motivated

to avoid situations in which they are unable to learn. These students want to avoid being incompetent. Students who pursue performance-approach goals are focussed on attaining positive outcomes like performing better than other students, whereas students who pursue performance-avoidance goals are focussed on avoiding negative outcomes like performing worse than other students (Cury et al., 2006; Elliot, 1999; Elliot & Murayama, 2008).

Prior studies have indicated that adopting a growth mindset cultivates mastery-oriented learning goals, promotes motivated learning and leads to greater academic achievement (Blackwel et al., 2007; Cury et al., 2006; Diaconu-Gherasim, Măirean & Brumariu, 2019). Performance-oriented learning, on the other hand, appears to have a feeble and less consistent relationship with achievement (Cury et al., 2006).

In a meta-analysis ($k = 113$; $N = 28,22$) across different achievement domains, Burnette and her colleagues (2013) found that a growth mindset was positively related to mastery goals (mastery-approach goals, $r = .18$ and mastery-avoidance goals $r = .04$) and negatively related to performance goals (performance-approach goals $r = -.61$; performance-avoidance goals $r = -.18$). The results from this study suggest that individuals holding a growth mindset show a tendency to set mastery goals instead of performance goals.

1.1.4 Implicit Beliefs of Intelligence and Situational Interest

A growth mindset can also facilitate the development of situation interest, in particular in relation to corresponding changes in goal orientations. The abovementioned achievement goals also play a role in interest development. Goal orientations, in particular mastery-goal orientation, has positive effects on interest in a learning environment, and stimulates learners to further develop their interest (Harackiewicz et al., 2002; Harackiewicz, Durik, Barron, Linnenbrink-Garcia & Tauer, 2008). O'Keefe, Dweck and Walton (2018) found that students who endorse a growth mindset towards interest development are likely to express greater interest in new areas and are able to maintain greater interest when materials become more complex and challenging. Relatively unique features of interest are its strong emphasis on the content of learning and the prominent role it plays in understanding the complex reciprocity between motivation, cognitive learning processes and learning performance (Hidi, Renninger & Krapp, 2004; Schiefele, 2009). Hence, understanding the factors that may cultivate the link between adopting a growth mindset and the development of interest in order to promote learning performance, is crucial for educational researchers and practitioners alike. Interest development theories such as the four-stage interest development theory proposed by Hidi and Renninger (2006; also see Renninger & Hidi, 2015) distinguish two major concepts of interest: individual interest and situational interest. Individual interest has a dispositional quality, residing in the person and relatively stable across situations. In contrast, situational interest gradually emerges in response to features in the

environment and involves focused attention, increased cognitive functioning, persistence, affective involvement and curiosity (Hidi, 2000; Linnenbrink-Garcia et al., 2010). Since situational interest is seen as a critical factor in the development of individual interest (Grund, Schäfer, Sohlau, Uhlich & Schmid, 2019), the focus of the present study lies on situational interest, which will be described in more detail in the following. Situational interest (SI) is known to comprise both an attentional and affective reaction to the situation and can be further differentiated into triggered-SI and maintained-SI. Triggered -SI involves situation-initiated interest and is heightened by affective experiences individuals associate with the environment, such as the presentation of course material (Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006). If sustained, triggered-SI can lead to maintained-SI, which is a more developed form of situational interest in which learners begin to build and maintain a meaningful and enjoyable connection with the content of the material and realize its deeper significance (Grund et al., 2019; Hidi & Renninger, 2006). Maintained-SI can be further decomposed into feeling-related components (maintained-SI feeling), reflecting the extent to which the presented course material is experienced as enjoyable and engaging, and value-related components (maintained-SI value), reflecting the extent to which the material is viewed as important and valuable (Schiefele, 2009; Linnenbrink-Garcia et al., 2010). Together, triggered-SI, maintained-SI value and maintained-SI feeling represent students' general perceptions and reactions to the classroom context, and has shown to predict academic performance (e.g., Bernacki & Walkington, 2018; Linnenbrink-Garcia et al., 2010;). For instance, Burnette et al. (2019) investigated if adopting a growth mindset could increase interest and improve academic achievement in computer science. The mediated effect was small, but significant, for performance 95% CI [0.02, 0.09], and career interest, 95 % CI [0.05, 0.20]. The current study investigated whether an induced growth mindset also could foster a development in interest in the learning context which, in addition, might affect cognitive load perception and learning performance.

1.1.5 The Cognitive Load Theory
To date, the research demonstrating the link between implicit beliefs of intelligence and achievement has been somewhat inconsistent in terms of magnitude, with the effect being stronger under certain intervention conditions. To provide a better insight into how implicit beliefs of intelligence might affect learning and the conditions under which experimental manipulation can be used to improve learning performance, it is of practical and theoretical interest to look at the cognitive processes which take place when students work on a task, learn, or solve a problem. The Cognitive Load Theory (CLT) is based on how these cognitive processes work and provides a theoretical foundation for developing instructional designs that take into account the limited space in the working memory, exploiting the opportunity for learning to the greatest possible extent (Sweller, 1994, 1999; Sweller & Chandler,

1994), and building mental schemas in long-term memory (Van Gerven, 2002; Van Merriënboer & Sweller, 2010).

Cognitive load imposed on the working memory by assessment factors are mental load, mental effort and performance (Paas, Van Merriënboer & Adam, 1994). Mental load is a task-centered dimension imposed by the task or environmental demands, indicating the cognitive capacity which is needed to process the complexity of a task, or the interaction between the learning task and the subject features (Krell, 2017). Mental effort on the other hand, is a human-centered dimension and refers to the individual's invested cognitive capacity while working on a task. The level of performance is considered the learner's achievement (Paas, Renkl & Sweller, 2004). More recent development of the CLT theory further distinguished cognitive load into three categories depending on its function (Paas et al., 2004; Sweller, 2011; Sweller, Van Merriënboer, & Paas 2019; Van Merriënboer & Sweller, 2005). The first category is called intrinsic cognitive load (ICL). This load refers to the complexity of the instructional information being processed, which is related to the number of interacting elements in a task (Sweller, 2011; Valcke, 2010). The second category is called extraneous cognitive load (ECL). This load is imposed solely because of the instructional procedures being used and is under many circumstances irrelevant or unnecessary and does not contribute to, or even hinders the learning process (Kirschner, 2002; Sweller, 2011). Finally, germane cognitive load (GCL) is the third category that first was assumed to refer to the working memory recourses that learners use to deal with intrinsic cognitive load, which leads to effective and deep learning (Knörzer, Brünken & Park, 2016; Moreno & Park, 2010). However, instead of considering GCL as a contributor to the overall load by substituting for ECL as previously thought (Sweller, Van Merriënboer, & Paas, 1998), it is currently proposed that GCL redistributes working memory sources from extraneous, or irrelevant activities, to activities directly relevant to learning by dealing with information intrinsic to the learning task (Sweller, Van Merriënboer & Paas, 2019).

1.1.6 Implicit Beliefs of Intelligence and the Cognitive Load Theory
It has been suggested that cognitive load perceptions are affected by motivation and affect, enhancing learning performance (Paas & Van Merriënboer, 1994). For example, Moreno and Mayer (2007) hypothesized that affective, motivational factors are crucial for students to engage in generative processing. Also, recent studies have begun to show a connection between positive emotions and a decline in perceived task difficulty (Plass & Kalyuga, 2019). Since learners who adopt a growth mindset are more likely to remain involved in their learning, show persistence and embrace a more positive perception on task difficulties (Dweck & Master, 2008, b), it is plausible that they will experience lower ICL and ECL. Subsequently, GCL is expected to increase, because of learners' engagement and effort to redistribute extraneous activities to intrinsic factors relevant to learning.

So far, Cook, Castillo, Gas and Artino (2017) are the first researchers who investigated the link between cognitive load, the implicit theory of intelligence and achievement goals. The objective of their study was to evaluate the validity of instruments' scores from the Implicit Theories of Intelligence Scale (ITIS) (Dweck, 2000), the Achievement Goal Questionnaire-Revised (AGQ-R) (Elliot & Murayama, 2008) and the Cognitive Load Index (CLI) (Leppink, Paas, Van der Vleuten, Van Gog & Van Merriënboer, 2013). In their study, Cook et al. (2017) invited secondary school students ($N = 232$) to participate in a half-day medical simulation-based activity. After completing the ITIS and the AGQ-R, the students rotated among seven stations replicating several clinical scenarios. Then, the students filled in the CLI. At one station, the students were allowed to repeat a clinical procedure as often as they desired within the allotted time. The number of repetitions was used to estimate task persistence (i.e., a behavioural index of motivation). The results showed that a growth mindset was moderately correlated with mastery-approach goals ($r = .34$). Also, both a growth mindset and mastery-approach goals were negatively related to ECL (resp. $r = -.24$ and $r = -.17$), but positively related to GCL (resp. $r = .44$ and $r = .48$). There was no relationship found between a growth mindset and mastery-avoidance goals ($r = .00$). Furthermore, a growth mindset was slightly negatively related to performance-avoidance goals ($r = -.02$) and, unexpectedly, positively related to performance approach goals ($r = .18$). The overall findings largely support the validity of the three instruments. However, this study was correlational in design, thus gives limited validity in drawing a causal relationship between these variables (Field, 2013).

In the current randomised, double blind and controlled experiment, a more causal relationship between this recent developed connection between cognitive load, motivation and learning performance was examined.

1.2 Hypotheses

From both practical and theoretical perspective, it is of importance to enhance the ability to measure, improve and optimise motivation to learn. Therefore, the aim of the present experimental study was to investigate how the effect of a growth mindset facilitates effective learning by assessing the effect of an experimenter manipulated growth mindset on achievement goals, situational interest, cognitive load, and learning performance. The following hypotheses are based on the relationships that have been examined and supported by the past research reviewed above.

Hypothesis I: Participants in the experimental condition will show higher growth mindset ratings on the ITIS than participants in the active control condition, suggesting a successful manipulation of a growth mindset.

Hypothesis II: Adopting a growth mindset has effects on achievement goals.

(a) Participants in the experimental group will report higher mastery-approach goal ratings, compared to participants in the active control group.

(b) Participants in the experimental group will report higher mastery-avoidance goal ratings, compared to participants in the active control group.

(c) Participants in the experimental group will report lower performance-approach goal ratings, compared to participants in the active control group.

(d) Participants in the experimental group will report lower performance-avoidance goal ratings, compared to participants in the active control group.

Dweck (2000), Dweck and Leggett (1988) and Teunissen and Bok (2013) found that goal orientations reflect learners' underlying implicit beliefs about their intelligence and that adopting a growth mindset predicts higher mastery-approach goal setting. The abovementioned hypothesis is based on the findings by Burnette et al. (2013). However, the avoidance exercise construct is relatively new to the achievement goal theory, and previous research has not yet provided conclusive evidence about its distinctiveness (e.g., Cook et al., 2017; Hart, Mueller, Royal & Jones, 2013; Strunk, 2014). The evidence accumulated thus far on holding a growth mindset and the avoidance goal construct is limited and somewhat inconsistent.

Hypothesis III: Adopting a growth mindset will have an effect on situational interest.

(a) Participants in the growth mindset condition are expected to report higher triggered-SI compared to participants in the active control condition.

(b) Participants in the growth mindset condition are expected to report higher maintained-SI-feeling compared to participants in the active control condition.

(c) Participants in the growth mindset condition are expected to report higher maintained-SI-value compared to participants in the active control condition.

Learners who adopt a growth mindset report that they value learning to a greater extent (Dweck, 2000), and that they hold a more positive attitude towards their academic efforts (Aronson et al., 2002). These feelings of belonging and enjoyment are important to enhance interest. Thus, participants in the growth mindset group are expected to display and maintain more situational interest.

Hypothesis IV: Adopting a growth mindset has effects on cognitive load perceptions.

(a) Participants in the growth mindset condition are expected to report lower ICL compared to participants in the active control condition.

(b) Participants in the growth mindset condition are expected to report lower ECL compared to participants in the active control condition.

(c) Participants in the growth mindset condition are expected to report higher GCL compared to participants in the active control condition.

It has been suggested that motivation factors may facilitate learning by investing cognitive load in meaningful learning processes (Moreno & Mayer, 2007). To date, there has been limited research investigating motivation and cognitive load (see Cook et al., 2018). It is expected that adopting a growth mindset is associated with lower ICL and ECL, and higher GCL (resp. *hypothesis IV a*, *IV b*, and *IV c*). The reason is that learners with a growth mindset are likely to show higher motivation to engage in learning (e.g., adopting mastery learning goals), lower attribution to task difficulty, and less focus on instructional design factors that do not facilitate knowledge acquisition.

Hypothesis V: Participants in the experimental condition will score higher on the comprehension and transfer test compared to participants in the active control condition.

Since students who adopt a growth mindset are expected to show persistence, high achievement strivings, higher germane processing and motivation to learn (Blackwell et al., 2007; Moreno & Mayer, 2007), it is assumed that the participants in the growth mindset group will outperform the participants in the active control group regarding both the comprehension and transfer test.

2. Method

2.1 Design

In this double blind, lab-controlled and 'between-subjects' design experiment, participants were randomly assigned to either the experimental condition or the active control condition to answer the abovementioned research hypotheses. The experimental condition was operationalized as the predictor. The achievement goals, situational interest, the cognitive load perceptions and the learning performance were treated as the outcome of this experimental study. Prior knowledge was treated as a covariate. All conditions were measured by either questionnaires, reading or writing tasks.

2.2 Participants

An a priori power analysis indicated that 128 participants were needed for this experiment to have a moderate effect size ($d = 0.50$), for power = 80%, and type I error rate = 5%. In total, 141 students participated in the current experiment. One participant with a high prior knowledge score (8) on the Doppler effect was excluded from the experiment. Two further participants were excluded as they did

not complete the experiment. Thus, the final sample consisted of 138 participants with a mean age of $M = 16.0$ ($SD = .74$). There were 50 male, 84 female, and 4 non-binary participants, which were all 10th grade students in higher general secondary education. This is the same age group as used in the study by Yeager et al. (2016). Each participant was randomly assigned to either the experimental group ($n = 69$), or the active control group ($n = 69$). The participants were recruited from two similar comprehensive public high schools that work closely together through a partnership. These schools are situated in two mid-sized cities in the North-eastern part of the province Groningen in the Netherlands. School one serves approximately 570 students in higher general secondary education and the at-large school population is 47 % male and 53 % female. School two serves about 730 students in higher general secondary education and the at-large school population is 48 % male and 52 % female.

2.3 Materials and Measures

The materials that were used before and after the experiment contained an information letter, a consent form for the students and the schools, and a debriefing letter.

During the experiment, the paper-based materials consisted of two reading texts with accompanying questions, writing tasks and several questionnaires.

Materials. To induce a growth mindset, the materials for the experimental condition consisted of a scientific article titled "You Can Grow Your Intelligence", (adapted from Blackwell et al., 2007; Paunesku et al., 2015; Yeager et al., 2016) and an interactive "Saying-is-believing" writing assignment (see Aronson et al., 2002; Burnette & Finkel, 2012; Yeager et al., 2016) which contained writing a letter to another student who is struggling with learning a difficult subject. The materials for the active control condition consisted of an article only about the function of the brain and a summary writing assignment (adapted from Yeager et al., 2016). The materials used in both conditions are presented in Appendix A.

In this experiment, all participants performed the same multimedia instructional reading task to learn about the Doppler effect (adapted from Fiorella & Mayer, 2014). This reading task consisted of two single-sided pages of both text and illustrations regarding travelling sound waves (see Appendix B), and was accompanied by one open-ended comprehension question, and three open-ended transfer questions.

Measures. To verify participants' low prior knowledge of the Doppler effect, one self-rating item ("How much knowledge do you already have of the Doppler effect?") was posed that could be rated on a nine-point Likert scale from (1) very little to (9) very much ($M = 1.83$, $SD = 1.16$). Additionally, an eight-item checklist (e.g., ''I have taken a college course in physics'' and ''I know what Hz means'') was administered to confirm low prior knowledge on this topic ($M = 4.72$, $SD = 1.98$). Both questions were previously administered by Fiorella and Mayer (2013, 2014) in order to

determine prior knowledge on the Doppler effect.

Dweck's established Implicit Beliefs of Intelligence Scale (ITIS) (Dweck, 2000) was used to measure students' implicit beliefs of intelligence. The scale consists of four fixed mindset statements (e.g., "You have a certain amount of intelligence, and you can't really do much to change it") and four growth mindset statements (e.g., "No matter who you are, you can significantly change your intelligence level"). Participants rated the statements using a six-point Likert scale from (1) completely disagree to (6) completely agree. The two subscales were highly correlated ($r = .82$), and therefore combined into one scale. The internal consistency reliabilities were high for the baseline, Cronbach's $\alpha = .92$, and also for the manipulation check, Cronbach's $\alpha = .93$.

In order to measure achievement goal orientation, the Achievement Goal Questionnaire-Revised (AGQ-R) (adapted from Elliot & Murayama, 2008) was used. This is a twelve-item instrument measuring mastery-approach goals (e.g., "My aim is to completely master the Doppler effect"), mastery-avoidance goals (e.g., "My aim is to avoid learning less than I possibly could"), performance-approach goals (e.g., My goal is to perform better than the other students"), and performance-avoidance goals (e.g., "My aim is to avoid doing worse than other students"). Response options comprised a five-point Likert scale from (1) strongly disagree to (5) strongly agree. The three subscales mastery-approach goals, performance-approach goals and performance-avoidance goals reported high reliabilities, resp. Cronbach's $\alpha = .87$, Cronbach's $\alpha = .82$ and Cronbach's $\alpha = .89$. The mastery-avoidance goal subscale reported lower reliability, Cronbach's $\alpha = .69$.

The Situational Interest Scale (SIS) (adapted from Linnenbrink-Garcia et al., 2010) was used to measure situational interest. This scale consists of fourteen items measuring the subscales trigered-SI (e.g., "I enjoy the Doppler effect learning phase"), maintained-SI-feeling (e.g., "I'm excited to learn about the Doppler effect") and maintained-SI-value (e.g., "I think the Doppler effect is an important subject"). The items can be rated on a seven-point Likert scale from (1) strongly disagree to (7) strongly agree. The internal consistency reliabilities were high for triggered-SI, Cronbach's $\alpha = .79$, maintained-SI-feeling, Cronbach's $\alpha = .79$ and for maintained-SI-value, Cronbach's $\alpha = .87$.

Cognitive load was assessed by task difficulty, mental effort, as well as ICL, ECL and GCL. To assess perceived task difficulty, one item (e.g., "The question that I just answered was:") was measured using a nine-point Likert scale for the responses, ranging from (1) very, very easy to (9) very, very difficult (Kalyuga, Chandler, & Sweller, 1999). Perceived mental effort is also one item (e.g., "In the question that I just answered, I invested:") that was measured using a nine-point Likert scale for the responses, ranging from (1) very, very low mental effort to (9) very, very high mental effort (Paas, 1992)[1]. Although both the task difficulty and the mental effort scales are widely used,

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[1] Analyses on task difficulty and mental effort are not presented in the current study, because these items were added for exploratory reasons. However, further information can be made available for interested requests.

they are limited, because they provide only an overall concept of cognitive load that does not reflect its multidimensional character (Makransky, Terkildsen & Mayer, 2019). Therefore, indicators of ICL, ECL and GCL, were measured by the psychometrically validated Cognitive Load Index (CLI) (Leppink et al., 2013). This questionnaire includes three items on ICL (e.g., "The text that I just read was very complex"), three items on ECL (e.g., "The text was full of unclear language") and three items on GCL (e.g., "The text really helped me to increase my knowledge and understanding of the Doppler effect"). However, the ICL dimension focuses primarily on situations where overly complex is experienced. To be able to differentiate better between the measures of cognitive load, two more items were added to the ICL ("The Doppler effect was easy to learn" and "When reading the text, I had to retain many things simultaneously in my mind") (adapted from Klepsch, Schmitz & Seufert, 2017). The items were rated on an eleven-point Likert scale from (0) not at all to (10) totally. The ICL and GCL had high reliabilities, resp. Cronbach's α = .87 and Cronbach's α = .95. The ECL had lower reliability, Cronbach's α = .66. Finally, when looking at learning performance, transfer is highly related to comprehension. In the case of comprehension, the learned task is examined during testing, representing remembering, rote learning and adding new information to the construction of knowledge schemas. Subsequently, in the case of transfer, the learned task is applied in novel situations, representing adaptive learning strategies such as deep and effective learning, which is related to higher germane processing (Knörzer, Brünken & Park, 2016; Moreno & Park, 2010). Hence, learning performance was assessed with one open-ended question for comprehension ("Explain how the Doppler effect works") and three open-ended questions for transfer (e.g., "The Doppler effect can also be applied to another scenario, for example the movement of ocean waves. Imagine there is a ship at sea. The wind is picking up and there are many waves. Every second, another wave arrives at the prow (the front) of the ship. Now imagine the ship starts navigating against the direction of the waves. What will happen with the time between two waves that arrive at the prow? Explain your answer"). The questions were scored based on the knowledge points answered by students (for details see rubrics presented in Appendix C). Two raters independently rated the answers from 25 % of the participants. The interrater reliability was Cronbach's α = .97 for comprehension and Cronbach's α = .87 for transfer. Because the range of the score points for transfer was 0 to 6, Pearson's correlation was also calculated, r = .98 One rater completed the remaining 75% of the given answers. Both raters were able to remain blind to the experimental and control conditions, because it was possible to disconnect the performance test pages from the rest of the experimental materials.

2.4 Procedure

All experimental materials were translated into Dutch with assistance from a professional translator. Physics teachers of the two participating schools were consulted to make sure that the students had not

been taught the Doppler effect prior to this experiment. Next, all 10th grade students (approximately *n* = 350) in higher general secondary education in the contacted schools were invited to participate in the experiment through the electronic learning environment of the schools. A week later, an information letter and a consent form were handed out during an oral invitation by the experimenter one week prior to the experiment. With this, all participants were informed about the procedure of the current experiment and were asked to give their consent. To stimulate participation, a gift card of € 30, - was raffled. The experiment altogether took about 45 minutes for both groups to complete and was situated in a classroom setting during a regular mentor lesson. The experiment was conducted in seven separate sessions, consisting of 11 to 25 participants per session. Before the experiment started, participants entered the classroom and handed over the signed consent forms to the experimenter. They were asked to randomly sit down at a table on which there already lay a pencil, eraser, the briefing letter and either the experimental, or the control condition paper-based materials. Both conditions were blind to the experimenter and the participants. These conditions remained blind to the experimenter throughout the entire experiment, since no situation occurred where the conditions were exposed to influence the randomisation process.

The participants read the briefing letter together with the experimenter who read aloud. After reading, participants were given the opportunity to enter their e-mail address on a separate piece of paper for a chance to win the gift card. The email addresses were collected separately before the experiment started. The paper-based materials of both conditions consisted of four phases which were all in a plastic folder on the upper left side of each table. The participants were asked to take out one phase at the time and leave the remaining phases unopened in the folder until they were asked to take the next phase out. The participants placed each finished phase on the upper right side of their table, so the experimenter could collect every phase separately during the experiment. Because there was a certain time frame for the parts in each phase, it was made clear by means of a signal that participants could complete to go to the next part.

In the first phase, all participants were again made aware of the procedure and were asked to fill in demographic data, their prior knowledge of the Doppler effect via the eight-item checklist, and the ITIS.

During the second phase, participants in the experimental group read "You can grow your intelligence" and then were asked to write the "Saying-is-believing" assignment. Participants in the active control group read about the function of the brain and then were asked to write a summary of that text. Afterwards, both groups filled in the ITIS for the second time.

In the third phase, all participants filled in the AGQ-R and then performed the reading task on the Doppler effect.

Finally, in the fourth phase, all participants filled in the Situation Interest Scale, the mental effort and

task difficulty items and the CLI. Then, the comprehension question and the three transfer questions were posed. After each question, participants were asked to rate perceived mental effort and task difficulty.

2.5 Data-Analysis

One-way Univariate analyses of variance (ANOVA) and Pearson's chi-square tests were used to determine whether the experimental group and the active control group were comparable regarding age, gender, prior knowledge, and the growth mindset at baseline (randomisation check).
A mixed ANOVA was used to ascertain whether there was a difference within and between the two conditions regarding the baseline and the post-test.
One-way Univariate Analyses of Covariance (ANCOVA) with prior knowledge as a covariate were conducted to analyse the effect of a growth mindset on achievement goals, situational interest, perceived cognitive load, and subsequently, performance. An ANCOVA can reduce the within-group error variance, increasing statistical power (Field, 2013). Prior knowledge was used as a covariate since it has been shown to affect perceived cognitive load and learning performance (Chen, Kalyuga & Sweller, 2017). Before the main analyses were performed, the assumptions of ANCOVA's were assessed[2].
Partial η^2 was used as an effect size, representing the proportion of variance explained by a specific predictor, which was not explained by other independent variables. A partial η^2 of .01 is considered to have a small effect, a partial η^2 .06 is considered to have a medium effect, and a partial η^2 bigger than .14 indicates a large effect (Richardson, 2011).
A 95% confidence interval was applied so that in 95% of the sample used in this experimental study, the true value of the population mean would fall within its limits (Field, 2013).

3. Results

In the current study, a sample of 138 10th grade participants was randomly divided over the experimental condition ($n = 69$) and the active control condition ($n = 69$) to examine the effects of an induced growth mindset on motivation, perceived cognitive load, and performance. Sample means and standard deviations, as well as ANOVA and ANCOVA of all relevant variables regarding values in both the experimental and the active control group, are displayed in Table 1. Additionally, correlations

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[2] Linearity between the covariates and the dependent variable for each level of the independent variable, homogeneity of regression slopes, normality of within group residuals, normality of the overall model residuals, homoscedasticity, homogeneity of variances and no outliers were assessed. In the case that one or more assumptions appeared violated, it is reported prior to the results of the analysis concerned with measures taken to improve interpretability of the results.

among all relevant variables are presented in Table 2. All variables were normally distributed based on skewness and kurtosis statistics (between -3 to 3; see Table 1). Also, a visual inspection of the Q-Q Plot confirmed that all variables were approximately normally distributed.

In the following, the results of the randomisation check and the manipulation check are reported. Then, the main analyses of the effects of the induction of a growth mindset are reported on achievement goals, situational interest, perceived cognitive load and learning performance.

Randomisation Check

The experimental group ($n = 69$) consisted of 34.8% boys, 62.3% girls and 2.9% non-binary participants, and the active control group ($n = 69$) consisted of 37.7% boys, 59.4% girls and 2.9% non-binary participants. There was no significant difference in gender between the two groups, Fisher's exact $p = .946$. The mean age of the participants in the experimental group was $M = 15.86$ ($SD = 0.69$), and in the active control group $M = 16.06$ ($SD = 0.78$). There was also no significant difference in age $F(1, 136) = 2.60$, $p = .109$, partial $\eta^2 = .019$. Additionally, there was no significant difference between the two groups for prior knowledge of the Doppler effect with a $M = 4.72$ ($SD = 1.98$) for the experimental group and a $M = 4.91$ ($SD = 2.04$) for the active control group, $F(1, 136) = .302$, $p = .583$, partial $\eta^2 = .002$. With a mean of $M = 30.29$ ($SD = 8.13$) for the experimental group and a mean of $M = 28.99$ ($SD = 8.04$) for the active control group, the growth mindset baseline showed no significant difference between the two groups, $F(1, 136) = 0.89$, $p = .348$, partial $\eta^2 = .006$. In sum, the descriptive statistics regarding gender, age, prior knowledge and the growth mindset baseline were distributed equally across the experimental and the active control condition, indicating a successful randomisation of the two groups.

Manipulation Check (*Hypothesis I*)

In order to test whether the intervention had led to a higher level of growth mindset, the post-test growth mindset scores were compared between the experimental group and the active control group using an ANCOVA analysis, while controlling for prior knowledge. On average, the experimental group reported a higher growth mindset ($M = 35.58$, $SD = 7.07$) than the active control group *($M = 28.12$, $SD = 7.80$; Table 1)*. This difference, the main effect of the intervention, was significant, $F(2, 135) = 36.70$, $p < .001$, partial $\eta^2 = .214$ (Table 1). This statistically significant group difference in mindset ratings indicates a successful growth mindset manipulation. The covariate, prior knowledge, was significantly related to the growth mindset post-test, $F(1, 135) = 4.47$, $p = .036$, partial $\eta^2 = .032$.

To ascertain whether there was a difference within and between the two conditions regarding the baseline and the post-test, a mixed ANOVA was used with *time* as the within subjects factor, and the

intervention groups as the between subjects factor (see Figure 1). The participants in the growth mindset group reported a mean of $M = 30.29$ ($SD = 8.19$) at the baseline and a mean of $M = 35.58$ ($SD = 7.07$) at the post-test. In comparison, the control group reported a mean of $M = 28.99$ ($SD = 8.09$) at the baseline and of a mean $M = 28.11$ ($SD = 7.80$) at the post-test. On average, both groups together scored a significant main effect on time, indicating a difference of a growth mindset between the baseline and immediately after the experimental induction task (Figure 1), $F(1, 136?) = 27.30$, $p < .001$, partial $\eta^2 = .167$.

Also, a significant interaction effect, $F(1, 136) = 53.01$, $p < .001$, partial $\eta^2 = .280$, and a significant between-subjects effect, $F(1, 136) = 12.31$, $p = .001$, partial $\eta^2 = .082$ were found, indicating that the difference was larger in the growth mindset condition in terms of growth mindset belief between the baseline and the post-experimental induction, and that on average the experimental group scored higher on growth mindset belief (Figure 1).
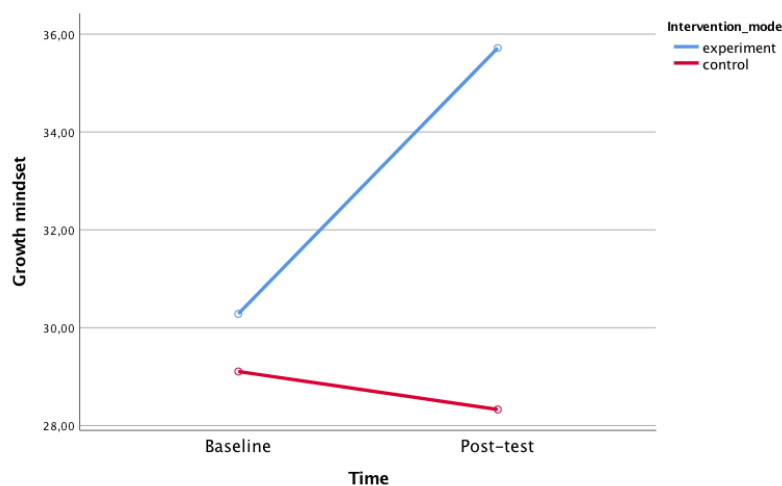

Figure 1. Means of growth mindset belief at baseline and post-test for the experimental and active control conditions.

Achievement Goals (*Hypothesis II*)

      Mastery-Approach Goals. To examine whether the induction of a growth mindset had led to higher mastery-approach goal ratings, the scores between the experimental group and the active control group were compared using an ANCOVA analysis, while controlling for prior knowledge. Participants in the growth mindset condition reported a higher mean score on mastery-approach goals $M = 10.54$ ($SD = 2.63$; Table 1) than participants in the active control condition who scored on average $M = 9.72$ ($SD = 2.57$). After controlling for prior knowledge, the effect of a growth mindset on mastery-approach goal ratings did meet statistical significance, $F(2, 135) = 3.87$, $p = .051$, partial

$\eta^2 = .028$), thus confirming *Hypothesis II (a)*. Prior knowledge also was significantly related to mastery-approach goals, $F(1, 136) = 5.16$, $p = .025$, partial $\eta^2 = .037$.

Mastery-Avoidance Goals. Table 1 shows that participants in the experimental group reported a slightly higher mean ($M = 10.07$, $SD = 2.33$) on mastery-avoidance goal ratings compared to the participants in the active control group ($M = 9.64$, $SD = 2.54$). According to the one-way ANCOVA results, after controlling for prior knowledge, the relationship between a growth mindset and mastery-avoidance goals did not appear to be significant, $F(2, 135) = 1.20$, $p = .275$, partial $\eta^2 = .009$. Prior knowledge was also not significantly related to mastery-avoidance goals.

Performance-Approach Goals. The mean of the participants in the experimental group for performance-goal ratings was $M = 9.90$ ($SD = 2.60$), which was slightly lower than the mean of the participants in the active control group, $M = 9.41$ ($SD = 2.81$; Table 1). One-way ANCOVA revealed that, after controlling for prior knowledge, the expected effect of adopting a growth mindset on performance-approach goals did not show statistical significance, $F(2, 135) = 1.35$, $p = .248$, partial $\eta^2 = .010$. Also, prior knowledge had no significant relationship with performance-approach goals.

Performance-Avoidance Goals. The participants in the experimental group showed higher mean performance-avoidance goals ratings, $M = 10.45$ ($SD = 2.74$) than the participants in the active control group $M = 9.43$ ($SD = 3.19$; see Table 1). After controlling for prior knowledge, the one-way ANCOVA showed that a growth mindset unexpectedly appeared to be positively related to performance-avoidance goals $F(2, 135) = 4.31$, $p = .040$, partial $\eta^2 = .031$. Prior knowledge was not significantly related to performance-avoidance goal ratings.

Situational Interest (*Hypothesis III*)

Triggered-SI. Participants in the growth mindset condition ($M = 24.49$, $SD = 5.36$) reported marginally higher triggered-SI than did the participants in the active control condition ($M = 23.57$, $SD = 5.61$; Table 1). After controlling for prior knowledge, a one-way ANCOVA revealed that adopting a growth mindset did not significantly relate to triggered-SI, $F(2, 135) = 1.18$, $p = .279$, partial $\eta^2 = .009$. Prior knowledge was also not significantly related to triggered-SI.

Maintained-SI Feeling. The mean of maintained-SI Feeling ratings of the participants in the experimental group was $M = 18.20$ ($SD = 5.60$), which was higher than the mean of the participants in the active control group, $M = 16.46$ ($SD = 5.73$; Table 1). A one-way ANCOVA revealed that the relationship between a growth mindset and maintained-SI feeling appeared to be significant after

Table 1

Means and Standard Deviations of all Variables as well as ANOVA and ANCOVA Results of Group Comparisons

		Mean		S.D.						ANOVA			ANCOVA*		
		exp.	control	exp.	control	skew	kurtosis	min	max	F (1,136)	p **	η_p^2	F (2,135)	p **	η_p^2
Prior knowledge		4.72	4.91	1.98	2.04	0.33	-0.54	1.00	10.00	0.30	.583	.002			
Growth mindset baseline		30.29	28.99	8.19	8.09	-0.53	-0.26	8.00	47.00	0.89	.348	.006	1.10	.296	.008
Growth mindset post-test		35.58	28.12	7.07	7.80	-0.48	0.08	8.00	47.00	34.69	**.000**	.203	36.70	**.000**	.214
AGQ-R	Mastery-approach	10.54	9.72	2.63	2.57	-0.73	0.19	3.00	15.00	3.36	.069	.024	3.87	.051	.028
	Mastery-avoidance	10.07	9.64	2.33	2.54	-0.25	-0.09	3.00	15.00	1.10	.297	.008	1.20	.275	.009
	Performance-approach	9.90	9.41	2.60	2.81	-0.28	-0.47	3.00	15.00	1.14	.287	.008	1.35	.248	.010
	Performance-avoidance	10.45	9.43	2.74	3.19	-0.38	-0.47	3.00	15.00	4.02	**.047**	.029	4.31	**.040**	.031
SIS	Triggered-SI	24.49	23.57	5.36	5.61	-0.70	1.19	5.00	35.00	.99	.323	.007	1.18	.279	.009
	M-SI feeling	18.20	16.46	5.60	5.73	-0.50	-0.12	4.00	28.00	3.26	.074	.023	3.93	**.049**	.028
	M-SI value	20.19	19.33	6.87	5.55	-0.11	0.18	5.00	35.00	.65	.423	.005	.93	.338	.007
Mental effort		3.35	3.57	1.61	1.64	0.57	-0.17	1.00	8.00	.618	.433	.005	0.96	.330	.007
Task difficulty		3.57	3.99	1.38	1.48	0.70	1.49	1.00	9.00	2.98	.086	.021	3.74	.055	.027
CLI	ICL	13.07	15.91	9.32	8.58	0.77	0.32	1.00	42.00	3.47	.065	.025	4.71	**.032**	.034
	ECL	3.84	6.61	3.33	4.97	0.99	0.56	0.00	20.00	14.79	**.000**	.098	15.89	**.000**	.105
	GCL	27.83	25.49	8.78	9.83	-0.95	0.37	0.00	40.00	2.16	.144	.016	2.05	.154	.015
Comprehension test		3.19	2.49	1.93	2.10	0.22	-1.11	0.00	7.00	4.09	**.045**	.029	4.93	**.028**	.035
Transfer test		3.46	2.97	1.26	1.32	-0.35	-0.01	0.00	6.00	5.06	**.026**	.036	5.51	**.020**	.039

*Note. ANCOVA analyses included prior knowledge as a covariate.

**Note. Bold and underscored: $p < .01$; bold: $p < .05$.

Table 2

Correlation Matrix of all Variables

Scale		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Prior knowledge																	
2. Growth mindset baseline		.172*															
3. Growth mindset man. check		.138	.748**														
4. AGQ_R Mastery-approach		.182*	.146	.166													
5. Mastery-avoidance		.086	.137	.124	.526**												
6. Performance-approach		.148	.092	.203*	.285**	.320**											
7. Performance-avoidance		.108	.031	.216*	.274**	.368**	.757**										
8. SIS Triggered-SI		.152	.315**	.353**	.478**	.305**	.259**	.234**									
9. Maintained-SI feeling		.229**	.256**	.296**	.609**	.313**	.270**	.204*	.779**								
10. Maintained-SI value		.239**	.249**	.253**	.460**	.223**	.157	.096	.559**	.558**							
11. Mental effort		-.279**	.005	-.034	.096	.061	.041	.050	-.014	-.044	-.005						
12. Task difficulty		-.257**	-.168*	-.246**	-.099	-.013	-.147	-.185*	-.389**	-.340**	-.309**	.432**					
13. CLI ICL		-.329**	-.215*	-.291**	-.062	.051	-.151	-.162	-.401**	-.397**	-.365**	.516**	.752**				
14. ECL		-.153	-.258**	-.435**	-.153	-.067	-.177*	-.164	-.457**	-.342**	-.371**	.258**	.486**	.655**			
15. GCL		-.065	.318**	.351**	.096	.114	.080	.120	.416**	.275**	.300**	.174*	-.130	-.086	-.301**		
16. Comprehension test		.240**	.078	.079	.003	-.088	-.096	-.141	-.055	.000	-.008	-.154	-.144	-.059	.053	-.030	
17. Transfer test		.138	.129	.127	.017	.102	.071	.065	.284**	.186*	.204*	-.002	-.222**	-.316**	-.303**	.191*	.371**

Note. Correlation is significant at the 0.05 level (2-tailed).

**Note*. Correlation is significant at the 0.01 level (2-tailed).

controlling for prior knowledge, $F(2, 135) = 3.93$, $p = .049$, partial $\eta^2 = .028$, thus confirming *Hypothesis III (b)*. Prior knowledge was also significantly related to maintained-SI feeling, $F(1,136) = 8.17$, $p = .005$, partial $\eta^2 = .057$.

Maintained-SI value. Table 1 shows that the participants in the experimental condition reported little higher maintained-SI value ($M = 20.19$, $SD = 6.87$) than the participants in the active control condition ($M = 19.33$, $SD = 5.55$). A one-way ANOVA showed that, after controlling for prior knowledge, the effect of adopting a growth mindset on maintained-SI did not appear to be significant, $F(2, 135) = .93$, $p = .338$, partial $\eta^2 = .007$. Prior knowledge, on the other hand, was significantly related to maintained-SI value, $F(1,136) = 8.47$, $p = .004$, partial $\eta^2 = .059$.

Cognitive Load Perceptions (*Hypothesis IV*)

Intrinsic Cognitive Load. Participants in the experimental condition showed a lower mean ICL ($M = 13.07$, $SD = 9.32$) than the participants in the active control condition ($M = 15.91$, $SD = 8.58$; Table 1). According to the one-way ANCOVA, there was a significant effect of a growth mindset on ICL after controlling for prior knowledge, $F(2, 135) = 4.71$, $p = .032$, partial $\eta^2 = .034$. Prior knowledge had also a significant relationship with ICL, $F(1, 136) = 17.71$, $p = <.001$, partial $\eta^2 = .116$. These findings confirm *Hypothesis IV (a)*.

Extraneous Cognitive Load. Participants in the growth mindset condition reported lower ECL ($M = 3.84$, $SD = 3.33$) than the participants in the control condition ($M = 6.61$, $SD = 4.97$; see Table 1). The ANCOVA revealed that there was a significant effect of a growth mindset on ECL after controlling for the effect of prior knowledge, $F(2, 135) = 15.89$, $p = <.001$, partial $\eta^2 = .105$. These findings support *Hypothesis IV (b)*. The covariate, prior knowledge, also had a significant relationship with ECL, $F(1, 136) = 4.34$, $p = .039$, partial $\eta^2 = .03$.

Germane Cognitive Load. Participants in the growth mindset condition were expected to report higher GCL compared to participants in the active control condition. The experimental condition reported a slightly higher mean ($M = 27.83$, $SD = 8.78$) than the control condition, ($M = 25.49$, $SD = 9.83$; Table 1). The ANCOVA results, however, failed to show a significant difference after controlling for the effect of prior knowledge, $F(2, 135) = 2.05$, $p = .154$, partial $\eta^2 = .015$. Prior knowledge was also not significantly related to GCL.

The Learning Performance Test (*Hypothesis V*)

To ascertain if the participants in the growth mindset condition scored higher on the learning performance test, performance was assessed with a comprehension test and, subsequently, a transfer test, making the answer to *Hypothesis IV* two-fold. A one-way ANCOCVA showed that, for comprehension, the participants in the growth mindset condition ($M = 3.19$, $SD = 1.93$) outperformed

the participants in the active control condition (M = 2.49, SD = 2.10; Table 1), after controlling for prior knowledge $F(2, 135) = 4.93$, $p = .028$, $\eta_P^2 = .035$. The covariate, prior knowledge, was significantly related to the comprehension test, $F(1, 136) = 8.76$, $p = .004$, $\eta^2 = .063$.

For transfer, a one-way ANCOVA affirmed that participants in the growth mindset condition (M = 3.46, SD = 1.26; Table 1) also outperformed the participants in the active control condition (M = 2.97, SD = 1.32), after controlling for prior knowledge, $F(2, 135) = 5.51$, $p = .020$, $\eta^2 = .039$). Prior knowledge was not significantly related to transfer. Both findings for comprehension and transfer confirm *Hypothesis V*.

3. Conclusion and Discussion

As stated in the theoretical frame, the benefit of adopting a growth mindset in order to improve students' academic performance has been proclaimed by both researchers and practitioners in the educational context. While many mindset interventions have shown weak to no effects, research is still lacking in terms of how a growth mindset might interact with the learning process. Therefore, the primary purpose of this experiment was to investigate the effect of a growth mindset on learners' motivation, cognitive load, and subsequent performance during a single learning lesson in a lab-controlled setting. The current research confirmed that students who endorse more of a growth mindset, also endorse a stronger mastery-goal orientation, show more engagement and enjoyment in the learning task, and perceive lower ICL and ECL, ultimately resulting in a positive impact on learning performance. These findings indicate that adopting a growth mindset plays a key role on learners' perception of cognitive load in terms of task complexity and instructional quality and, indeed, is beneficial for learning.

The Growth Mindset Induction

In support of *Hypothesis I*, participants in the growth mindset condition reported a stronger growth mindset belief at the post-test relative to participants in the active control condition. Also, within the experimental condition, participants showed a stronger growth mindset belief after the post-test compared to the baseline. Participants in the growth mindset condition read an article about the malleability of the brain. Then, they were asked to write to a fellow (imaginary) student who could be struggling with learning a difficult subject. To illustrate, in the current study one of the students in the experimental condition wrote: "Dear student, I know that in the beginning it will be hard and maybe even discouraging, but you can certainly do it! As long as you practice and repeat, you can apply what you have learned after a certain amount of time. For example, you cannot perform a somersault if you have never done one before. You can only succeed with a lot of trial and error and, after a while it just works and in hindsight you think: actually, this wasn't difficult at all." This self-persuasion strategy

which fosters learners to embrace a growth mindset, has been used successfully in prior investigations (e.g., Aronson et al., 2002; Burnette & Finkel, 2012; Yeager et al., 2016).

The participants in the active control condition read an article only about the function of the brain, which contained approximately the same amount of words and pictures as the article about the malleability of the brain. Also, the participants in the control condition performed a writing assignment by writing a summary of the article. Because the participants in both conditions carried out similar reading and writing assignments, the comparison of outcomes is more conservative, and thereby increases the validity of the findings in the current experiment.

The Effect of a Growth Mindset Induction on Achievement Goals

After the mindset induction phase, the participants in the growth mindset condition reported a significantly higher mastery-approach goal orientation compared to the participants in the active control condition. These results are in line with previous findings indicating that adopting a growth mindset cultivates mastery-oriented learning goals (e.g., Blackwel et al., 2007; Cury et al., 2006; Diaconu-Gherasim et al., 2019). Although prior studies have indicated that adopting a growth mindset is posited to prompt mastery goals, which are predicted to lead to positive learning outcomes (Blackwel et al., 2007; Cury et al., 2006; Diaconu-Gherasim et al., 2019), mastery-goal orientation failed to significantly correlate with cognitive load, or the comprehension and the transfer test (see correlations, Table 2). Since the conceptual definition of the achievement goal orientation is not only state, but also trait like, which is a more stable and enduring characteristic (e.g., Cellar et al., 2011; Dweck and Leggett, 1988), it is possible that in this single learning lesson experiment, mastery-goal orientation did not directly have an influence on perceived cognitive load. Therefore, it is plausible that the higher mastery-goal ratings of the participants in the experimental group are not associated with the higher ratings in learning performance.

Adopting a growth mindset did not have a significant effect on mastery-avoidance goals, which indicates that participants in the experimental condition were not specifically motivated to avoid situations in which they were unable to learn in order to reach mastery. Although a growth mindset focuses on skill development, this is framed as a learning process rather than an end state in which a kind of "perfection" of knowledge acquisition must be achieved.

Also, the experimental condition did not have a significant relationship with performance-approach goals. Thus, participants in the growth mindset condition were neither negative nor positive about focusing on attaining positive outcomes.

Additionally, participants in the experimental condition unexpectedly scored significantly higher on performance-avoidance ratings. It has been suggested that students who adopt a growth mindset tend to develop a more mastery-goal orientation, and regard performance competing as less important

(Cury et al., 2006; Elliot, 1999; Elliot & Murayama, 2008). Hence, an explanation for this unexpected positive relationship could be that participants in the experimental condition might have wanted to avoid such competition and focus more on developing their skills.

Since the findings of the current experiment and of other studies (Burnette et al., 2013; Cook et al., 2017; Hart et al., 2013; Strunk, 2014) are inconsistent in terms of adopting a growth mindset and the pursuit of achievement goals, additional investigation on the domain construction of the measurement of students' beliefs about mastery and performance goals in relation to a growth mindset is recommended. The current experiment was based on an individual learning task, thus no inter-group dynamic was explicitly fostered in terms of comparison of performance which would have been reflected in performance goals. Future research could implement experimental conditions testing social comparison where participants are made aware of performance of one another.

Furthermore, the four subscales strongly related between themselves, especially performance-approach goals and performance-avoidance goals ($r = .76$; see Table 2). A reason for not being able to confirm *hypothesis II* fully could be that the participants experienced difficulties with interpreting the items of the four subscales as predetermined. For instance, the double negative wording in the avoidance goals construct of the AGQ-R (e.g., "avoid performing poorly" and "avoid learning less") might have been difficult for participants to comprehend.

The Effect of a Growth Mindset Induction on Situational Interest

Participants in the experimental condition did not report significantly higher Triggered-SI ratings compared to participants in the active control condition, which implies that the growth mindset condition did not affect the participants' interest initiated by the peripheral aspects of the multimedia instructional reading task about the Doppler effect. As predicted, participants in the experimental condition reported significantly higher maintained-SI feeling, indicating enjoyment and engagement in the content of the presented reading task. However, adopting a growth mindset failed to significantly predict a relationship with maintained-SI value, which means that the participants in the experimental condition did not significantly view the learning task as important and valuable. In sum, two out of three components of SI failed to show a significant relationship with a growth mindset, which is not entirely in line with the aforementioned prior research on this subject.

It is proposed that triggered-SI refers to individuals association with the environment (Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006). Since the environment (e.g., the presentation of course material) was not altered in the current experiment, it is possible that the presumed relationship with a growth mindset failed to be significant.

The maintained-SI value component of situational interest is considered to be developed overtime, reflecting a deeper and meaningful connection with the learning material (Schiefele, 2009;

Linnenbrink-Garcia et al., 2010). Hence, there is be a possibility that the current single learning lesson experiment might have been too short to have a vigorous impact on the value component of SI. Maintained SI-feeling on the other hand, is a more emotional, temporary way of being in the short term (Grund et al., 2019; Hidi & Renninger, 2006), which could explain why the relationship between a growth mindset and maintained-SI feeling appeared to be significant.

Furthermore, triggered-SI and maintained-SI were measured at a single time point in the current experiment, therefore a causal ordering in these constructs cannot be made.

Additionally, the sub factors appeared to be strongly related, in particular triggered-SI and maintained-SI feeling $r = .78$ (see Table 2), This might reflect a focus on the extent to which the participants in the experimental group became significantly emotionally involved in the learning task, but with less clarity whether the emotional response was emanated from triggered- SI. Also, it is possible that the participants did not interpret the items of the three subscales as intended.

Since SI is posited to relate to goal orientations and to have a positive influence on learning outcomes and increased cognitive functioning (Aronson et al., 2002; Hidi, 2000; Linnenbrink-Garcia et al., 2010), it is noteworthy to mention that all three subscales of situational interest had a significant inverse relationship with ICL and ECL, and a significant positive relationship with mastery-approach goal ratings and the transfer test (see Table 2), which indicates that SI could possibly mediate the effect of an induced growth mindset on learning performance, through more intricate pathways involving further casual relationships with achievement goals.

The Effect of a Growth Mindset Induction on Cognitive Load Perceptions

Although the Doppler effect learning task was identical for all participants who engaged in this experiment, there appeared to be a significant difference in perceived ICL and ECL between participants in the experimental condition and participants in the active control condition. In line with hypotheses *IV a* and *IV b*, the growth mindset induction indeed led to significantly lower perceived ICL and ECL. Since the connection between a growth mindset and cognitive load has only been investigated in an observational design by Cook et al. (2017), the current randomised, double blind and controlled experiment provides stronger evidence of a causal relationship. Furthermore, Cook and his colleagues (2017) invited secondary school students to participate in a half-day medical simulation, which is not an everyday scholastic activity for students. Therefore, a learning task such as the Doppler effect represents a more realistic representation of the curriculum that is taught, providing the current experiment with a stronger ecological validity.

ICL appeared to be relatively strongly correlated with ECL, $r = .66$ (Table 2). This correlation could imply that the two subscales are not interpreted by the participants as intended. Another explanation

could be that, since the prior knowledge on the Doppler effect was low, it was harder for participants to distinguish between ICL and ECL.

Also, ICL and ECL both had a significant inverse relationship with the transfer test (resp. $r = -.32$ and $r = -.30$), which suggests the possibility that cognitive load could play an important mediating role as a cognitive process indicator of transfer.

Adopting a growth mindset did not significantly predict higher ratings in perceived GCL. The definition of GCL has recently been reworded, but still contains some ambiguities (Sweller et al., 2019). It is possible that there could be a discrepancy between the item characterization of the GCL subscale and the definition of germane load. Therefore, conclusions regarding these findings must be interpreted with caution.

Also, GCL was negatively correlated with ICL, $r = -.09$. This modest negative correlation could be explained by the given that lower ICL can release cognitive capacity that can then be administered as germane or relevant load (Cook et al., 2017).

The Effect of a Growth Mindset Induction on Learning Performance

With regard to aforementioned associations between a growth mindset and learning performance, the findings in the current investigation are consistent with the theory-based predictions. Participants in the experimental condition significantly outperformed participants in the active control condition in reference to both the performance and the transfer test. The results of the current experiment are the first to confirm that endorsing more of an incremental theory of malleable intelligence can boost learning performance after a short lesson. An explanation for this outcome could be that in the current investigation the induced growth mindset occurred immediately prior to learning and lasted in all probability up to and including the performance test. This in contrast to the longer lasting field interventions included in the meta-analysis by Sisk et al. (2018) in which the induced effect possibly lessened in due course. Thus, for future mindset interventions to be more effective, it might be advisable to embed the induction of a growth mindset in closer proximity to the learning activities of the students.

Furthermore, the present study was based on one learning task about the Doppler effect with accompanying questions and knowledge points to score the answers. This novel approach differs from the abovementioned field interventions, which are namely based on average grades that students achieve on school subjects. Therefore, it is possible that growth mindset interventions are more effective for certain subjects or measures. In follow-up research, it may be important to investigate under which specific circumstances mindset interventions thrive best.

3.1 Limitations and Recommended Future Directions

In spite of practical and theoretical applications, there are some limitations that ought to be addressed in future research. First, While the sample for this study (n = 138) exceeded the needed number of 128, the fact that the participants were drawn from only two schools may limit the generalizability of the results. Also, prior studies have indicated that low-achieving students (e.g. Aronson et al., 2003; Blackwell et al., 2007; Yeager et al., 2016) in particular benefit most from growth mindset interventions in terms of improving their academic achievement. Thus, it is of theoretical and policy relevance to replicate these results in other samples and contextual factors in order to further investigate what works best for whom, and under what circumstances.

Second, some high correlations among sub factors within the AGQ-R, SIS and CLI emerged in the current experiment. The high correlation indicates limited differentiation between different facets of a situation, which might be a result of the relatively short duration of the study. Although possible explanations for these patterns have been suggested above, further research is proposed in order to understand how these variables operate sequentially and in unison.

Third, in order to induce a growth mindset, participants in the experimental condition performed a 'Saying-is-believing' writing assignment in which the person perspective was directed towards a third person, namely, another (imaginary) student who was struggling with learning a difficult subject. Participants in the active control group only wrote a summary of the presented reading text. It cannot be entirely excluded that there is a possibility that this person perspective influenced the effects of the current experiment, although the effect might be minimal since the writing assignment was meant to induce a growth mindset and not relevant to the actual learning task. Therefore, it is suggested that future investigations use an active control condition in which a summary is also provided towards a third person to further explain the effects of the person perspective.

Fourth, in the current experiment, the physics learning task about the Doppler effect was used to examine the effects of a growth mindset on cognitive load and performance. Because motivational beliefs are subject-matter specific, the structure of students' engagement varies by topic (Ben-Eliyahu, Moore, Dorph & Schunn, 2018; Bong, 2004). Thus, an increase in motivation for one subject does not automatically mean an increase in motivation for another subject. Therefore, it is of theoretical and practical interest to further examine in what manner growth mindset interventions can also be effective in other school subjects.

Finally, with exception of the effect of an induced growth mindset on ECL, it is of importance to note that the current study results yielded mostly small to medium effect sizes. These results were not unanticipated, since smaller effect sizes are frequently encountered with this type of measurement

(see e.g., McCoach, Gable & Madura, 2013). Still, the effect sizes found in the current experiment exceeded the effects found in the meta-analysis by Sisk et al. (2018).

In the present study, participants subjectively rated their perceived cognitive load immediately after the multimedia reading task about the Doppler effect. Future research could assess the measurement of perceived cognitive load after answering the comprehension and transfer questions. In that way, both the perceived cognitive load and learning performance can be simultaneously used as an indicator of the quality of the constructed schemas, with higher performance and lower perceived cognitive load being indicative for a more effective construction of students' schemas. Also, subjective ratings on cognitive load could provide useful feedback for teachers and instructional designers in order to (re)design instructional materials in a way in which they reduce perceived ICL and ECL. Additional investigation could further determine the conditions under which subjective perceived cognitive load may affect students' use of cognitive recourses during the learning process.

It is proposed in this study that cognitive load perceptions and situational interest could have an indirect effect on the relationship between an induced growth mindset and the transfer test. In future research it may be useful to examine the mediating effect of cognitive load and situational interest in order to establish whether students can benefit from a reduced perception of cognitive load and enhanced situational interest in pursuance of improving their learning performance.

3.2 Implications

The current experiment contributes to the existing literature by allowing researchers and practitioners to begin to understand the process of how mindset interventions can generate meaningful changes in students' learning, which may benefit academic achievement in the longer term. Therefore, it is essential to emphasize the practical implications of these findings. Much of the research conducted in the educational context argue for didactics and pedagogics that are relevant and authentic to students. That being said, instructional designers and educators ought to be prepared to implement instructional principles that are able to manage cognitive load within reasonable threshold and also enhance motivation in order to improve learning performance. For example, to enhance students' growth mindset in learning a difficult subject within the course of physics, the instructional design of course materials could include an interesting story-based instruction that models how famous scientists overcame relevant learning problems through failures and struggles (Lin-Siegler et al., 2016). Also, educators could incorporate videos containing modelling examples of growth mindset messages in their pedagogy (Rattan et al., 2015), or integrate applicable growth mindset messages into the instructional design of course materials in the online school environment. This strategy of adapting and integrating a growth mindset message to the content of course materials could most likely prove to be more effective, by making it possible for students to feel more connected to the specific learning

content, enhance their motivation, perceive lower cognitive load, and improve and sustain their learning performance. Therefore, additional research is required to further investigate the relationship between these variables. In particular, whether the effect of an induced growth mindset on learning performance can be explained by cognitive load.

3.2 Scientific significance

A fundamental question of both theoretical and practical interest is how to enhance students' motivation in learning and learning performance. While both motivation and cognitive load are important predictors of learning, the relationship between motivational processes and cognitive load perceptions has been less understood. To date, very little research has been conducted on the relationship between motivation and cognitive load (Cook et al., 2017). The current experiment contributed to the existing literature by investigating the effect of an induced growth mindset belief on learners' motivation (i.e., achievement goals, situational interest), cognitive load, and subsequent learning performance, in a well-controlled experimental study situated in a classroom setting. This is one of the first studies that has shown how motivation affects cognitive load perception and learning performance during a learning task and has provided first evidence regarding the role of motivation in the cognitive load theory.

3.2 Social significance

Considering that motivation in learning and learning performance has been a topic of discussion for quite some time, it was the aim of this study to provide a better insight in processes involved in effective learning and the context in which it can be implemented effectively. Results from the current study have shed light on the role of motivation in cognitive load and learning performance and bestows useful information for the design of learning materials and environments. In particular, this study can potentially lay out a useful approach to motivate students and enhance their learning performance. Both parents and teachers can gain information on how to support childrens' motivation to learn and to achieve better academically. Future interventions incorporating findings from the current study can be developed for different courses and can be implemented in larger scales in order to promote learning for a wider scope of student populations.

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Control condition
The Neuron, Building Block of the Brain
Your brain looks like an oversized walnut, not much bigger than two clenched fists against each other. What the brain does, is too much to list: it regulates countless activities in your body, processes stimuli and make you think, laugh, remember and much more. How does a soft mass of just over 1 kilogram achieve this? The cell is the smallest unit from which everything that lives, including man, is built. There are different types of cells, each with a distinctive form and function. One of those species is the nerve cell or the neuron: a cell that specializes in receiving and transmitting signals.

Communication
Neurons are found in large numbers in your brain and spinal cord, but they also run like wires, the peripheral nerves, throughout the body.
Everything that happens in the brain is all about communication between the neurons. Billions of electrical and chemical signals are constantly being circulated. Also over longer distances, all the way to the tip of your toes.
The human brain is made up of about 100 billion neurons. These are all present at birth.
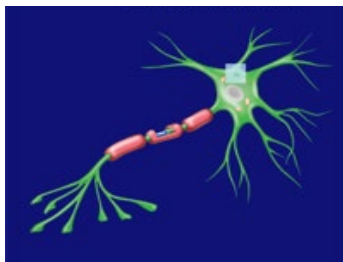
the neuron

Support cells. **1**
The billions of neurons that make up the nervous system have their own support cells: the neuroglia or glial cells. They can be compared with the connective tissue in other organs.
Unlike the neurons, these cells do not transmit electrical signals. Their job is to protect and support the neurons. For example, some support cells destroy microbes, others provide the circulation of the brain and spinal fluid. Yet other support cells form a protective layer that ensures that signals can not jump from one neuron to another.
The nervous system contains more support cells than neurons.

2

Complex networks
Already during the pregnancy, a start is made with the embryo on establishing connections between the neurons. These are suitable for performing a number of basic functions that are required just after birth.
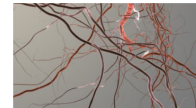
In order to perform all tasks well, large groups of neurons work closely together. As a result, there are specialized areas in the brain, such as for perception (hearing, seeing or smelling) or motor functions (walking or cycling).
The network does not stand still, but always changes.

Neurons do not divide after birth and therefore do not form new cells as happens in other cells. Neurons are able to always make new interconnections: the plasticity.
The plasticity is greatest immediately after birth. Our brains are rapidly adapted to our environment.

Thanks to this adaptability, there is also a chance to recover from a limited brain injury. The complexity of the network - there are many more connections than necessary - makes it possible to build detours if the 'direct route' to certain areas of the brain is closed. In other words, when an area in the brain is damaged, so that a function no longer exists

can be performed, other (unused) areas in the brain can take over this function. This is called: reorganization.
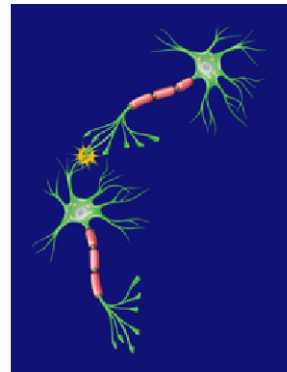
The transmission of signals in the neuron

Construction of the neuron.   **4**

Like other cells, neurons have a cell body with a nucleus. All parts that also provide cell management for other cells are present. The main difference is the form: the cell body of the neuron has a number of offshoots: the neurites. The number of neurites can differ per neuron. Nor can the cell body divide and multiply. If the cell body is damaged, there is a risk that the entire neuron dies.

Core.   **5**

At the core is the genetic code, or the DNA stored, that determines how the cell develops and works. The DNA contains the instructions for everything that happens in the cell, resulting in thousands of chemical reactions. Without these reactions, cells would not be able to perform their tasks.

Assignment: Please write down a short summary about 'The Neuron, Building Block of the Brain':

You can grow your intelligence
New research shows that the brain can develop as a muscle

Many people think that the human brain is a mystery. They do not know much about intelligence and how it works. With the word intelligence, many people think that this means that you are born either smart, average or stupid and that this remains the same throughout your life.

However, new research shows that the human brain works more like a muscle that changes and becomes stronger when you use it. Scientists have succeeded in showing how your brain grows and become stronger as you learn.

The brain

When you exercise and learn new things, parts of the brain change and become bigger, just like muscles change and become bigger when you exercise.

1
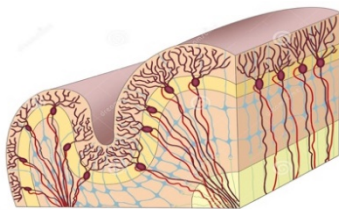
A section of the cerebral cortex

Inside the cerebral cortex there are billions of tiny nerve cells called neurons. These nerve cells have branches with which they connect to other cells in a complex network. The communication between these brain cells makes it possible for us to think and solve problems.
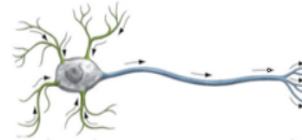

Nervecell or neuron

2

When you learn new things, these small connections in the brain multiply and become stronger. The more you challenge your brain to learn, the more your brain cells grow. Subsequently, the things you first thought were very difficult or even impossible, such as speaking a foreign language or making mathematics, seem to be easier. The result is a stronger, smarter brain.

How do we know that the brain can grow stronger?

Scientists began to think that the human brain could develop and change when they started to examine the brains of animals. They discovered that animals that lived in a challenging environment in which they could train their brains by playing with toys or other animals, were much more active than animals that lived only in bare pens. These active animals had more larger and stronger connections between their nerve cells in their brains. Their brains were about 10% heavier than the brains of the animals that lived only in bare pens. The active animals were also 'smarter', they were better at solving problems and learning new things.

Effect of an enriched environment
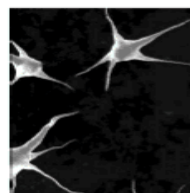
Nerves in brain of animal living in bare cage
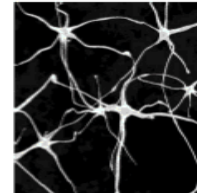
Brain of animal living with other animals and toys.

Children's brain growth

3 Another reason why scientists began to think that brain could grow was: babies. What makes it possible for them to learn to speak the language of their parents in the first few years of their lives? In a sense, babies train their brains by first listening very carefully and then starting to practice talking.

Once children have learned a language, they will not forget them, because learning makes a lasting change in the brain. The brain cells have become larger and new connections have developed between the nerve cells, making the children's brain actually stronger and smarter.

4

Growth of neuron connections in a child from birth to 6 years old
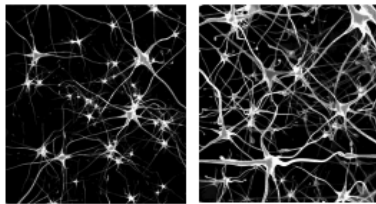
At birth | At age 6

The truth about 'smart' and 'stupid'

No one thinks that babies are stupid because they can't talk. They have not yet learned how to do this. But some people will call others stupid because they cannot solve maths, spell a word, or read quickly - even though all these things can be learned by practicing. The more you learn, the easier it becomes to learn new things.

The key to growing the brain: practice!

Pupils of whom everyone thinks they are 'the smartest' can simply be born without being different from others. But perhaps these 'smart' students have already started practicing reading, for example, before they went to school, so that they could already build their 'read muscles'. Other pupils might learn to do as well with practice.

5

What can you do to become smarter?

Just like an athlete you will have to train and practice. As you practice, you make your brain stronger. You will also learn skills that allow you to use your brain in a smarter way.
Only many people miss the opportunity to make their brains grow stronger because they think they can not, or because it is too difficult. It takes effort, but if you feel that you are getting stronger and better, it is worth it!

Perhaps you have experienced at times that you found a subject, such as for example the effect of sound waves (the Doppler effect) very difficult to learn, but that you succeeded after hard practice and effort. What would you like to say to another student who is really struggling with a subject like this? What would you say to help him or her? Write below:

Dear student, What I'd like to say to you to help you is:

Appendix B

The learning task

The Doppler Effect

Almost everyone has experienced the Doppler Effect, though perhaps without knowing what caused it. For example, imagine you are standing on a street corner as a fire truck approaches with its siren blaring. The perceived pitch of the siren will sound higher as it comes closer to you. Then, as it passes by, the pitch will sound lower. This is one of many examples of the Doppler Effect: the change in how sounds are perceived due to movement.

Sound waves

Why does this change occur? Movement changes the way different characteristics of sound waves are perceived, and therefore, how the sound is perceived. Sound waves have two primary characteristics: frequency and wavelength. As we will see, movement causes changes in how we perceive the frequency and length of sound waves, which ultimately impact how we perceive the sound. First, let's briefly go over each of these characteristics.

Wave frequency

Wave frequency refers to the number of waves passing through a given point during one second. It corresponds to how we perceive the pitch of a sound: if waves occur at a high frequency, they will produce a high pitch; if waves occur at a low frequency, they will produce a low pitch. For example, the cry of a baby has a relatively high pitch, while the sound of thunder has a relatively low pitch. The reason these two sounds are perceived differently is because they have different wave frequencies. Figs. 1 and 2 illustrate the difference between low and high frequency sound waves.
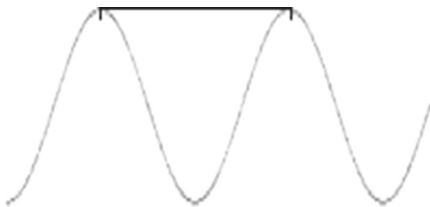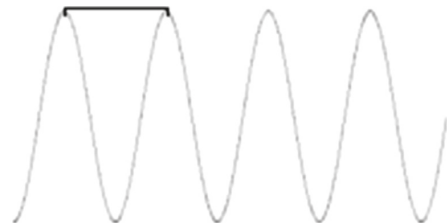
Fig. 1. low frequency sound waves　　　　　　　Fig. 2. High frequency soundwaves

Wavelength

Closely related to wave frequency is wavelength. Wavelength refers to the distance between adjacent waves. As you might expect, longer waves require more time to travel a given distance than shorter waves. Consequently, longer sound waves have a lower frequency and a lower pitch. On the other hand, short sound waves have a higher frequency and higher pitch.

See next page

How the Doppler Effect works

The Doppler Effect is about how movement influences how the frequency and length of sound waves are perceived. To illustrate this, imagine a bug jiggling on the surface of a pond. If the bug is stationary, the waves on the surface of the water around it will be at the same frequency and length in all directions, as in fig. 3. Now suppose that the bug begins moving to the right. The waves it produces become shorter and more frequent to the right of the bug and longer and less frequent to the left of the bug, as shown in fig. 4.
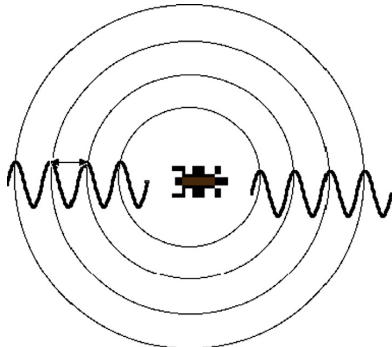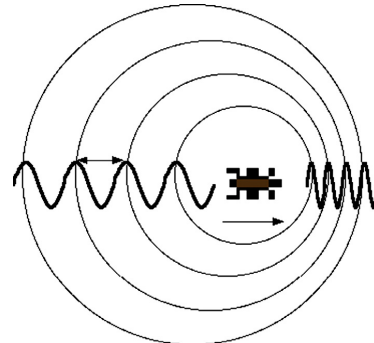
Fig. 3 stationary bug.   Fig. 4. Bug moving to the right.

Now let's relate the bug example to how the Doppler Effect occurs in sound waves. Imagine again that a fire truck is approaching with its siren blaring, as illustrated in fig. 5. As the fire truck approaches, the sound waves between the fire truck and you become shorter and more frequent, resulting in a higher perceived pitch. As the ambulance drives by, the sound waves between the fire truck and you are longer and less frequent. As a result, you will perceive the pitch as getting lower. This is because the movement of the fire truck causes changes in how the sound is perceived. This influence of movement on perceived sound is the core principle of the Doppler Effect.
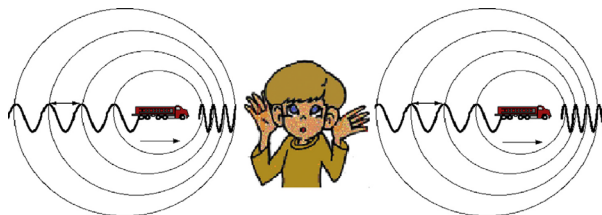
Fig. 5 the Doppler effect soundwaves

Rubrics of Performance Tests

Comprehension question: Explain how the Doppler Effect works.
- As a sound source <u>approaches</u> an observer, the sound waves between the source and the observer:
  A. Increase in frequency (or the waves become more frequent), and
  B. Decrease in wavelength (or the waves get shorter)
- This is because:
  C. The distance between the source and observer is getting shorter and shorter (or the waves are being compressed), and
  D. The time it takes for the sound waves to reach the observer gets less and less
  E. This results in an increasing perceived pitch.
- As the sound source <u>passes by</u> the observer, the sound waves between the source and the observer:
  F. Decrease in frequency (or the waves become less frequent), and
  G. Increase in wavelength (or the waves get longer)
- This is because:
  H. The distance between the source and the observer is getting longer and longer (or the waves are being stretched), and
  I. The time it takes for the sound source to reach the observer gets higher and higher
  J. This results in a decreasing perceived pitch.

Total possible points: 10
Note:"The closer, the higher the frequency" is not correct. The point is that there is movement (or difference in speed), so that distance becomes larger or smaller (this must therefore be ongoing). If both the source and the viewer are stationary, the Doppler effect does not apply.

Transfer question 1: The Doppler effect can also be applied to other situations, such as the movement of water. Imagine: a ship is at sea. The wind is strong and there are many waves. Every second a wave arrives at the bow (the front) of the ship. Now the ship will sail. Against the waves. So in the direction where they come from. What happens to the time between two waves that hit the bow? Explain.

Max 3 points (A=1; B=2)
  o A. The time between two waves approaching the bow becomes shorter (they come behind each other faster)
  o B. Because (1) the distance that the waves have to travel becomes smaller, so that (2) the wavelength becomes shorter and (3) the frequency is higher (1 aspect = 1 point; ≥ 2 aspects = 2 points).

Transfer question 2: In astronomy, we also know the Doppler effect. Light consists of tiny waves. With every different wave length, a different color is associated. The distance between two waves of blue light is smaller than between two waves of red light. (This question consists of part a and b).

Question 2 a: Which color, blue or red, has a higher wave frequency? Explain your answer.

Max 2 points (A = 1; B = 1)

  o A. Blue
  o B. Because blue has a shorter wavelength (smaller distance between waves) than red (only saying something about 'distance is smaller' is not enough. It is about wavelength, or distance between 2 waves).

Question 2 b: When perceived light becomes more blue, we call this *blue shift*. This can also happen in the opposite direction, in which case we call it *red shift*. What happens with the perceived color when the light source moves toward an observer?

Max 1 point

- o Becomes bluer / blue shift (explanation is not required) (answer about intensity is not sufficient).