MASTER'S THESIS

Using Evolutionary Approaches and Growth Mindset to Support Motivation and Lower Cognitive Load in Academic Learning.

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Evolutionaire Benaderingen en Groeimindset Gebruiken om Motivatie te Verhogen en Cognitieve Belasting te Verlagen bij Schools Leren

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Abstract

In evolutionary educational psychology, a difference is made between primary knowledge which is since long related to survival (e.g. food, animals), and secondary knowledge which is only more recently considered culturally necessary (e.g. math, grammar). For secondary knowledge, typically learned at school, our brain is not evolutionary adapted yet, making it more difficult and less motivating to acquire. The current two by two experimental design study explored whether setting an evolutionarily appealing (primary) context in the learning material (as the within factor) and promoting a growth mindset prior to learning (as the between factor) could lower cognitive load and increase motivation and learning performance in academic learning. This randomized controlled study was based on a sample of 101 students performing a foreign vocabulary learning task within a 50 minutes online experimental session. Half of the participants received a growth mindset intervention, the other half functioned as the active control group receiving a neutral task. All participants then studied 16 word pairs with an evolutionary primary context and 16 word pairs with an evolutionary secondary context. An evolutionary primary context lowered cognitive load and increased motivation. The mindset intervention itself proved successful in increasing growth mindset belief and having a growth mindset lowered germane cognitive load. The interaction of evolutionary context and mindset influenced enjoyment: having a growth mindset softened the negative impact of secondary learning context on enjoyment. In sum, the experiment shows promising effects to further explore the evolutionary perspective on increasing motivation in academic learning.

Keywords: evolutionary educational psychology, growth mindset, cognitive load, motivation, learning performance

Samenvatting

In de evolutionaire leerpsychologie wordt een onderscheid gemaakt tussen primaire kennis die al zolang gelinkt is aan overleven (e.g. voedsel, dieren), en secundaire kennis die meer recent cultureel noodzakelijk werd (e.g. wiskunde, grammatica). Voor secundaire kennis, typisch op school geleerd, heeft ons brein zich nog niet evolutionair kunnen aanpassen, wat het moeilijker en minder motiverend maakt om te leren. De huidige studie verkende, in een twee bij twee experimenteel ontwerp, of het toevoegen van een evolutionair aantrekkelijke (primaire) context aan het leermateriaal (als binnenfactor) en het stimuleren van een groeimindset vooraf aan de leertaak (als tussenfactor) de cognitieve belasting kon verminderen en de motivatie en leerprestatie kon verhogen. Deze gerandomiseerde gecontroleerde studie was gebaseerd op een steekproef van 101 studenten die in een 50 minuten durende online experimentele sessie woordenschat leerden in een vreemde taal. De helft van de deelnemers onderging een groeimindset interventie, de andere helft kreeg als actieve controlegroep een neutrale taak. Alle deelnemers studeerden daarna 16 woordparen met een evolutionair primaire context, en 16 met een evolutionair secundaire context. Een evolutionair primaire context verlaagde de cognitieve belasting en verhoogde de motivatie. De mindset interventie zelf bleek succesvol in het verhogen van de groeimindset overtuiging en een groeimindset hebben verlaagde de relevante cognitieve belasting. De interactie tussen evolutionaire context en groeimindset had effect op het ervaren plezier: een groeimindset hebben verzachtte de negatieve impact van een secundaire leercontext. Deze studie laat veelbelovende effecten zien om het evolutionaire perspectief op het verhogen van leermotivatie verder te onderzoeken.

Keywords: evolutionaire leerpsychologie, groeimindset, cognitieve belasting, motivatie, leerprestatie

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Using Evolutionary Approaches and Growth Mindset to Support Motivation and Lower Cognitive Load in Academic Learning

1. Introduction

Every teacher recognizes the challenge of keeping students motivated to learn. According to most recent figures for Flemish secondary schools, 3,57% of all secondary students skips school at least 30 half days per school year (Agentschap voor Onderwijsdiensten, 2019) and 11,9% eventually drops out of school without sufficient qualifications (Departement Onderwijs en Vorming, 2019). Research has shown that students often show a decline in motivation throughout primary to secondary education as they enter formal education (Wigfield & Eccles, 2002). This issue contrasts with the apparent ease of how learning outside school walls typically happens. We do not need to be motivated to learn a complex skill such as speaking the mother tongue, we simply pick it up naturally in daily life.

Within the field of evolutionary educational psychology, this distinction has been defined by the concepts of biologically or evolutionary primary and secondary knowledge. Geary (e.g. 2008) proposed that primary knowledge and skills, such as recognizing faces or speaking the mother tongue, have been indispensable for our survival for so long that the cognitive structure of our brain evolved to make them easy and motivating for us to learn, despite their complexity. Secondary knowledge on the other hand represents the more recent knowledge essential in our rapidly changing modern societies, such as reading or mathematics. Humans' minds are not yet developed to efficiently process and acquire this secondary knowledge, which makes it inherently more difficult and less motivating to learn, and thus more effort and deliberate practice is needed to do so. Schools are created to facilitate the learning of the difficult and unmotivating but culturally necessary secondary knowledge (Geary, 2008), which makes it an important task for teachers to promote motivation and engagement in learning this secondary knowledge (Braver et al., 2014; Cosnefroy et al., 2016).

Pioneering researchers have attempted to implement evolutionary perspectives into instructional design. They showed that an effective strategy to increase motivation in a secondary learning task, such as in solving logical problems, is to incorporate intrinsically motivating primary themes, such as food or animals as context or cover story (Lespiau & Tricot, 2018, 2019). Furthermore, Geary (2008) also suggested that fostering an effort belief might be helpful to overcome the motivational challenges posed by secondary knowledge learning. In particular, interventions that aim to direct students’ beliefs toward effort and ability have shown to promote motivation and achievement (Blackwell et al., 2007). This is more recently framed as the growth mindset theory by Carol Dweck (1999), a belief that regards human intelligence and abilities as the result of effort, not as a fixed state. This suggests that growth mindset interventions might also be an effective strategy to deal with the low motivation associated with secondary knowledge learning. Furthermore, both strategies have shown to help reduce the feeling of cognitive load (an overflow of the limited working memory capacity), foster motivation, and improve learning performance (Lespiau & Tricot, 2018, 2019; Xu et al., 2021). The aim of this study therefore was to investigate how students’ motivation and learning results in academic learning can be improved during a learning task, by adding primary knowledge elements to the learning material and promoting a growth mindset for the learner.

1.1 Theoretical Framework

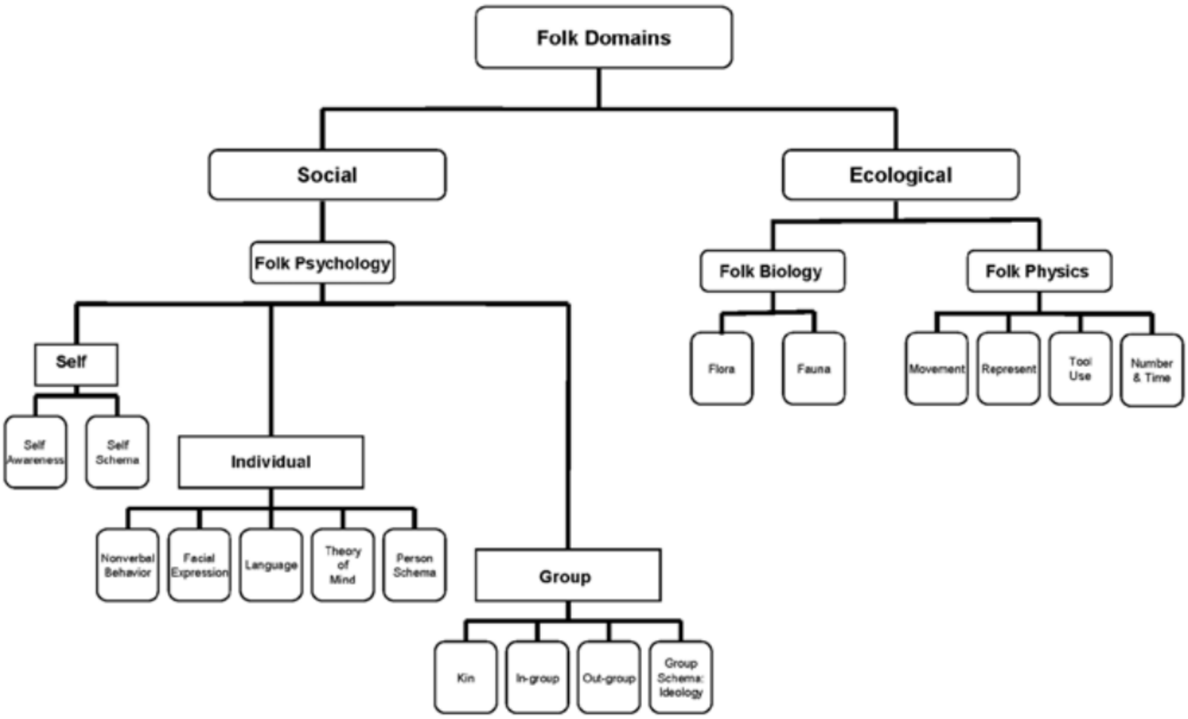
1.1.1 Primary and Secondary Knowledge: An Evolutionary Perspective on Learning

The idea of two different types of knowledge connected to our survival as a species was first posed by David Geary (1995). Drawing on Darwin’s (1859) theory of evolution, Geary outlined a theoretical framework that attempts to determine what social, psychological, cognitive and neural characteristics are typical for humans, and especially how these characteristics were developed and shaped through evolution by genetic and ecological mechanisms to ensure adaptation to local conditions (Geary & Bjorklund, 2000). For example, it is suggested that our memory systems are evolved to better remember information that is critically related to our survival (e.g. Nairne, 2016; Nairne et al., 2008), such as remembering animated objects better than inanimate (e.g. Leding, 2018) because of their relation to predators or prey.

In this theoretical framework universal forms of knowledge and competences are organized in a hierarchical structure of several folk domains. An overview of these folk domains is presented in Figure 1. The social survival knowledge is represented by the folk psychology domain, with skills concerning self-awareness, individual relationships (e.g. facial expressions, facial recognition, language) and group dynamics. The ecological survival knowledge consists of folk biology (e.g. categorizing plants and animals, edibility, danger) and folk physics (e.g. navigating, movement, tool use). These schemes have over time been implanted in our cognitive architecture, so that we are pre-wired to easily learn those types of knowledge, defined by Geary (1995) as *evolutionary primary knowledge*. In many current societies however, other knowledge and skills have been created over centuries and become indispensable, such as reading and writing, mathematics or speaking foreign languages. Unfortunately the cognitive structure in our brains has not had the evolutionary time to evolve and adapt to easily acquire this new but necessary knowledge, which is called *evolutionary secondary knowledge* (Geary, 1995). Therefore in contrast to primary knowledge we do not pick it up naturally, and we are not motivated to learn it as it requires effort to do so (Geary, 2008; Geary & Berch, 2016).

Figure 1

Overview of Evolutionary Primary Knowledge Folk Domains and Competences



Note. From “Evolution and children's cognitive and academic development,” by D. C. Geary and D. B. Berch, in D. C. Geary & D. B. Berch (Eds.), *Evolutionary perspectives on child development and education* (p. 220), 2016, New York: Springer. Copyright 2016 by Springer.

Because of this gap between folk knowledge and the competencies needed for living in the modern world, we need to pass this knowledge on, consciously and deliberately, generation by generation. This cross-generational transferal of knowledge is why schools exist and why universal schooling is only found in technologically and socially complex societies (Geary, 2008; Geary & Berch, 2016). The main aim of formal education in school is therefore to teach culturally important knowledge that we could not learn ourselves or through simple social interactions (Sweller, 2015). This means that knowledge typically learned at school is inherently difficult and unmotivating to the students (Geary, 2008; Geary & Berch, 2016). It is thus important to take into account the evolutionary perspective on knowledge when designing instructional materials in order to promote motivation for learning evolutionarily novel academic knowledge and information in school (Geary, 2008). Below, further theoretical and empirical literature is presented on the motivational and cognitive processes related to learning secondary knowledge.

1.1.2 Motivation and Cognitive Load in Secondary Knowledge Learning

Motivation to learn is also termed as achievement motivation, which is explained as the preference learners have for certain learning tasks and whether and to which level of intensity they are able to persist in these tasks to bring them to a good result (Wigfield et al., 2015). According to evolutionary educational psychology, students' motivation for learning evolutionary secondary knowledge in school is inherently low (e.g., Geary, 2008), and tends to decline over school years (Eccles et al., 1993; Larson, 2000; Wigfield et al., 2015). For example, children report being the happiest while talking to friends, and the least happy when doing homework, listening to lectures and doing mathematics (Hunter & Csikszentmihalyi, 2003). Similarly, high school students consider the weekend the highlight of their week because they can socialize with their peers (Larson & Richards, 1998). This can all be brought back to the evolved primary bias of group formation which gave a better chance for survival (Geary, 2008). While in these examples primary motivational biases interfere with academic learning, recent research suggested that by directly incorporating primary elements into a secondary knowledge learning task, students' motivation and performance on this task can be improved (Lespiau & Tricot, 2018, 2019).

Indeed, the intrinsically motivating primary knowledge can be used to address low motivation of students in academic learning. A fundamental process underlying these strategies is, at least in part, to manage the cognitive load - the working memory load - caused by the process of acquiring the secondary knowledge (Paas & Sweller, 2012; Sweller, 2015; Lespiau & Tricot, 2018, 2019). Many research points at the link between cognitive load and motivational factors in learning. For instance Brom et al. (2018) and Skuballa et al. (2019) found a decreased perceived task difficulty (a measure of perceived cognitive load) with positive emotions or topic interest (measures of higher motivation). Cognitive load theory states that our working memory, where all new information is processed before it can be stored in the long term memory, has a limited capacity and duration for processing information. So in order to learn efficiently, the cognitive load should not exceed working memory capacity, although a certain and manageable amount of load stimulates the learning process (Sweller et al., 2011).

According to cognitive load theory, three cognitive loads can be distinguished: intrinsic load originates from the intrinsic complexity of the task, extraneous load is caused by the external design of the learning task and germane load results from the necessary mental processes needed to transfer the new information from the working memory to the long term memory (Sweller, 2008). The goal of instructional design in secondary knowledge learning is thus to develop instruction in a way that it manages the intrinsic load and reduces excessive and unproductive extraneous load, in order to free cognitive resources for productive germane load only (Paas & Ayres, 2014; Sweller et al., 2011). The human acquisition of primary knowledge and primary knowledge based tasks, on the other hand, incurs only minimal cognitive load (Lespiau & Tricot, 2018, 2019; Paas & Sweller, 2012). Thus it is an important instructional goal to manage the cognitive load during the learning process in order to maintain motivation and facilitate successful learning outcome. Below two approaches are presented and proposed as means to foster motivation, manage cognitive load, and promote learning.

1.1.3 Adding Primary Knowledge Context as a Strategy to Improve Motivation and Learning Performance in Secondary Knowledge Learning

Given our predisposed nature in acquiring and performing primary knowledge tasks, adding primary knowledge content or context to secondary knowledge learning may offer the unique advantage of keeping the learner motivated without inducing additional cognitive load. This could reduce the feeling of cognitive load and make the secondary knowledge learning process easier and more motivating to learn (Paas & Sweller, 2012; Sweller, 2008). Turning to instructional techniques that mimic the spontaneous and unguided character of learning in natural environments, such as child initiated play and self-discovery learning, is an intuitive idea for many teachers to incorporate the positive motivational effect from the primary knowledge based instructional techniques.

Indeed, it has been shown in empirical research as well that primary knowledge can be incorporated to facilitate motivation and learning secondary knowledge (Paas & Ayres, 2014; Paas & Sweller, 2012). Paas and Sweller (2012) reviewed empirical research and proposed the collective working memory effect which indicates that primary knowledge, such as being able to communicate with others and work collaboratively, reduces perceived individual cognitive load while acquiring secondary information because of a shared working memory capacity (e.g., Kirschner, Paas, & Kirschner, 2011; Kirschner, Paas, Kirschner, & Janssen, 2011). Similarly, the human movement effect draws from our natural learning through observation and imitation and sees a lower impact of cognitive load when animations deal with human motor movement (e.g., Höffler & Leutner, 2007). More recently, in a series of experiments, Lespiau and Tricot (2018, 2019) looked more directly at the impact of incorporating primary knowledge context in secondary knowledge learning of solving logical problems. By framing formal logical problems (secondary knowledge itself) in evolutionary salient contexts such as food and animals, learners performed better and reported lower perceived cognitive load and higher motivation and engagement in learning.

The present study aimed to further the Lespiau and Tricot research by partially replicating their study. Although previous research used syllogism solving as the basis of logical problem solving tasks to examine the effect of evolutionary context (Lespiau & Tricot, 2018, 2019), for the current study a novel foreign language learning task was used. This because performance on solving syllogism is also considered a form of cognitive ability indicative of intelligence (Shikishima et al., 2009) and training on cognitive abilities, although it can be improved, is generally not transferrable to other academic settings and domains (Melby-Lervåg et al., 2016). Thus it would be more relevant to examine the potential effects using a learning task that resembles what is typically learned in school context. To this aim, a vocabulary learning task was chosen for the present study. Similar tasks have also been used in previous research on instructional design (e.g., Ariel & Karpicke, 2018) and are therefore considered suitable for the present investigation.

1.1.4 Growth Mindset as a Strategy to Improve Motivation and Learning Performance in Secondary Knowledge Learning

Geary (2008) had specifically emphasized the importance of effort in learning secondary knowledge, thus it is useful to promote learners' belief on the importance of effort. There are intervention strategies that directly target promoting student motivation and effort for school learning, for example from the perspective of growth mindset theory (Dweck & Yeager, 2019). Growth mindset refers to the belief regarding the malleability of human attributes, such as personality or intelligence. Some people see these attributes as unchangeable (a fixed mindset), others believe that they can develop over time (a growth mindset). The growth mindset theory states that the mindset students have regarding their intelligence and ability, impacts their motivation, engagement and learning results. For students with a growth mindset, learning something new is a result of effort, and struggling with new material is seen as a learning opportunity, as a natural step in the learning process. These students are said to maintain a higher motivation for learning and better learning results. In contrast students with a fixed mindset see their level of intelligence and ability as unalterable. As a result, effortful learning is seen as proof that they have reached the limit of their capacities and they avoid putting in effort because this demonstrates low ability. This results in lower motivation to learn new things and ultimately lowering their academic achievement (e.g., Dweck & Yeager, 2019; Xu et al., 2021).

In line with this theoretical perspective, growth mindset interventions have been implemented around the world and have shown to increase students' motivation and effort, and improve learning results (Sisk et al., 2018; Yeager et al., 2019). Since acquiring secondary knowledge requires more motivation and effort (Geary, 2008), using a growth mindset intervention as a strategy to encourage learners to sustain effort may be particularly helpful for success in secondary knowledge learning. Xu et al. (2021) examined the effect of a growth mindset intervention on performing an academic learning task and found a reduction of the perceived intrinsic and extraneous cognitive loads and increased motivation and learning results. They suggested that learners who adopt a growth mindset may have perceived lower intrinsic and extraneous loads because these learners are more focused on controllable factors such as their own effort to improve their learning, instead of uncontrollable factors such as the intrinsic difficulty of the learning task or the extraneous difficulty caused by the design of the learning task. This focus on effort would then redistribute the available cognitive resources in the working memory load to the necessary germane load caused by the process of learning (Xu et al., 2021).

The possible increasing of motivation by a growth mindset intervention was studied by Burnette et al. (2019) by looking at interest specifically as the motivational indicator. They investigated whether a growth mindset intervention could promote interest in a particular field and found that learners in the growth mindset group indeed reported higher interest than learners in the control group. The development of interest has been proposed to emerge in separate but related constructs of individual interest and situational interest (e.g., Hidi & Renninger, 2006), with situational interest posited as the basis for the formation of individual interest (Grund et al., 2019). Thus the present study focused on the former. Specifically, situational interest (SI) can be further divided into triggered-SI and maintained-SI. Triggered-SI relates to affective experiences triggered by the environment, such as how the learning materials are presented (Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006). Maintained-SI occurs when triggered-SI develops further and learners make a more meaningful connection to the materials and see their deeper significance (Grund et al., 2019; Hidi & Renninger, 2006). Maintained-SI (M-SI) further divides into M-SI feeling, which indicates whether the learning materials are perceived as enjoyable and engaging, and M-SI value, which indicates whether the learning materials are perceived as important and valuable (Linnenbrink-Garcia et al., 2010; Schiefele, 2009). The present study also looked at how a growth mindset intervention may affect the learner's reported SI.

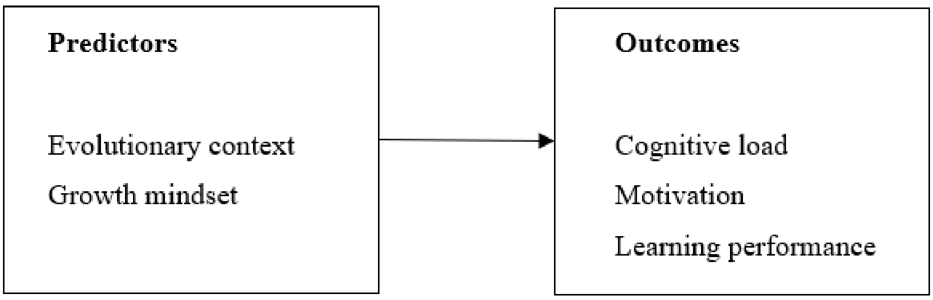
1.2 Current Study

Based on evolutionary educational psychology theory and the growth mindset theory, the present study investigated the effects of using these two approaches on cognitive load, motivation and performance, in a two by two randomized experimental study based on a vocabulary learning task. In the first experimental factor, primary knowledge context was applied to the learning material; whereas in the second experimental factor, a growth mindset intervention was implemented. Based on the research of Lespiau and Tricot (2018, 2019), lower perceived cognitive load, higher motivation and better learning performance were expected for the addition of primary context to secondary learning, because of its evolutionarily motivating and effortlessly processing nature. On the other hand, learners that receive a growth mindset intervention were expected to report lower perceived intrinsic and extraneous cognitive load and higher motivation, based i.a. on research by Xu et al. (2021) and Burnette et al. (2019). Both would in turn positively affect learning performance. Similarly, since both the addition of primary context and the induction of a growth mindset could have an effect on lowering cognitive load, increasing motivation and learning performance, it was expected that the group of learners who received both interventions would report the highest motivation and performance and the lowest cognitive load.

In sum, the main research questions in this study are focused on whether embedding primary knowledge context in learning materials and inducing a growth mindset has an effect on cognitive load, motivation and learning performance. These predictors and outcome variables are pictured in Figure 2.

Figure 2

Predictors and Outcomes in the Current Study



Below hypotheses and research questions are presented by predictor variables, i.e. each individual experimental condition and their interaction. For the main effects, research hypotheses (H) are posed because there is prior research supporting the effect directions. For the interaction effects, research questions (RQ) are posed because there has not been prior empirical research to refer to.

Evolutionary Context (H1 – H3)

- For the learning materials embedded with primary knowledge context, participants will report lower cognitive load (H1), higher motivation (H2) and have higher learning performance (H3).

Growth Mindset (H4 – H7)

- The participants who receive a mindset intervention will report a higher growth mindset (H4).
- The participants who receive a mindset intervention will report lower cognitive load (H5), higher motivation (H6) and have higher learning performance (H7).

The Interaction Between Mindset and Evolutionary Context (RQ8 - RQ10)

- Will the participants who receive a mindset intervention report even lower cognitive load (RQ8), higher motivation (RQ9) and have higher learning performance (RQ 10) for the learning materials embedded with primary knowledge context?

2. Method

This study was set up as an online experiment, based on a mixed two by two within and between subjects randomized controlled experimental design. The within factor was the evolutionary context of the learning materials and the between factor the growth mindset of the participants. For the evolutionary context factor, all participants performed the same vocabulary learning task based on 32 word pairs. Half of the word pairs were concepts related to evolutionary primary context (e.g., animals, fruit), while the other half were related to evolutionary secondary context (e.g., math, grammar). For the mindset factor, half of the participants underwent a growth mindset induction, while the other half performed a comparable control task and thus functioned as the control group. Participants were randomly assigned to one of the conditions.

The outcome variables examined include cognitive load, motivation and learning performance. Cognitive load and motivation were measured by subject ratings on questionnaire items. Learning performance was measured by the results of a word recall test and a word recognition test. Details of these measurements are presented in the measurement section.

2.1 Participants

Based on previous comparable research in an experimental setting on growth mindset or evolutionary context (e.g., Lespiau & Tricot, 2018, 2019; Xu et al., 2021), a target sample size of 130 was determined. This sample size provides a power of 80% for a medium effect size (Cohen's d = 0.5), basing on a type I error rate of 5%. The COVID-19 pandemic brought some challenges to the data collection, which resulted in a smaller sample size of 101 participants concluding the experiment.

Participants were recruited from students attending a Belgian University of Applied Sciences (in Dutch speaking region) and a Dutch University. Of the 71 Belgian students participated in the online experiment, 61 completed it. Only the data of the completed surveys were used for analysis. All of the 40 Dutch students fully completed the experiment.

The participants were native Dutch speaking bachelor students and they completed the experiment in Dutch. Their overall mean age was M = 21,99 (SD = 4.47), and the participants from the Belgian (M = 22.25, SD = 5.15) and Dutch (M = 21.60, SD 3.19) university were comparable in age composition, t(99)= 0.71, p = .480. The analysis in this thesis was thus based on the combined sample. All students took part in the study on a voluntary basis and were randomly assigned to the growth mindset condition or the control group.

2.2 Materials and Measures

2.2.1 Materials

Mindset Intervention. Growth mindset was the between factor of the experiment. For both the experimental and the control condition, participants performed a reading and a writing task (presented in Appendix A, adapted from Yeager et al., 2016). The growth mindset condition task was based on an intervention template shown to be effective in previous growth mindset intervention studies (Dweck & Yeager, 2019; Xu et al., 2021). Participants were asked to read an article about the malleability of the brain and to write a letter of a few sentences to an imagined fellow student struggling with learning. This type of self-persuasion strategy, “saying-is-believing” (Aronson, 1999), has been shown to be effective (e.g., Yeager et al., 2016). The participants in the control condition read a neutral article about brain function of similar length, and summarized the article within a few sentences.

Evolutionary Context and the Learning Task. The evolutionary context was embedded within the learning task, as the within factor of the experiment. This learning task consisted of 32 word pairs to be studied as new vocabulary of an unknown, fictional language. Each pair (e.g., vlinder – kodeiss) consisted of a Dutch word, the native language, paired with an invented translation of the word, a pseudoword. Pseudowords were used to rule out the influence of potential prior knowledge of the studied language (de Groot & Keijzer, 2000). The evolutionary context was embedded by using concepts related to evolutionary primary context in half of the word pairs, and concepts related to evolutionary secondary context in the other half of the word pairs. The primary concepts were based on theme categories such as animals, fruits and relationships, while the secondary concepts were based on theme categories such as electronic devices, grammar and mathematics. Appendix B provides an overview of the 32 word pairs arranged according to evolutionary context and theme category.

The rest of the design of the word pairs was based on lexical principles applied by de Groot and Keijzer (2000) and took into account other factors that may influence word recall such as the abstractness/concreteness, word length and frequency. Firstly, since concrete nouns are recalled better than abstract ones (e.g., Brysbaert et al., 2014; Paivio, 2013), the present study balanced word pairs in each evolutionary context by using the same number of abstract and concrete words (see Appendix B), with each study list of four word pairs consisting of two concrete and two abstract nouns (see Appendix C). Secondly, to minimize word length effect (i.e., shorter words and words with fewer syllables are better recalled; e.g., Ellis & Beaton, 1993), the word length of all pseudowords was kept approximately equal at six to eight letters, with each pseudoword consisting of two syllables. And finally given that familiar (i.e., more frequent) words can be better recalled than less frequently used words (e.g., Keuleers et al., 2010), average word frequency was kept approximately equal in each evolutionary context. According to the SUBTLEX-NL database (Keuleers et al., 2010), there was only a slight difference between the average word frequency of the primary concepts ($M = 4.65$, $SD = 0.83$) and secondary concepts ($M = 4.03$, $SD = 0.95$), and that difference was not significant (t (30) = 1,94, $p = .062$).

During the learning task, the 32 word pairs were arranged into eight study lists, of four word pairs each. Appendix C shows the word pairs as arranged in the eight study lists. The participants were presented with the words in unit of study list, with each study list based on either only primary knowledge word pairs or only secondary knowledge word pairs. The separation of study lists according to evolutionary context allowed measurement for cognitive load and motivation to correspond specifically to a certain evolutionary category. Within each study list, word pairs contained a random mix of theme categories within each evolutionary context. This design allowed counterbalance regarding potential effects related to the theme categories. The study lists also contained an equal amount of concrete and abstract words.

The duration and presentation of the word pairs shown to the learner followed a similar protocol as in de Groot and Keijzer (2000; see Table 1 and Figure 3). For each study list, the four word pairs were presented to the participant sequentially, with each of the four word pairs studied four times in so called study rounds. In the first two study rounds, each word pair appeared on screen, for 8 seconds each, with the Dutch word on the left and its translation on the right, connected by a hyphen. In the third round, each Dutch word appeared on screen for eight seconds without its corresponding translation. Participants were encouraged to think of the translation in the eight second window and type it in a text box. In the fourth round the full word pairs were shown again, similar to the first and second round. The order of the word pairs within each study round was randomized according to a 4x4 reduced Latin square, to account for any potential confounding effects related to the order of presentation.

Table 1

Overview of the way a Study List was Presented in the Learning Task

	Order word pairs	Word pairs appearing individually on screen for 8' each	Required action by the participant
Study round 1	1	vlinder - kodeiss	memorize
	2	liefde - wotsuit	
	3	peer - nufrijg	
	4	wraak - klaspert	
Study round 2	2	liefde - wotsuit	memorize
	3	peer - nufrijg	
	4	wraak - klaspert	
	1	vlinder - kodeiss	
Study round 3	3	peer -	type pseudoword
	4	wraak -	in text box for
	1	vlinder -	practice
	2	liefde -	
Study round 4	4	wraak - klaspert	check or
	1	vlinder - kodeiss	memorize
	2	liefde - wotsuit	
	3	peer - nufrijg	

Figure 3a

Example Screenshot of the Start of Presenting a Study List in the Learning Task

1-4 / 32	5-8 / 32	9-12 / 32	13-16 / 32	17-20 / 32	21-24 / 32	25-28 / 32	29-32 / 32
vlinder - ...	telefoon - ...	haar - ...	krant - ...	kikker - ...	computer - ...	lichaam - ...	boek - ...
liefde - ...	grammatica - ...	vijand - ...	zwaartekracht - ...	gunst - ...	werkwoord - ...	vriend - ...	atoom - ...
peer - ...	paraplu - ...	moeder - ...	auto - ...	citroen - ...	kraan - ...	vader - ...	tram - ...
wraak - ...	vermenigvuldiging - ...	gevaar - ...	geschiedenis - ...	haat - ...	wiskunde - ...	dreiging - ...	eeuw - ...

Figure 3b

Example Screenshots of the way a Word Pair was Presented in Each Study Round

2.2.2 Measures

Mindset Beliefs. The Implicit Theory of Intelligence Scale questionnaire (ITIS; Dweck, 1999) was used for the mindset baseline and manipulation check in order to confirm whether the growth mindset intervention had been successful in altering growth mindset belief. It holds four items on growth mindset (e.g., “No matter who you are, you can significantly change your intelligence level”) and four items on fixed mindset (e.g., “You have a certain amount of intelligence and you can’t really do much to change it”). Participants were asked to rate each statement on a six-point Likert scale ranging from “completely disagree” (1) to “completely agree” (6). The measure showed a good internal consistency in both the baseline (α = .90) and the manipulation check (α = .94).

Cognitive Load. Cognitive load was measured both during learning (to test the effect of evolutionary context) as well as after the learning phase (to test the effect of growth mindset intervention), see Figure 4. Throughout the learning task, perceived cognitive load regarding each study list was measured by two adapted questions, one on perceived task difficulty (”How difficult were the words that you just studied? ”; Kalyuga et al., 1999) and one on perceived mental effort (”How much mental effort did you have to invest for studying these words? ”; Paas, 1992). Participants were asked to answer each question on a nine-point Likert scale ranging from ”not at all” (1) to ”very much” (9). Specifically, after each study list was studied by the participant, the list was shown again with the short measures on cognitive load. The test-retest reliability of these repeated measures was measured by the Intraclass Correlation Coefficient (ICC), according to guidelines by Koo and Li (2016). For the measure on perceived task difficulty, the test-retest reliability was moderate, ICC =.61 with 95% confident interval = 0.53-0.69. For the measure on perceived mental effort, the test-retest reliability was also moderate, ICC =.68 with 95% confident interval = 0.61-0.75.

After the learning task, perceived cognitive load on the entire task was measured by an adapted Cognitive Load Index (CLI; Leppink et al., 2013; see Appendix D). Three items measure intrinsic cognitive load (ICL; e.g., ”I perceived the learning task as very complex”) and three measure extraneous cognitive load (ECL; e.g., “The instructions and/or explanations were very unclear”). Good internal consistency was found in both the ICL subscale (α= .90) and the ECL subscale (α= .85). The original items on germane cognitive load (GCL) were replaced by four self-developed items (e.g., “I could fully understand the concepts covered in the learning task”), since the original items do not reflect the current definition of germane load anymore (Sweller et al., 2019). Participants rated each statement on an eleven-point Likert scale, ranging from “not at all the case” (0) to “completely the case” (10). The GCL subscale showed an acceptable internal consistency (α= .69).

Motivation. Motivation was also measured both during learning (to test the effect of evolutionary context) as well as after the learning phase (to test the effect of growth mindset intervention), see Figure 4. Throughout the learning task, interest (e.g., Ryan, 1982) and enjoyment (Lespiau & Tricot, 2018, 2019) in each study list was measured, constructs that are considered to indicate intrinsic motivation. Interest was assessed by the question "How interesting did you find studying the words on this page?", while enjoyment was assessed by the question "How much did you enjoy studying the words on this page?". Participants were asked to answer each question on a nine-point Likert scale ranging from "not at all" (1) to "very much" (9). Ratings were measured in the same way as the cognitive load measures during learning for each study list. For the measure on interest, the test-retest reliability was good, ICC =.80 with 95% confident interval = 0.75-0.85. For the measure on enjoyment, the test-retest reliability was also good, ICC =.79 with 95% confident interval = 0.74-0.84.

After the learning task, situational interest on the entire task was measured as the motivational indicator with an adapted Situational Interest Scale (SIS; Linnenbrink-Garcia et al., 2010; see Appendix E). It consists of five items on triggered-SI (e.g., "I didn't like this vocabulary learning exercise"), four items on M-SI feeling (e.g., "I'm excited to learn foreign languages") and five items on M-SI value (e.g., "I find learning vocabulary in a foreign language personally meaningful"). Participants rated each item on a seven-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (7). Good internal consistency was found in the triggered-SI subscale (α= .84), the M-SI feeling subscale (α= .96) and the M-SI value subscale (α= .90).

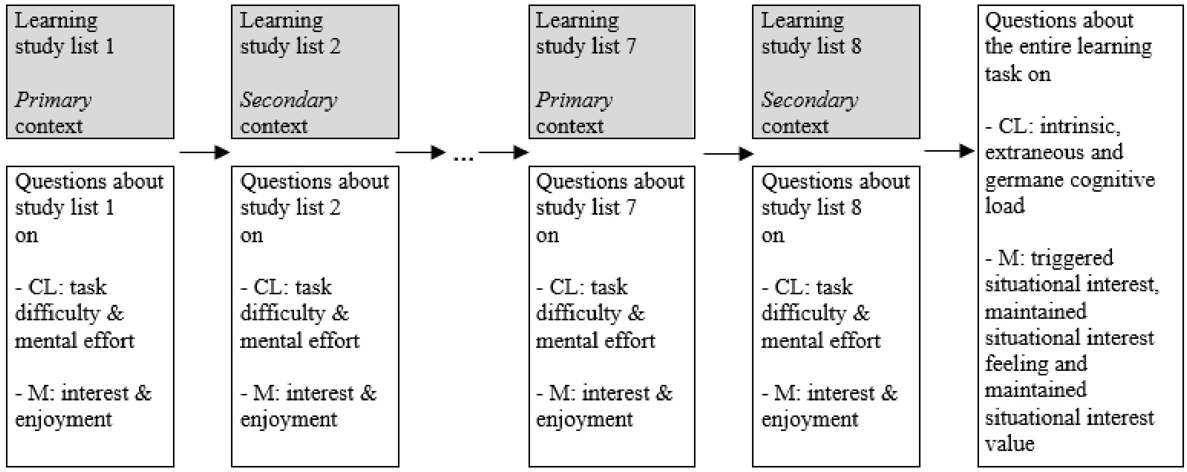
Learning performance. The learning performance outcome was measured by immediate word recall and recognition rates from the 32 pseudowords presented during the learning phase. The order of the tested words appearing in the test was scrambled so it was not the same as the order in the learning phase, while maintaining that the first 16 learned words were tested first, and the 16 last learned words were tested last. This ensured there was a more equal lap between the learning and testing moment. For word recall, firstly the native word was given as a prompt, then the participants were asked to write down what they remembered of the pseudoword in a text box. For word recognition, the same native word was again given as a prompt, then the participants were asked to choose the corresponding pseudoword from four options. Word recall scores were based on the number of letters of the word produced by the participant. Word recognition scores were based on whether the participant had chosen the correct word from the options given. Sum scores of correctly recalled letters of each word and correctly recognized words were created to represent two measures for learning performance as outcome variables for the effect of mindset.

2.3 Procedure

The experiment was set up entirely online using LimeSurvey and lasted approximately 50 minutes. All participants could go through the experiment at their own pace without external guidance, with the experiment leader present in a video conference. All participants received the information letter a few days beforehand and had the opportunity to partake in a lottery for a cash prize of 50 Euro, at the end of the study. The experiment consisted of four phases. In the first phase (10 min.), the experiment was introduced and the participants were familiarized with the procedures of the vocabulary learning task by practicing with four additional word pairs, excluded from the final test. The second phase (10 min.) started with the ITIS as a baseline. Then for the mindset intervention, the participants performed a reading and a writing exercise assignment, different for the manipulation and control group. This was then followed by a manipulation check using again the ITIS. In the third phase (25 min.; Figure 4), all participants were asked to study eight lists of four word pairs each, then rated short measures on cognitive load and motivation during the learning task, and more extensive measures on cognitive load (CLI) and motivation (SIS) after the entire task. In the final phase (5 min.), learning performance was tested through a word recall and word recognition test.

Figure 4

Overview Phase 3 of the Experiment: The Structure of the Learning Task With Accompanying Measures on Cognitive Load (CL) and Motivation (M)



2.4 Data-Analysis

All results were analyzed using IBM SPSS Statistics version 27. Independent t-tests were used for the randomization check on age and mindset baseline and crosstabs analysis with Pearson's chi squared test for gender, to check whether the growth mindset condition group and the control group were similar in age, gender and mindset baseline. Repeated measures ANOVA's were carried out to analyze the effect of evolutionary context of the learning materials on cognitive load (i.e. perceived task difficulty and perceived mental effort), motivation (i.e. interest and enjoyment) and learning performance (i.e. word recognition test and word recall test). Independent t-tests were used for the mindset manipulation check and to analyze the effect of growth mindset of the participants on cognitive load (i.e. CLI: ICL, ECL and GCL), motivation (i.e. SIS: triggered-SI, M-SI feeling, M-SI value) and learning performance (i.e. word recognition and recall). For the interacting effects of evolutionary context and mindset on perceived cognitive load (i.e. perceived task difficulty and perceived mental effort), motivation (i.e. interest and enjoyment) and learning performance (i.e. word recognition and recall), Mixed ANOVA's was performed.

3. Results

Randomization between the growth mindset condition group and the control group was checked on age, gender and mindset baseline. The mean age of the participants in the growth mindset condition group was M = 21.60 (SD = 3.54) and in the control group M = 22.41 (SD = 5.28), with the t-test showing no significant difference between both, $t(99) = 0.91$, $p = .364$. With the growth mindset condition group consisting of 23,1% males and 76,9% females, and the control group of 26,5% males and 73,5% females, crosstabs analysis showed no significant difference between the two groups regarding gender, χ^2 (1) = 0.16, p = 0.688. Also the t-test on the mindset baseline measure showed no significant difference between the two groups, $t(99) = -1.22$, $p = .225$, with a mean of M = 3.81 (SD = 0.98) for the growth mindset condition group and a mean of M = 3.57 (SD = 0.95) for the control group. These descriptive statistics regarding gender, age and mindset baseline being equally distributed across the manipulation and control condition indicated a successful randomization of the two groups. The descriptive data of all variables and the main analysis results are shown in Table 2. The correlation analysis of all variables are displayed in Table 3.

Table 2

Descriptive Statistics, ANOVA and T-test Results of Group Comparison of all Variables

	Growth mindset		Control mindset		Primary context		Secondary context						t-test			Repeated Meas. ANOVA			Mixed ANOVA		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	skew	kurtosis	min	max	*t*(99)	*p*	*d*	*F*(1,99)	*p*	η_p^2	*F*(1,99)	*p*	η_p^2
Mindset baseline	3.81	0.98	3.57	0.95					-0.34	0.31	1.00	6.00	-1.22	.225	0.24				42.52	**<.001**	.30
Mindset manipulation check	4.74	0.92	3.52	0.96					-0.21	-0.27	1.00	6.00	-6.51	**<.001**	1.30						
													growth mindset effect			**evolutionary context effect**			**interaction effect**		
Cognitive load: Task difficulty	5.92	1.73	5.62	1.68	5.65	1.75	5.90	1.76	0.62	-0.87	2.25	9.00				8.26	**.005**	.08			
Task difficulty primary context	5.77	1.78	5.51	1.73					0.15	-0.92	2.50	9.00							0.18	.675	.00
Task difficulty secondary context	6.06	1.76	5.73	1.76					-0.07	-0.80	2.00	9.00									
Cognitive load: Mental effort	6.09	1.71	5.80	1.60	5.85	1.70	6.05	1.67	-0.13	-0.61	2.13	9.00				8.95	**.003**	.08			
Mental effort primary context	6.02	1.76	5.67	1.64					-0.09	-0.70	2.25	9.00							0.75	.390	.01
Mental effort secondary context	6.16	1.73	5.93	1.62					-0.20	-0.53	2.00	9.00									
Motivation: Interest	4.42	2.45	4.20	1.73	4.42	2.14	4.21	2.15	0.21	-0.68	1.00	9.00				14.60	**<.001**	.13			
Interest primary context	4.48	2.45	4.36	1.76					0.10	-0.73	1.00	9.00							3.51	.064	.03
Interest secondary context	4.37	2.47	4.04	1.76					0.32	-0.71	1.00	9.00									
Motivation: Enjoyment	4.19	2.39	4.08	1.68	4.26	2.08	4.01	2.11	0.17	-0.83	1.00	9.00				12.80	**<.001**	.11			
Enjoyment primary context	4.24	2.38	4.28	1.74					0.05	-0.86	1.00	9.00							4.88	**.029**	.05
Enjoyment secondary context	4.14	2.42	3.88	1.72					0.30	-0.86	1.00	9.00									
CLI Intrinsic CL	4.53	2.86	4.93	2.90					0.11	-0.94	0.00	10.00	0.71	.480	0.14						
Extraneous CL	2.76	3.22	2.82	3.02					1.06	-0.08	0.00	10.00	0.10	.923	0.02						
Germane CL	4.03	2.47	5.34	2.40					0.13	-0.89	0.00	10.00	2.71	**.008**	0.54						
SIS Triggered-SI	3.95	1.52	3.65	1.28					-0.13	-0.75	1,00	6.60	-1.07	.286	0.21						
M-SI feeling	4.97	1.95	5.11	1.52					-0.84	-0.26	1,00	7.00	0.39	.697	0.08						
M-SI value	5.38	1.38	5.33	1.03					-1.10	1.79	1,00	7.00	-0.21	.836	0.04						
Word recall	0.52	0.27	0.59	0.25	0.54	0.27	0.56	0.27	-0.06	-0.74	0.00	1.00	1.33	.188	0.26	3.42	.067	.03			
W recall primary context	0.51	0.27	0.57	0.26					-0.05	-0.79	0.00	1.00							0.75	.388	.01
W recall secondary context	0.52	0.27	0.60	0.27					-0.15	-0.71	0.00	1.00									
Word recognition	0.82	0.21	0.88	0.14	0.84	0.20	0.85	0.19	-1.42	-1.44	0.25	1.00	1.64	.105	0.33	1.27	.263	.01			
W recognition primary context	0.81	0.23	0.87	0.15					-1.58	2.57	0.06	1.00							0.00	.974	.00
W recognition secondary context	0.82	0.21	0.88	0.16					-1.37	-1.10	0.25	1.00									

Note. Bold: p< .05

Table 3

Correlation Matrix of all Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Mindset baseline																									
2. Mindset manipulation check	.63**																								
3. Task difficulty	.05	.13																							
4. Task difficulty primary context	.08	.16	.97**																						
5. Task difficulty secondary context	.01	.09	.97**	.87**																					
6. Mental effort	.02	.14	.88**	.85**	.85**																				
7. Mental effort primary context	.06	.18	.86**	.87**	.80**	.98**																			
8. Mental effort secondary context	-.01	.09	.86**	.79**	.87**	.98**	.92**																		
9. Interest	.21*	.21*	-.24*	-.22*	-.24*	-.19	-.17	-.21*																	
10. Interest primary context	.18	.19	-.24*	-.23*	-.23*	-.19	-.18	-.19	.99**																
11. Interest secondary context	.23*	.22*	-.23*	-.20*	-.25*	-.19	-.16	-.21*	.99**	.96**															
12. Enjoyment	.18	.14	-.33**	-.30**	-.33**	-.27**	-.26**	-.27**	.91**	.91**	.90**														
13. Enjoyment primary context	.15	.10	-.33**	-.33**	-.30**	-.28**	-.28**	-.26**	.90**	.91**	.87**	.99**													
14. Enjoyment secondary context	.21*	.16	-.32**	-.27**	-.34**	-.26**	-.23*	-.28**	.90**	.88**	.90**	.99**	.95**												
15. Intrinsic cognitive load	-.00	-.03	.32**	.32**	.29**	.27**	.27**	.25*	-.19	-.18	-.19	-.30**	-.30**	-.30**											
16. Extraneous cognitive load	.02	.10	-.15	-.12	-.17	-.09	-.05	-.12	-.04	-.05	-.03	-.02	-.04	.00	.41**										
17. Germane cognitive load	.13	-.07	.14	.18	.09	.13	.16	.10	-.27**	-.27**	-.27**	-.31**	-.31**	-.30**	.42**	.33**									
18. Triggered-SI	.03	.12	-.45**	-.42**	-.45**	-.42**	-.41**	-.40**	.57**	.57**	.55**	.68**	.66**	.68**	-.22*	.06	-.21*								
19. M-SI feeling	-.06	-.05	-.17	-.16	-.18	-.21*	-.21*	-.21*	.28**	.28**	.26**	.26**	.26**	.25*	-.15	-.15	-.07	.32**							
20. M-SI value	-.03	-.01	-.16	-.13	-.17	-.16	-.16	-.16	.15	.16	.14	.13	.13	.12	-.04	-.09	-.06	.22*	.64**						
21. Word recall	-.02	-.12	-.44**	-.46**	-.39**	-.45**	-.47**	-.41**	.33**	.34**	.31**	.39**	.40**	.37**	-.26**	-.11	-.13	.42**	.52**	.30**					
22. W recall primary context	-.01	-.11	-.44**	-.48**	-.37**	-.48**	-.49**	-.41**	.31**	.32**	.29**	.37**	.38**	.34**	-.26**	-.13	-.16	.40**	.49**	.25*	.98**				
23. W recall secondary context	-.03	-.13	-.42**	-.42**	-.39**	-.42**	-.42**	-.39**	.33**	.34**	.32**	.39**	.39**	.38**	-.24*	-.09	-.10	.42**	.53**	.33**	.97**	.90**			
24. Word recognition	-.08	-.22*	-.37**	-.39**	-.33**	-.37**	-.39**	-.33**	.19	.21*	.17	.31**	.32**	.29**	-.29**	-.16	-.09	.39**	.41**	.27**	.79**	.77**	.77**		
25. W recognition primary context	-.05	-.17	-.34**	-.39**	-.27**	-.33**	-.36**	-.28**	.21*	.23*	.18	.31**	.33**	.27**	-.30**	-.17	-.08	.31**	.38**	.26**	.74**	.75**	.69**	.94**	
26. W recognition secondary context	-.11	-.24*	-.35**	-.33**	-.35**	-.36**	-.37**	-.34**	.15	.15	.14	.27**	.27**	.27**	-.24*	-.14	-.09	.42**	.39**	.25*	.74**	.69**	.75**	.94**	.77**

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

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

3.1 Effect of Evolutionary Context

Repeated measures ANOVA were used to determine the main effect of the evolutionary context of the learning materials on cognitive load, motivation and learning performance.

3.1.1 Cognitive Load

Hypothesis 1 stated that for the learning materials embedded with primary knowledge context, participants would report lower cognitive load, measured by perceived task difficulty and perceived mental effort. On average, participants reported lower task difficulty for the primary knowledge concepts (*M* = 5.65, *SD* = 1.75) in comparison to the secondary knowledge concepts (*M* = 5.90, *SD* = 1.76), and analysis showed that this difference was significant, $F(1, 99) = 8.26$, $p = .005$, $\eta_p^2 = .08$. The reported mean for mental effort was also lower for the primary knowledge concepts (*M* = 5.85, *SD* = 1.70) in comparison to the secondary knowledge concepts (*M* = 6.05, *SD* = 1.61), and analysis showed that this difference was significant as well, $F(1, 99) = 8.95$, $p = .003$, $\eta_p^2 = .08$.

3.1.2 Motivation

Hypothesis 2 stated that for the learning materials embedded with primary knowledge context, participants would report higher motivation, measured by interest and enjoyment. On average, participants reported a higher interest with the primary knowledge concepts (*M* = 4.42, *SD* = 2.14) in comparison to the secondary knowledge concepts (*M* = 4.21, *SD* = 2.15), and analysis showed that this difference was significant, $F(1, 99) = 14.60$, $p < .001$, $\eta_p^2 = .13$. Similarly, participants on average reported a higher enjoyment with the primary knowledge concepts (*M* = 4.26, *SD* = 2.08) in comparison to the secondary knowledge concepts (*M* = 4.01, *SD* = 2.11), and analysis showed that this difference was significant as well, $F(1, 99) = 12.80$, $p < .001$, $\eta_p^2 = .11$.

3.1.3 Learning Performance

Hypothesis 3 stated that for the learning materials embedded with primary knowledge context, participants would have a higher learning performance, measured by word recognition and word recall. The descriptive means can be found in Table 3. Analysis showed no significant difference between primary knowledge concepts as opposed to secondary knowledge concepts in word recall, $F(1, 99) = 3.42$, $p = .067$, $\eta_p^2 =.03$, or word recognition, $F(1, 99) = 1.27$, $p = .263$, $\eta_p^2 = .01$.

3.2 Effect of Growth Mindset

Independent t-tests were used to determine the effect of the mindset intervention and the mindset condition of the participants on their reported cognitive load, motivation and learning performance.

3.2.1 Growth Mindset Induction

Hypothesis 4 stated that the participants who received a mindset intervention would report a higher growth mindset. No significant difference was found in the mindset baseline test between the growth mindset condition group and the control group, $t(99) = -1{,}22$, $p < .225$, $d = 0.24$. The mindset post-test showed a higher mean in the growth mindset condition group ($M = 4.74$, $SD = 0.92$) compared to the control group ($M = 3.52$, $SD = 0.96$), and the t-test showed that this difference was significant, $t(99) = -6{,}51$, $p < .001$, $d = 1.30$.

3.2.2 Cognitive Load

Hypothesis 5 stated that participants who received a mindset intervention would report lower cognitive load, measured by ICL, ECL and GCL. The descriptive means can be found in Table 3. No significant difference was found between the growth mindset condition group and the control group for ICL, $t(99) = 0.71$, $p = .480$, $d = 0.14$, or ECL, $t(99) = 0.10$, $p = .923$, $d = 0.02$. For GCL, the participants from the growth mindset condition group perceived it as lower ($M = 4.03$, $SD = 2.47$) than the participants from the control group ($M = 5.34$, $SD =$

2.40), and analysis showed that this difference was significant, $t(99) = 2.71$, $p = .008$, $d = 0.54$.

3.2.3 Motivation

Hypothesis 6 stated that the participants who received a mindset intervention would report higher motivation, measured by triggered-SI, M-SI feeling and M-SI value. The descriptive means can be found in Table 3. Analysis showed no significant differences between the growth mindset condition group and the control group for triggered-SI, $t(99) = -0.76$, $p = .449$, $d = 0.15$, for M-SI feeling, $t(99) = 0.39$, $p = .697$, $d = 0.08$, or for M-SI value, $t(99) = -0.21$, $p = .836$, $d = 0.04$.

3.2.4 Learning Performance

Hypothesis 7 stated that the participants who received a mindset intervention would have a higher learning performance, measured by word recognition and word recall. The descriptive means can be found in Table 3. Analysis showed no significant differences between the growth mindset condition group and the control group for word recall, $t(99) = 1.33$, $p = .188$, $d = 0.26$, or word recognition, $t(99) = 1.64$, $p = .105$, $d = 0.33$.

3.3 Interaction Effect of Evolutionary Context and Mindset

Mixed ANOVA's were used to explore the interacting effect of the evolutionary context of the learning materials and the mindset condition of the participants on cognitive load, motivation and learning performance. In this section, emphasis is on the interaction effects rather than the main effects, since the main effects were presented in the previous result sections for each experimental factor.

3.3.1 Cognitive Load

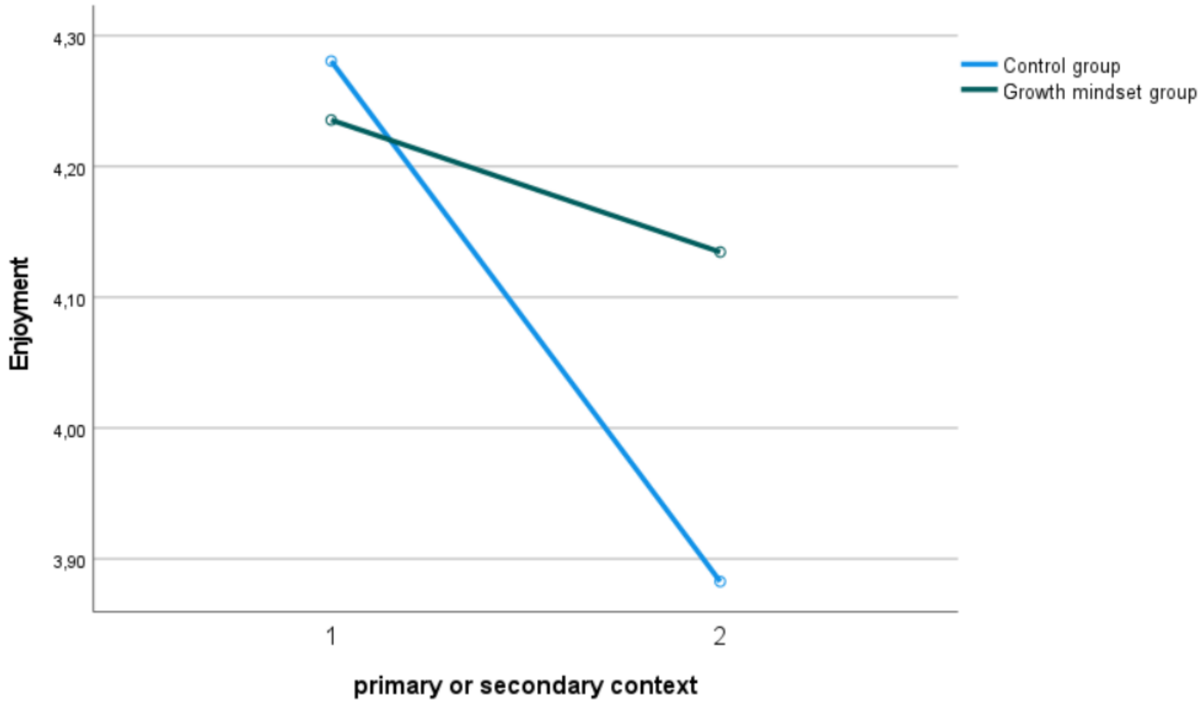
Research Question 8 asked whether the participants who received a mindset intervention would report even lower cognitive load when they also studied learning materials embedded with primary knowledge context, with cognitive load measured by perceived task difficulty and perceived mental effort. All descriptive means can be found in Table 3. No significant interacting effect was found between the evolutionary context of the learning material and the mindset condition group on task difficulty, $F(1, 99) = 0.18$, $p = .675$, $\eta_p^2 = .00$, or mental effort, $F(1, 99) = 0.75$, $p = .390$, $\eta_p^2 = .01$.

3.3.2 Motivation

Research Question 9 asked whether the participants who received a mindset intervention would report higher motivation when they studied learning materials embedded with primary knowledge context, with motivation measured by interest and enjoyment. All descriptive means can be found in Table 3. No significant interacting effect was found between the evolutionary context of the learning material and the mindset condition group on interest, $F(1, 99) = 3.51$, $p = .064$, $\eta_p^2 = .03$. For enjoyment, the growth mindset condition group reported a mean of $M = 4.24$ ($SD = 2.38$) for the primary knowledge concepts and a mean of $M = 4.14$ ($SD = 2.42$) for the secondary knowledge concepts. In comparison, the control group reported a mean of $M = 4.28$ ($SD = 1.74$) for the primary knowledge concepts and a mean of $M = 3.88$ ($SD = 1.72$) for the secondary knowledge concepts. Analysis showed a significant interacting effect between the evolutionary context of the learning material and the mindset condition group on enjoyment, $F(1, 99) = 4.88$, $p = .029$, $\eta_p^2 = .05$, see Figure 5.

Figure 5

Means of Enjoyment for the Primary (1) and Secondary (2) Context for the Growth Mindset and Control Group.



3.3.3 Learning Performance

Research Question 10 asked whether the participants who received a mindset intervention would have a higher learning performance for the learning materials embedded with primary knowledge context, with learning performance measured by word recall and word recognition. All descriptive means can be found in Table 3. Analysis showed no significant interacting effect found between the evolutionary context of the learning material and the mindset condition group on word recall, $F(1, 99) = 0.75$, $p = .388$, $\eta_p^2 = .01$, or on word recognition, $F(1, 99) = 0.00$, $p = .974$, $\eta_p^2 = .00$.

4. Discussion

Since from an evolutionary standpoint academic learning appears to be intrinsically unmotivating, this research investigated two proposed strategies to offer support in evolutionary secondary learning. It firstly aimed to investigate whether using that same evolutionary perspective in making the learning materials evolutionary more appealing, would have a beneficial effect on student's perceived cognitive load, motivation, and eventually learning performance. In the controlled experimental setting of this study, based on a foreign vocabulary learning task, a significant effect was found for the evolutionary context of the learning materials on participants' reported cognitive load (through task difficulty and mental effort) and their reported motivation (through interest and enjoyment). There was however no significant effect found on learning performance (through word recall and word recognition).

Also a second strategy to support academic learning was proposed, namely helping students adopt a growth mindset. Research is still looking at which factors influence the effect of such growth mindset interventions, as to apply them in an efficient way. With research often showing weak to no effect, this study aimed to verify the influence of a mindset intervention in the context of a randomized controlled experiment with an actual learning task for greater insight on learning processes involving cognitive load, motivation and learning performance. The mindset induction itself was successful, and growth mindset lowered germane cognitive load. No significant effect was found for the effect of mindset on intrinsic and extraneous cognitive load, motivation (through triggered situational interest, maintained situational interest feeling and maintained situational interest value) and learning performance (through word recall and word recognition) of the participants.

Finally, a combined effect of evolutionary context and mindset was found significant for one of the motivational measures, enjoyment. There was however no significant combined effect found for the second motivational measure interest, or for cognitive load (through task difficulty and mental effort) or learning performance (through word recall and word recognition). Below, the key findings for each experimental condition are discussed in relation to previous literature.

4.1 Evolutionary Context

This research aimed to further the results of the experiments of Lespiau and Tricot (2018, 2019), who used syllogisms with an evolutionary primary or secondary context to see its effect on reported cognitive load, motivation and learning performance. In search of increasing ecological validity, the current study had the evolutionary context embedded in a more common academic learning activity, a vocabulary learning task, where half of the words had an evolutionary primary connection, and half an evolutionary secondary connection. For the primary context learning materials, participants reported significantly lower on cognitive load measures and significantly higher on motivational measures, with medium to large effect sizes, therefore confirming the first and second hypothesis of this study. These results are in line with the results found by Lespiau and Tricot (2018, 2019), who also reported consistent beneficial effects of primary context on cognitive load and motivation. For cognitive load specifically, it supports the idea that primary knowledge and primary knowledge based tasks incur only minimal cognitive load (Paas & Sweller, 2012). On the other hand, participants in the present study did not recall or recognize primary context words significantly better, which does not confirm the expectation for learning performance described in the third hypothesis. This is in contrast with the findings of Lespiau and Tricot (2018, 2019), where adding primary elements generally did increase performance.

A first possible explanation for the lack of effect on learning performance can lie in the type of measurement. The current experiment concerned remembering a translation of a single word, which is a very different type of learning outcome than solving a logical problem as used in the Lespiau and Tricot (2018, 2019) experiments. The difference in measurement is also closely related to the difference in subject of the learning tasks. Although learning a foreign language is considered to be secondary knowledge itself (e.g. Roussel et al., 2017), it is possible that it has a closer relationship to the primary social survival knowledge, by connecting to the motivational drive to communicate with other people. In that way, foreign language learning might still be close to the acquisition of a primary skill such as native language. The effect of the added primary context might therefore had an immediate effect on accompanying measures such as cognitive load and motivation, but not necessarily on later measured learning performance. Previous research seems to support this possibility. In the experiments of Lespiau and Tricot (2018, 2019), performance was mostly measured immediately for each syllogism. When it was measured at a later stage, in two out of three experiments a primary context in the learning material did not increase performance.

Secondly, the syllogisms of Lespiau and Tricot (2018, 2019) provided a more elaborate evolutionary context than the vocabulary task of the present study. A syllogism consists of sentences, therefore describing a situation and action, whereas that is not the case when using individual words or concepts in vocabulary learning. Combined with the previous point made on the timing of the measurements, the lack of a more elaborate context and the isolation of the word from its accompanying words in the performance test might have prevented to carry on the effect of the evolutionary context reported in the accompanying measures into the later performance test.

Finally, since there was a general absence of effect on learning performance, it could point at weaknesses in the design of the measurement. For example, the average mean on the word recognition test was 85%, thus rendering lower sensitivity to detect any experimental effects. This implies that the words used in the learning task might not be cognitively demanding enough.

4.2 Growth Mindset

Participants who received the growth mindset intervention reported a significantly stronger growth mindset belief compared to the control group after the intervention, and this effect was found strong ($d = 1.30$). This confirms the fourth hypothesis of this study and confirms previous findings (Dweck & Yeager, 2019; Xu et al., 2021) on the effectivity of the used mindset intervention template. Participants in the growth mindset intervention wrote sentences like “With hard work and practice you can reach more than you think”, “If you keep practicing, your brains will grow stronger” and “Everyone is capable at becoming good at learning new things”, proving that they had internalized a growth mindset attitude. Contrary to some other mindset intervention studies, this experiment also measured the experienced growth mindset prior to the intervention as a baseline, which showed that there was no initial difference between both groups in mindset beliefs. By doing so, these findings on the effect of a mindset intervention can be considered more valid.

Previous research (e.g. Burnette et al., 2019; Sisk et al., 2018; Xu et al., 2021; Yeager et al., 2019) has seen positive effects of mindset on cognitive load, motivation and/or learning performance. These effects were not replicated in the current study, with the exception of participants in the growth mindset condition reporting a significant lower germane cognitive load. Therefore results do not confirm the sixth and seventh hypothesis of this study, and only part of fifth hypothesis. Whether a low germane cognitive load is a confirmation of the hypothesis is even debatable, since the point of managing cognitive load is to keep the productive amount and thus a certain amount of germane load is needed (Paas & Ayres, 2014; Sweller et al., 2011). The general absence of effect of growth mindset is in line with the meta-analysis by Sisk et al. (2018) which showed general lacking or only small effects in research, suggesting additional factors influence the impact of a growth mindset intervention. Therefore determining what is specific to the current experiment can help adapt mindset interventions and make them more efficient.

Firstly, as well the prior motivation as the prior knowledge could be unidentified influencing factors in this study. Previous research showed that motivational beliefs are subject-matter specific (Bong, 2004) and therefore could differ from participant to participant, according to how they relate to a certain topic. While for instance the study by Xu et al. (2021) revolved around a physics learning task, the current research was based on a foreign vocabulary learning task. Also, no covariates were taking into account in this study, while in other comparable studies (e.g. Xu et al., 2021) personal characteristics of the participants such as prior knowledge were taking in account. Prior knowledge, in this case on foreign language learning in general, could be a determining covariate in the current study because of its influence on cognitive load and learning performance (Chen et al., 2017).

Secondly, the participants in this study are students in higher education, therefore typically from a higher socioeconomic class and less academically at risk than the population average, while previous research showed more success for growth mindset interventions for learners with a low socioeconomic status or who are academically at risk (Sisk et al., 2018).

4.3 Interaction Evolutionary Context and Mindset

In the absence of comparable research, it was expected based on results for the separate strategies that the combination of both adding primary context and inducing a growth mindset would elicit the highest motivation and performance and the lowest cognitive load. The results did not confirm the eighth, ninth and tenth research question as phrased. However for enjoyment, one of the motivational measures, there was an interacting effect found. Figure 5 shows that for both the growth mindset and the control group the reported enjoyment was lower for secondary context learning materials. But for the control group, the difference between enjoyment for primary versus secondary context learning materials was substantially larger than the same difference in the growth mindset group, which would be the opposite as to what was expected. A similar trend was observed with the other motivational factor interest, although this effect was just over the significancy level. This effect could be interpreted as mindset interventions having an easing effect on the intrinsically lower motivation in secondary learning materials, and that a mindset intervention would be more effective in increasing motivation with secondary learning materials that lack any evolutionary motivational (primary) elements.

4.4 Limitations and Future Directions

This research holds some limitations, as well in general as specific to the individual experimental factors. In general, data collection was hampered by the COVID-19 pandemic, which resulted in a lower sample size than targeted. This could impact the statistical power of this research. Future research should provide sufficient participants to increase the power. Also, a general absence of effect on learning performance can indicate that the test was too cognitively undemanding. Future research can increase the cognitive demand of the task, for example by increasing word lengths, in order to possibly differentiate the effect better.

For evolutionary context specifically, there was only a lack of effect on performance. Apart from the general issue with the learning performance measure, other explanations were offered that were specific to the effect of evolutionary context. These concerned a combination of factors that could strengthen each other: a possible primary connection in what should be a secondary learning task, the measurement of performance happening at a later time, and a more limited evolutionary context. These limitations could be addressed in future research by further exploring the effect of evolutionary context in other subjects. Topics such as math or physics are less connected with primary knowledge skills and can thus better distinguish the effect of embedding an evolutionary appealing context in secondary learning at school. Future research can also try providing a more elaborate evolutionary context so that the evolutionary difference would be more emphasized and would carry on in the performance test. That said, it needs to be pointed out that the effects on cognitive load and motivation were indeed replicated with the current evolutionary learning task, which does supports the overall validity of this task, and so primary attention should be paid to adjusting the performance test.

For growth mindset specifically, the explanations offered for the mostly lacking results concerned overlooking the prior knowledge, prior motivation and characteristics of the participants. Future research can therefore integrate questions on prior knowledge and prior motivation relating to the study subject at hand and take them into account as covariates, and replicate the current study with participants who have a lower socioeconomic status or are academically at risk.

4.5 Implications

The results of this study have relevant implications on both a scientific and social level. On a scientific level, it adds to previous research in the field of evolutionary learning psychology and growth mindset by extending the first studies on embedding evolutionary context in learning materials (Lespiau & Tricot, 2018, 2019) for a different type of learning task and by partially replicating a first experimental study on the effect of a growth mindset intervention (Xu et al., 2021). For both motivation-enhancing techniques individually, empirical research is still lacking and no previous research has explored the combination of applying both techniques in a single experimental study. The results of the current study indicate that it is worthwhile further examining these techniques, while adjusting the learning performance measurement, possibly using a more fitting learning subject in the experimental learning task and with more attention to the characteristics of the participants.

On a social level, this study contributes to the development of strategies to increase the supposedly intrinsically unmotivating secondary learning at school. Firstly, this study provides additional evidence that teachers can enhance the motivational character of their learning materials by adding primary contexts to these materials. Secondly, it contributes to improving the effectiveness of growth mindset interventions implemented by schools. This study adds to previous findings that these interventions don't always work and attention should be paid to the circumstances and the target group in order for them to be successful. This study particularly indicates that mindset interventions can be successful with learning materials where no evolutionary motivating elements are present or can be added.

Overall, the current study indicates that it is worthwhile further exploring the evolutionary perspective on learning in dealing with the issue of low motivation in academic learning and so helping teachers in the everyday challenge of keeping their students motivated to learn.

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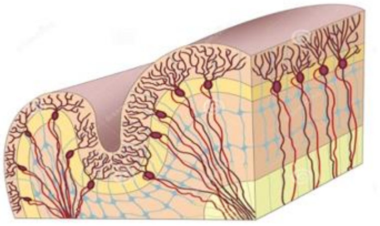
Appendixes

Appendix A : Materials for the Growth Mindset Intervention

Table A1

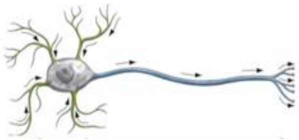
Experimental Condition: English and Dutch Version of the Growth Mindset Intervention (Adapted From Yeager et al., 2016)

English version	Dutch version
You can grow your intelligence	**Je kunt je intelligentie laten groeien**
New research shows that the brain can develop as a muscle	**Nieuw onderzoek laat zien dat de hersenen kunnen ontwikkelen als een spier**
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.	Veel mensen denken dat het menselijk brein (ook wel hersenen genoemd) een mysterie is. Ze weten niet veel over intelligentie en hoe het werkt. Bij het woord intelligentie denken veel mensen dat dit betekent dat je slim, middelmatig of dom geboren bent en dat dit je hele verdere leven hetzelfde blijft.
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 becomes stronger as you learn.	Echter, nieuw onderzoek laat zien dat het menselijk brein meer als een spier werkt die verandert en sterker wordt wanneer je het gebruikt. Het is wetenschappers gelukt om te kunnen laten zien hoe je hersenen groeien en sterker worden als je leert.
 *De hersenen*	 *De hersenen*
When you exercise and learn new things, such as with studying a new language, parts of the brain change and become bigger, just like muscles change and become bigger when you exercise.	Wanneer je namelijk oefent en nieuwe dingen leert, zoals tijdens het studeren van nieuwe taal, veranderen er gedeeltes van de hersenen en worden ze groter, net zoals spieren veranderen en groter worden wanneer je sport.



Een gedeelte van de hersenschors

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.

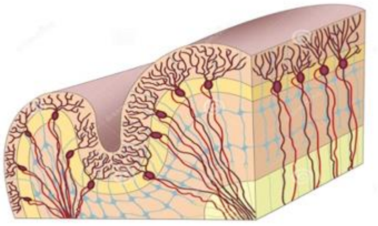


Zenuwcel of neuron

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 studying vocabularies of a new language, seem to be easier. The result is a stronger, smarter brain.

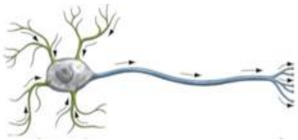
How do we know that the brain can grow stronger?

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.



Een gedeelte van de hersenschors

Binnenin de hersenschors zijn er biljoenen kleine zenuwcellen die neuronen genoemd worden. Deze zenuwcellen hebben vertakkingen waarmee ze verbinding maken met andere cellen in een ingewikkeld netwerk. De communicatie tussen deze hersencellen maakt het mogelijk voor ons om te denken en problemen op te lossen.



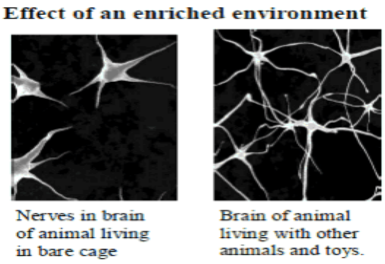
Zenuwcel of neuron

Wanneer je nieuwe dingen leert, vermenigvuldigen deze kleine verbindingen in de hersenen zich en worden ze sterker. Hoe meer je je hersenen uitdaagt om te leren, hoe meer je hersencellen groeien. Vervolgens lijken de dingen waarvan je eerst vond dat ze heel erg moeilijk of zelfs onmogelijk waren, zoals bijvoorbeeld woordenschat van een nieuwe taal instuderen, makkelijker te worden. Het resultaat is een sterker, slimmer brein.

Hoe weten we dat de hersenen sterker kunnen groeien?

Wetenschappers begonnen te denken dat het menselijk brein kon ontwikkelen en veranderen toen ze de hersenen van dieren gingen onderzoeken. Ze ontdekten namelijk dat dieren die in een uitdagende omgeving leefden waarin ze hun hersenen konden trainen door met speelgoed of met andere dieren te spelen, veel actiever waren dan dieren die

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.

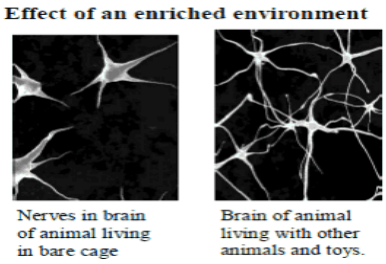


Children's brain growth

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.

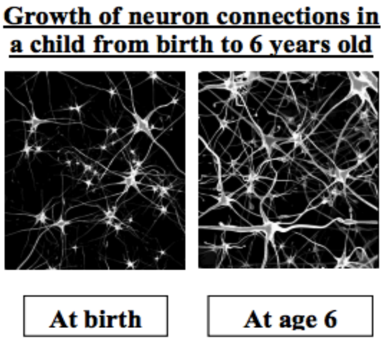
alleen in kale hokken leefden. Deze actieve dieren hadden meer grotere en sterkere verbindingen tussen hun zenuwcellen in hun hersenen. Hun hersenen waren ongeveer 10% zwaarder dan de hersenen van de dieren die alleen in kale hokken leefden. De actieve dieren waren ook 'slimmer', ze waren beter in het oplossen van problemen en het leren van nieuwe dingen.



De groei van hersenen bij kinderen

Nog een andere reden waarom wetenschappers begonnen te denken dat hersenen kunnen groeien was: baby's. Wat maakt het mogelijk dat zij de taal van hun ouders leren spreken in de eerste paar jaren van hun leven? In zekere zin trainen baby's hun hersenen door eerst heel goed te luisteren en vervolgens zelf te gaan oefenen met praten.

Als kinderen eenmaal een taal hebben geleerd, zullen ze deze niet meer vergeten, omdat leren een blijvende verandering aanbrengt in de hersenen. De hersencellen zijn groter geworden en er zijn nieuwe verbindingen gegroeid tussen de zenuwcellen waardoor het kinderbrein feitelijk sterker en slimmer is geworden.



The truth about 'smart' and 'stupid'

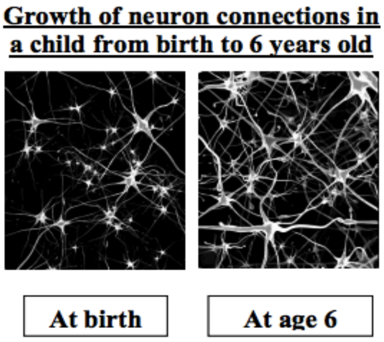
No one thinks that babies are stupid because they can’t talk. They have not yet learned how to do this. But some people will call others stupid because they cannot solve math’s, spell a word, or aren’t good at learning a new language - even though all these things can be learned by practicing. The more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

The key to growing the brain: practice!

Pupils 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.

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.



De waarheid over ‘slim’ en ‘dom’

Niemand denkt dat baby’s dom zijn omdat ze niet kunnen praten. Ze hebben alleen nog niet geleerd hoe ze dit moeten doen. Toch zijn er mensen die anderen dom noemen omdat ze geen wiskundesom op kunnen lossen, een woord niet goed kunnen spellen, of niet goed zijn in een nieuwe taal leren - ook al zijn al deze dingen te leren door te oefenen. Hoe meer je leert, hoe makkelijker het wordt om nieuwe dingen te leren.

De sleutel tot het laten groeien van de hersenen: oefenen!

Leerlingen van wie iedereen denkt ze ‘de slimste’ zijn, kunnen gewoon geboren zijn zonder te verschillen van anderen. Maar misschien zijn deze ‘slimme’ leerlingen al begonnen met oefenen van bijvoorbeeld lezen voordat ze naar school gingen, waardoor ze hun ‘lees spieren’ al op konden bouwen. Andere leerlingen zouden wellicht net zo goed kunnen lezen als zij ook zoveel zouden oefenen.

Wat kun je doen om slimmer te worden?

Net als een sporter zul je moeten trainen en oefenen. Als je oefent maak je je hersenen sterker. Je zult ook vaardigheden leren waardoor je je hersenen op een slimmere manier kunt gebruiken.

Only many people miss the opportunity to make their brains grow stronger because they think they cannot, or because it is too difficult. It takes effort, but if you feel that you are getting stronger and better, it is worth it!	Alleen lopen veel mensen de kans mis om hun hersenen sterker te laten groeien, omdat ze denken dat ze het niet kunnen, of omdat het te moeilijk is. Het kost moeite, maar als je voelt dat je sterker en beter wordt, is het het waard!
You can now make the reflection assignment below. Perhaps you have experienced at times that you found a subject, such as studying new vocabulary as you did a moment ago, 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 and motivate him or her? Do this in about 5 sentences below. *Dear …, What I'd like to say to you to help you is:*	*Je mag nu hieronder de reflectie-opdracht maken.* Misschien heb je weleens meegemaakt dat je een onderwerp, zoals het instuderen van nieuwe woordenschat zoals je zonet gedaan hebt, erg lastig vond om te leren, maar dat het je na hard werken en oefenen toch lukte. Wat zou je aan een medestudent willen zeggen die echt worstelt met een onderwerp als dit? Wat zou je zeggen om hem of haar te helpen en te motiveren? Doe dit in ongeveer 5 zinnen: *Beste ….., Wat ik je graag wil meegeven om je te helpen is:*

Table A2

Control Condition: English and Dutch Version of the Control Task

English version	Dutch version
The Neuron, Building Block of the Brain	**Het neuron, bouwsteen van de hersenen**
Your brain looks like an oversized walnut, not much bigger than two clenched fists against each other. What the brain does, it is too much to list: they regulate countless activities in your body, process 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 up. 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.	Je brein ziet eruit als een uit de kluiten gewassen walnoot, niet veel groter dan twee gebalde vuisten tegen elkaar. Wat de hersenen doen, het is teveel om op te sommen: ze reguleren talloze activiteiten in je lichaam, verwerken prikkels en zorgen ervoor dat je kunt denken, lachen, onthouden en nog veel meer. Hoe krijgt een weke massa van iets meer dan 1 kilogram dit voor elkaar? De cel is de kleinste eenheid waaruit alles wat leeft, dus ook de mens, is opgebouwd. Er zijn verschillende soorten cellen met elk een kenmerkende vorm en functie. Een van die soorten is

de zenuwcel ofwel het neuron: een cel die gespecialiseerd is in het ontvangen en doorgeven van signalen.

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.

Communicatie

Neuronen vind je in grote aantallen in je hersenen en ruggenmerg maar ze lopen ook als draden, de perifere zenuwen, door het hele lichaam.

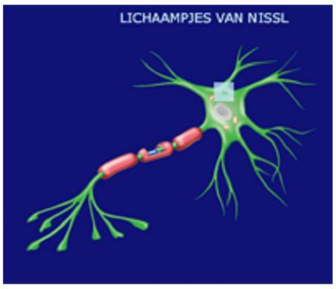
De hersenen

De hersenen

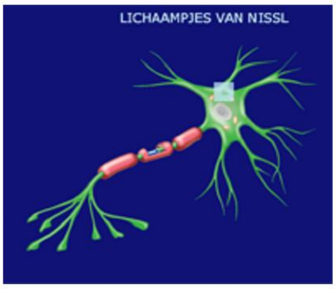
Everything that happens in the brain is all about communication between the neurons. Billions of electrical and chemical signals are constantly being circulated. Also over longer distances, all the way to the tip of your toes. The human brain is made up of about 100 billion neurons. These are all present at birth.

Bij alles wat er in de hersenen gebeurt draait het om de communicatie tussen de neuronen onderling. Er worden voortdurend miljarden elektrische en chemische signalen rondgestuurd. Ook over grotere afstanden, helemaal tot in het puntje van je tenen.

De hersenen van de mens zijn opgebouwd uit ongeveer 100 miljard neuronen. Deze zijn allemaal al bij de geboorte aanwezig.



Bouw van het neuron



Bouw van het neuron

Support cells

The billions of neurons that make up the nervous system have their own support cells: the neuroglia or glial cells.

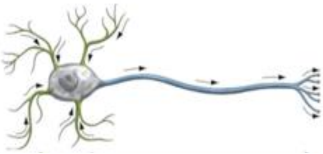
Steuncellen

De miljarden neuronen waaruit het zenuwstelsel bestaat hebben eigen steuncellen: de neuroglia of gliacellen. Ze

The 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.

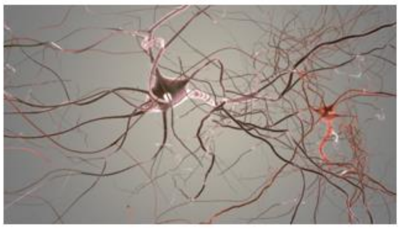
The nervous system contains more support cells than neurons.



Zenuwcel of neuron

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.



Verbinding tussen neuronen

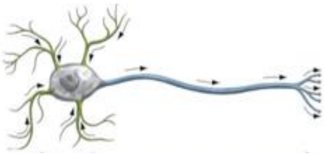
In order to perform all tasks well, large groups of neurons work closely together. As a result, there are specialized areas in the brain, such as for perception (hearing, seeing or smelling) or motor functions (walking or cycling).

The network does not stand still, but always changes.

zijn te vergelijken met het bindweefsel in andere organen.

In tegenstelling tot de neuronen geven deze cellen geen elektrische signalen door. Hun taak is de neuronen te beschermen en te ondersteunen. Sommige steuncellen vernietigen bijvoorbeeld microben, andere zorgen voor de circulatie van het hersen- en ruggenmergvocht. Weer andere steuncellen vormen een beschermlaagje dat ervoor zorgt dat signalen niet van het ene neuron op het andere over kunnen springen.

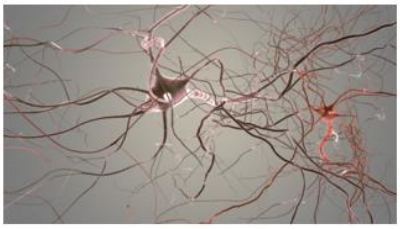
Het zenuwstelsel bevat meer steuncellen dan neuronen.



Zenuwcel of neuron

Complexe netwerken

Al tijdens de zwangerschap wordt er bij het embryo een begin gemaakt met het leggen van verbindingen tussen de neuronen onderling. Deze zijn geschikt voor het uitvoeren van een aantal basisfuncties die vlak na de geboorte nodig zijn.



Verbinding tussen neuronen

Om alle taken goed uit te kunnen voeren werken grote groepen neuronen nauw samen. Daardoor zijn er gespecialiseerde gebieden in de hersenen aanwezig, zoals bijvoorbeeld voor waarneming (horen, zien of ruiken) of motorische functies (lopen of fietsen).

Het netwerk staat niet stil, maar verandert altijd.

Plasticity

The possibility of changes is called plasticity, or adaptability. 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.

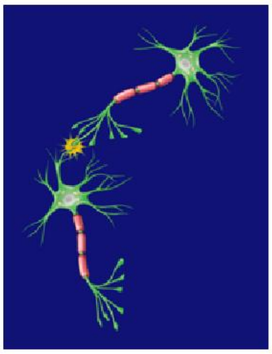
Thanks to this adaptability, there is also a chance to recover from a limited brain injury. The complexity of the network – there are many more connections than necessary – makes it possible to build detours if the ‘direct route’ to certain areas of the brain is closed. In other words, when an area in the brain is damaged, so that a function no longer can be performed, other (unused) areas in the brain can take over this function. This is called: reorganization.

Plasticiteit

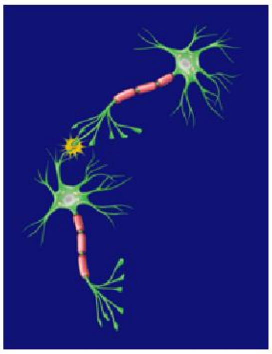
De mogelijkheid tot veranderingen noemen we plasticiteit, ofwel aanpassingsvermogen. Neuronen delen zich na de geboorte niet meer en vormen dus geen nieuwe cellen zoals dat bij andere cellen gebeurt. Neuronen zijn in staat om steeds nieuwe onderlinge verbindingen te maken: de plasticiteit.

Vlak na de geboorte is de plasticiteit het grootst. Onze hersenen worden razendsnel aangepast aan onze leefomgeving.

Dankzij dit aanpassingsvermogen is er ook een kans te herstellen van een beperkt hersenletsel. De complexiteit van het netwerk -er zijn veel meer verbindingen dan nodig zijn- maakt het mogelijk 'omwegen' aan te leggen als de 'rechtstreekse route' naar bepaalde hersengebieden afgesloten is. Met andere woorden: wanneer een gebied in de hersenen beschadigd is waardoor een functie niet meer uitgevoerd kan worden, kunnen andere (onbenutte) gebieden in de hersenen, deze functie overnemen. Dit heet: reorganisatie.



Doorgeven van signalen in het neuron



Doorgeven van signalen in het neuron

Construction of the neuron

Like other cells, neurons have a cell body with a nucleus. All parts that also provide cell management for other cells

Bouw van het neuron

Net als andere cellen hebben neuronen een cellichaam met een kern. Alle onderdelen die ook bij andere cellen zorgen

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.	voor de celhuishouding zijn aanwezig. Het voornaamste verschil is de vorm: het cellichaam van het neuron heeft een aantal uitlopers: de neurieten. Het aantal neurieten kan per neuron verschillen. Ook kan het cellichaam zich niet delen en vermenigvuldigen. Als het cellichaam beschadigd wordt bestaat het risico dat het hele neuron afsterft.
Core At the core is the genetic code, or the DNA stored, that determined 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.	**Kern** In de kern is de genetische code, ofwel het DNA opgeslagen, die bepaalt hoe de cel zich ontwikkelt en werkt. Het DNA bevat de instructies voor alles wat er in de cel gebeurt met als gevolg duizenden chemische reacties. Zonder deze reacties zouden cellen hun taken niet kunnen uitvoeren.
You may now make the reflection assignments below.	*Je mag nu hieronder de reflectie-opdracht maken.*
Please write down a short summary about the text 'The Neuron, Building Block of the Brain'. Do this in about 5 sentences below.	Schrijf een korte samenvatting van 'Het neuron, bouwsteen van de hersenen'. Doe dit in ongeveer 5 zinnen hieronder.

Appendix B : Word Pairs for the Evolutionary Context Manipulation Organized by Evolutionary Context, Concreteness Category and Theme Category

Primary context		Secondary context	
Concrete			
Animals		**Electronic devices**	
1 vlinder-kodeiss	*butterfly*	5 telefoon-bumqit	*phone*
17 kikker-jedoek	*frog*	21 computer-schomik	*computer*
Fruits		**Recent non-electronic tools**	
3 peer- nufrijg	*pear*	7 paraplu-miftee	*umbrella*
19 citroen-karsing	*lemon*	23 kraan-geschak	*faucet*
Body parts		**Objects for reading & writing**	
9 haar-kodiel	*hair*	13 krant-morees	*newspaper*
25 lichaam-voliekt	*body*	29 boek-ipseel	*book*
Members of kin		**Recent transportation means**	
11 moeder-soeluup	*mother*	15 auto-zappel	*car*
27 vader-stoger	*father*	30 tram-boddelt	*tram*
Abstract			
Positive concepts relationships		**Language concepts**	
2 liefde-wotsuit	*love*	6 grammatica-breefje	*grammar*
18 gunst-bisdalf	*favor*	22 werkwoord-aaluuk	*verb*
Negative concepts relationships		**Math concepts**	
4 wraak-klaspert	*revenge*	8 vermenigvuldiging-ellaan	*multiplication*
20 haat-muspert	*hate*	24 wiskunde-bijnjert	*math*
In- and outgroup concepts		**Physics concepts**	
10 vijand-pardaan	*enemy*	14 zwaartekracht-plarker	*gravity*
26 vriend-plokerts	*friend*	31 atoom-rufoen	*atom*
Survival concepts		**History and time concepts**	
12 gevaar-strokit	*danger*	16 geschiedenis-bekaar	*history*
28 dreiging-fileek	*threat*	32 eeuw-spodent	*century*

Note. The numbers indicate the order in which the pairs are studied and organised in study lists (see Appendix C)

Appendix C : Word Pairs for the Evolutionary Context Manipulation Organized by Study Lists

Study list 1	**Study list 2**	**Study list 3**	**Study list 4**
1 vlinder - kodeiss	5 telefoon - bumqit	9 haar - kodiel	13 krant - morees
2 liefde - wotsuit	6 grammatica - breefje	10 vijand - pardaan	14 zwaartekracht - plarker
3 peer - nufrijg	7 paraplu - miftee	11 moeder - soeluup	15 auto - zappel
4 wraak - klaspert	8 vermenigvuldiging - ellaan	12 gevaar - strokit	16 geschiedenis - bekaar

Study list 5	**Study list 6**	**Study list 7**	**Study list 8**
17 kikker - jedoek	21 computer - schomik	25 lichaam - voliekt	29 boek - ipseel
18 gunst - bisdalf	22 werkwoord - aaluuk	26 vriend - plokerts	30 atoom - rufoen
19 citroen - karsing	23 kraan - geschak	27 vader - stoger	31 tram - boddelt
20 haat - muspert	24 wiskunde - bijnjert	28 dreiging - fileek	32 eeuw - spodent

Note. Uneven study lists consist of primary concepts, even study lists consist of secondary concepts. Of each study list the first and third concepts are concrete, the second and fourth abstract.

Appendix D : Adapted Cognitive Load Index

English version	Dutch version
Intrinsic CL	
The topic of the learning task was very complex	Het onderwerp van de leertaak was heel complex.
I perceived the learning task as very complex	Ik ervaarde de leertaak als heel complex.
The activity covered concepts that I perceived as very complex	De activiteit bevatte concepten die ik heel complex vond.
Extraneous CL	
The instructions and/or explanations were very unclear	De instructies en/of uitleg waren erg onduidelijk.
The instructions and/or explanations were, in terms of learning, very ineffective	De instructies en/of uitleg waren, voor het leren, erg ineffectief.
The instructions and/or explanations were full of unclear language	De instructies en/of uitleg stonden vol onduidelijke taal
Germane CL	
I could fully understand the concepts covered in the learning task	Ik kon de concepten die in de leertaak behandeld werden volledig begrijpen.
I could make sense of most of the words presented in the learning task	Ik snapte de meeste woorden uit de leertaak.
I could see how all words are interconnected	Ik kon zien hoe de woorden met elkaar verbonden zijn.
I could connect the new information I learnt in this learning task to what I already knew	Ik kon de nieuwe informatie die ik in deze taak leerde, koppelen aan wat ik al wist.

Appendix E : Adapted Situational Interest Scale

English version	Dutch version
Triggered SI	
I didn't like this vocabulary learning exercise	Ik vond het oefenen van de woordenschat niet leuk.
The exercise on vocabulary learning was not very interesting	Het oefenen van de woordenschat was niet erg interessant.
I enjoyed this vocabulary learning exercise	Ik vond het leuk om woordenschat te oefenen.
The vocabulary learning exercise really seemed to drag on forever	Het leek alsof het oefenen van de woordenschat maar bleef duren.
I liked the way this learning task was organized	Ik vond het oefenen van de woordenschat goed georganiseerd.
M-SI feeling	
I think learning foreign languages is very interesting.	Ik vind nieuwe talen leren erg interessant.
Learning foreign languages fascinates me.	Nieuwe talen leren fascineert mij.
I'm excited to learn foreign languages.	Ik ben enthousiast om nieuwe talen te leren.
To be honest, I don't find learning foreign languages interesting.	Om eerlijk te zijn, ik vind nieuwe talen leren niet interessant.
M-SI value	
I see how knowledge on a foreign language can be applied to real life.	Ik zie hoe kennis van een nieuwe taal kan toegepast worden in het dagelijks leven.
I think learning vocabulary in a foreign language is important.	Ik vind woordenschat leren van een nieuwe taal belangrijk.
I think learning vocabulary in a foreign language is useful.	Ik vind woordenschat leren van een nieuwe taal nuttig.
I think learning foreign languages is an important subject.	Ik vind nieuwe talen leren een belangrijk onderwerp.
I find learning vocabulary in a foreign language personally meaningful.	Ik vind woordenschat leren van een nieuwe taal persoonlijk zinvol.