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Abstract

Many large scale, school-based interventions have attempted to improve academic performance through promoting students' growth mindset, defined as the belief that one's intellectual ability can increase with practice and time. However, most have shown weak to no effects. Thus, it is important to examine how growth mindset might affect retention and transfer of learning, as well as process-related variables such as cognitive load. In a double blind, randomised controlled experiment, based on 138 secondary school students, the effects of an experimentally induced growth mindset belief were examined during a learning phase, in a classroom setting. Participants in the growth mindset condition perceived a lower intrinsic load and extraneous load, and performed better on retention and transfer tests. Students with some prior knowledge also reported a higher mastery goal orientation. Supplementary mediation analysis suggested that the effect on transfer could be fully accounted for by changes in cognitive load perceptions. Future interventions may benefit from designs that promote motivational beliefs that reduce intrinsic and extraneous cognitive load perceptions.

Key words: growth mindset; cognitive load; motivation; learning; goal orientation

Educational Impact And Implications Statement

The experimental study is based on a sample of secondary school students who were presented a short lesson on how sound travels. The study showed that cultivating a growth mindset helped the learners adopt learning goals that focus on development of knowledge and skill. Learners also experienced less cognitive load, and achieved deeper understanding of the lesson. These results imply that interventions targeting growth mindset may indeed increase learner motivation and improve learning.

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In order to improve academic performance, many recent school-based interventions have targeted cultivating a growth mindset belief, the belief that intelligence is malleable through effort and practice (Dweck & Yeager, 2019). Nevertheless, results from large scale studies (Foliano, Rolfe, Buzzeo, Runge, & Wilkinson, 2019; Yeager et al., 2019) and meta-analyses showed that these interventions have mostly yielded small or nearly null effects on academic performance (Sisk, Burgoyne, Sun, Butler, & Macnamara, 2018). This has led to debates regarding the practical implications of growth mindset interventions (Lee & Wiggins, 2015; Miller, 2019). Nevertheless, the moderate effects in such "real world interventions" are not surprising (Hulleman & Cordray, 2009), because there are various factors that could undermine intervention fidelity (e.g. participant compliance). Also the achievement measures used in interventions, such as grades are also subject to factors other than learning alone, for example, level of prior knowledge. There is no doubt that the growth mindset interventions are based on strong theoretical grounds suggesting effects on motivational beliefs underlying learning and academic performance. Yet to our knowledge no experimental research has been conducted in a controlled laboratory environment to demonstrate the effect of growth mindset on immediate retention and transfer learning outcomes, ruling out factors such as compliance or prior knowledge.

Furthermore, there is still a lack of understanding in terms of the role of motivation and students' cognitive processes important to understanding learning and instruction

(Mayer, 2014b; Sweller, van Merriënboer, & Paas, 2019). In particular, the experienced cognitive load that results from instructional design features of the learning tasks (e.g., task complexity) have been hypothesised to bear a close relationship with motivation (Mayer, 2014a; Moreno & Mayer, 2007). Understanding the interplay between perceived cognitive load and motivational beliefs such as growth mindset may be important when designing effective intervention programmes. The present study examined the effect of an experimentally induced growth mindset in relation to learners' perceived cognitive load, learning performance, and motivation. The following sections of the Introduction elaborate these.

Mindset, Attribution, and Cognitive Load

Mindset

Students often hold different views about their academic aptitude and whether it can be improved. According to Dweck (Dweck, 2000), these views reflect implicit yet distinct theories regarding the malleability of human attributes such as intelligence. Someone with a fixed mindset belief, views intelligence as fixed and unalterable (also called an entity view). A person with a growth mindset belief, on the other hand, considers intelligence as something that can be improved with practise and help from others (also called an incremental view). Dweck and her colleagues (Dweck, 2000; Dweck & Leggett, 1988) developed a social-cognitive theoretical framework that explains how mindset beliefs affect the way in which people ascribe attributions to success and failures. These beliefs set out the paths to divergent motivational and behavioural consequences (Dweck, 2017; Dweck & Master, 2008b). Students who view ability as fixed tend to focus on demonstrating their abilities and attribute failures to a lack of ability. For those students, validating their ability by outperforming other students is more important than mastering new skills. For students who believe ability is fixed, high investment in effort is viewed as a demonstration of low ability. In contrast, students with a growth mindset tend to perceive the development of ability (by taking on challenging learning goals) as more important. Thus, failure can more readily be seen as part of the learning process. High investment in effort is thus viewed as a desirable process to skill mastery and does not necessarily imply low ability.

Attribution

The importance of the views on effort and ability are also elaborated in attribution theory. Weiner (1974, 1979; 2010, 2018) proposed that people's interpretation of their success and failure can affect their subsequent motivation and behaviour, through motivation and emotion. The main attribution factors proposed by Weiner, namely ability, effort, task difficulty, and luck, are also the most frequently studied in empirical research (Hau & Salili, 1993). In their review of measurement tools of attribution, Hau and Salili (1993) noted that teacher explanation in terms of instructional skill was the next most studied attribution factor in empirical research (e.g. Bouchaib, Ahmadou, & Abdelkader, 2018; Perry, Stupnisky, Daniels, & Haynes, 2008; Soriano-Ferrer & Alonso-Blanco, 2019).

Attributing learning to uncontrollable causes such as innate ability or task difficulty is detrimental to subsequent motivation and expectation of success (Weiner, 2010), whereas attribution to controllable causes such as effort is beneficial, in particular for failure, since this type of attribution frames failure as fixable (Dweck & Leggett, 1988; Robins & Pals, 2002). However, the effect of attribution on learning can be dependent on views regarding malleability of ability (Hong, Chiu, Dweck, Lin, & Wan, 1999). For example, an attribution to ability has been generally considered to be detrimental for learning. However, for individuals who have a growth mindset towards ability, ability is no longer an uncontrollable factor since it can be developed and improved with effort and practice. For someone with a fixed mindset regarding ability, attributing failure or success to ability confirms the lack or demonstration of ability. Therefore, when facing a challenging task, learners with a growth mindset would invest increased effort in order to improve, whereas learners with a fixed mindset will doubt their ability and will thus be discouraged from taking up the challenge in order to avoid displaying their lack of ability. Although empirical research is yet to confirm this conjecture, students with a fixed mindset may be likely to blame the materials for being too difficult, or instructors for a lack of clarity in their explanations.

There is empirical support for the notion that change in mindset leads to shifts in attribution beliefs towards effort and ability. In an experimental study based on 60 undergraduate students, Hong et al. (1999; study 3) induced growth mindset in a random half of their participants. After receiving feedback on a cognitive task that they performed during the experiment, the participants in the growth mindset condition reported stronger effort attribution compared to those in the fixed mindset condition. Although no group differences were observed in terms of ability attribution, participants in the fixed mindset condition reported a much higher attribution to ability than to effort. In an attempt to explain the latter result, the authors suggested that the concept of ability might be defined as intellectual ability in the fixed mindset group but as task expertise by the growth mindset group. In a more recent experimental study, attribution was studied in terms of controllability of ability and effort in a sample of 172 primary school students (Song et al., 2020). Although the study unfortunately did not measure attribution to ability and effort separately, it still showed that children in the growth mindset group reported lower controllability of effort/ability for their performance on the task.

Cognitive Load

The relationship between mindset and controllability related attribution beliefs can be used to explain the potential effect that mindset might have on the concept of cognitive load, which is an important construct posited in learning theories to guide the design of instructional materials. Cognitive load refers to information processing load induced by learning tasks (Sweller, 1988; Sweller, Van Merrienboer, & Paas, 1998). Learning theories, in particular cognitive load theory (CLT; Van Merrienboer & Sweller, 2005) and cognitive theory of multimedia learning (CTML; Mayer, 2014b) propose that during learning, novel information is processed in a limited-capacity working memory before being stored in long-term memory which is assumed to have an unlimited capacity. Cognitive load theory categorises three types of cognitive load that arise from the interaction of the learner with the instructional materials (Sweller et al., 1998; Sweller, van Merrienboer, & Paas, 2019) namely intrinsic load, extraneous load and germane load. Intrinsic load refers to the complexity of the information being processed, which is determined by the number of interacting elements in a task. Extraneous load, also determined by the number of interacting elements, is the part of cognitive load that is irrelevant or unnecessary, caused by the way the information is presented to the learner, or the procedure required to perform the task. For example, unguided learning tasks can impose an extraneous load for learners with low prior knowledge, because cognitive load is generated as a result of inefficient search processes. Germane load refers to the cognitive resources that are actually allocated to meaningful, effective learning of the information represented by the intrinsic load. For example, germane load is considered to take place when the learner actively relates new information to existing knowledge, and forms schemas that are stored in long-term memory, indicating successful learning. These three categories form the basis of instructional design goals when constructing learning materials: managing the appropriate level of intrinsic load, reducing extraneous load, and fostering germane load (Mayer & Moreno, 2003; Sweller et al., 2019).

Although the construct of cognitive load typically refers to the load imposed by the objective characteristics (e.g. complexity as determined by element interactivity) of the instructional material, in empirical research it has been assessed using both objective measure (e.g. pupil dilation) as well as subjective measure (e.g. self-reported mental effort or perceived difficulty) (F. Paas, Tuovinen, Tabbers, & Van Gerven, 2003). In particular, the subjective measures have been the primary instrument used to measure cognitive load in empirical research (Anmarkrud, Andresen, & Bråten, 2019; F. Paas et al., 2003). Although the specificity of cognitive load measures regarding mental effort and perceived difficulty is debated in the literature, it is commonly accepted that both represent a global cognitive load divided between intrinsic and extraneous load.

While the task characteristic itself (e.g. task difficulty or how the information is presented) is not necessarily relevant to the learner's motivational state, it may become a relevant attributional factor from the learner's perspective. When learners adopt a growth mindset, they might be more likely to focus on controllable factors such as effort rather than uncontrollable aspects that pertain to the intrinsic and extraneous load aspects of the learning task. There is empirical research indicating perceived difficulty can be affected by learner's motivation (Milyavskaya, Galla, Inzlicht, & Duckworth, 2018). In a series of three experiments, Milyavskaya et al. (2018) showed that motivated learners tend to experience decreased fatigue but exert more actual effort by spending more time on the task as well as by choosing more difficult task. Growth mindset may also affect the perception of cognitive load since it primes the learner to place higher attribution to effort as a result of altered belief regarding the malleability of ability (Hong et al., 1999; Song, Kim, & Bong, 2020).

Growth mindset and mastery goal orientation

Mindset beliefs also are hypothesised to affect achievement goal orientations (Ames & Archer, 1988; Dweck & Master, 2008b). Achievement goals are the reasons or purposes of task engagement which direct the learners' responses to learning related events in achievement situations (Elliot, 2005; Elliot & Church, 1997). A common and widely used distinction identifies two types of goal orientations: mastery/learning goals, and performance goals (Dweck & Leggett, 1988; see also Korn, Elliot, & Daumiller, 2019). A mastery goal focuses on the development of competence and task mastery whereas a performance goal focuses on the demonstration of competence. Mastery goals in particular have been found to be positively associated with academic performance (Huang, 2012). The relationship between achievement and performance goals, on the other hand, is weaker and less consistent (J. A. Chen & Pajares, 2010; Cury, Elliot, Da Fonseca, & Moller, 2006).

Since a growth mindset primes the learner to perceive skill development as malleable, and effort as the means to achieve skills, it follows that a mastery goal orientation should be adopted. Mastery goal orientation has been found to be positively associated with growth mindset, both in observational (J. A. Chen & Pajares, 2010; Diaconu-Gherasim, Tepordei, Mairean, & Rusu, 2019) and experimental settings (Dinger & Dickhäuser, 2013; Lou & Noels, 2016; Song et al., 2020). In Dinger and Dickhäuser's experimental study (Dinger & Dickhäuser, 2013), 80 university students were randomly assigned to a fixed or growth mindset condition. Participants in the growth mindset group reported higher mastery goal orientation after completing a mindset induction exercise. Similar results were found by Lou and Noels (2016) in a sample of 150 university students, who showed stronger endorsement of mastery goals after growth mindset was induced in language learning. The Song et al. (2020) study presented earlier also reported a positive effect of induced growth mindset on mastery goal orientation.

Mindset and Performance

The positive effect of growth mindset interventions on academic achievement measured by grades has been largely confirmed in the literature, although this effect tends to be modest and not consistently found (Sisk et al., 2018). While grades may well represent how well the students have acquired the knowledge the course intended to deliver, a global measure of test score does not necessarily inform knowledge retention and transfer. Mayer describes transfer as “the ability to construct a coherent mental representation from the presented material” and “to use the presented material in novel situations”. Retention on the other hand represents remembering and rote learning (2014b, p. 20). The learners in the growth mindset condition are also expected to perform better on retention, because deep learning such as transfer requires successful construction of knowledge schemas.

Although there are some studies which examined whether growth mindset would affect performance on tasks based on intelligence test items under experimental settings (Hong et al., 1999), these results are not directly comparable to the process of acquiring new knowledge (Diamond, 2013). This is because cognitive functions as measured by intelligence test are in general rather stable and highly heritable (Sniekers et al., 2017), and this notion is further supported by inconsistent replications of these studies (Li & Bates, 2019). Although intelligence is no doubt an important basis for learning (Diamond & Lee, 2011), the acquisition of school based knowledge is essentially a process of processing and storing new information into long term memory, for which prolonged effort and practise are critical factors (Geary, 2008). To our knowledge no study has examined whether immediate learning outcomes such as retention or transfer can be affected by growth mindset.

The Present Study and Research Hypotheses

It has been long suggested that cognitive load and motivational factors jointly affect the learning process (Brünken, Plass, & Moreno, 2010; Moreno & Mayer, 2007). Moreno and Mayer, for example, proposed that affective and motivational factors facilitate the learning processes by fostering cognitive engagement: “When learners lack motivation they may fail to engage in generative processing even when cognitive capacity is available" (Moreno & Mayer, 2007, p. 315; see also F. G. Paas & Van Merriënboer, 1994). However, it is only since more recently that research has started to more extensively elaborate on the relationship between cognitive load and affective, motivational factors (Jan L. Plass & Kalyuga, 2019; Jan L Plass, Moreno, & Brünken, 2010). For example, positive emotions (Brom, Stárková, & D'Mello, 2018) or topic interest (Skuballa, Xu, & Jarodzka, 2019) have been found to be associated with decreased perceived task difficulty. In the present study, we build on the recent development by connecting cognitive load, affective and motivational factors, and learning to the theory of mindset beliefs.

The theory of mindset beliefs provides an informative avenue to bridge the relationship between motivation and cognitive load, given its role in fostering attributional beliefs that are relatable to cognitive load and its perceptions. As aforementioned, when learners adopt a growth mindset, they attribute learning to effort and therefore, are potentially more willing to engage in the learning materials and achieve deep learning such as transfer. On the other hand, adopting a growth mindset reduces attribution to factors not malleable by the learner, such as intrinsic load (e.g. task complexity) or extraneous load (e.g. how well the learning materials are designed). As a result, it is likely that learners with a growth mindset experience a reduced perception of intrinsic and extraneous cognitive loads. Hence, by promoting a growth mindset, potential detrimental cognitive load perceptions during learning could be alleviated by redirecting the learner's attention to meaningful processing of the materials. When a learner feels the task is too difficult or the teacher or material does not explain the task well, a growth mindset could help to reduce the feeling of cognitive load and focus on active learning. Furthermore, the learner will also be more likely to adopt a mastery goal orientation under a growth mindset, and thus more actively engage in the learning task (Dweck & Master, 2008a).

In sum, given that a growth mindset is associated with higher attribution to effort and less attribution to task difficulty and teacher explanation, it is likely that learners would perceive a lower intrinsic and extraneous load. As a result, by directing working memory resources to acquiring necessary knowledge, cognitive processing germane to learning should increase because resources are directed to intrinsic factors relevant to knowledge acquisition rather than extraneous factors that interfere with knowledge acquisition.

To date there has been limited empirical research investigating the effect of growth mindset in terms of how it affects learning processes such as cognitive load perceptions, and learning outcomes such as retention and transfer. To our knowledge, there has only been one correlational study that studied the relationship between mindset, goal orientations, and cognitive load perceptions (Cook, Castillo, Gas, & Artino Jr, 2017). In a sample of 232 secondary school students who performed a medical simulation task, Cook et al. (2017) showed that learners who reported a higher growth mindset belief also had a lower perceived extraneous load, and higher mastery goal orientation. Nevertheless, the ratings did not differ in perceptions of intrinsic load. These patterns of correlations are largely consistent with the theoretical predictions: a growth mindset is associated with lower attribution to learning task materials in terms of lower perceptions of extraneous load. Although a growth mindset would also suggest less attribution on task difficulty, i.e. lower intrinsic load perceptions, the Cook et al. (2017) study did not confirm such an expectation. However, given the observational nature of the study design, it is important to show that the relationship could be replicated under controlled, randomised, experimental settings.

The present study aimed to demonstrate how a growth mindset could influence the learning processes and outcomes in an experimental setting, based on a double blind, randomised, single-factorial design, consisting of two groups: a growth mindset condition, and an active control condition where no mindset belief was implied. Specifically, the following research hypotheses were addressed:

Hypothesis 1. The materials used in our experimental conditions have shown to successfully induce mindset in previous research (Paunesku et al., 2015; Yeager et al., 2016). Based on these studies, and as a manipulation check, we hypothesized that the learners in the growth mindset condition will report a higher growth mindset belief compared to learners in the control condition.

Hypothesis 2. Literature on growth mindset and attribution theories suggests that learners who adopt a growth mindset are likely to place higher attribution to effort as a result of viewing knowledge and skill as malleable. As a corollary, it is to be expected that they are less likely to attribute towards non-malleable factors such as characteristics represented by intrinsic cognitive load and extraneous cognitive load. Thus, we hypothesize that in comparison to the control condition, the learners in the growth mindset condition will report lower intrinsic and extraneous loads.

Hypothesis 3. The fourth hypothesis was based on the assumption that learners with a growth mindset belief tend to adopt learning goals towards learning and skill development (Dweck & Master, 2008a). The attributional focus towards effort as a means to achieve knowledge and skill acquisition is in line with a learning goal orientation. Therefore, we hypothesized that learners in the growth mindset condition will have higher mastery goal orientation ratings compared to learners in the control condition.

Hypothesis 4. Given that a growth mindset primes the learners to place more emphasis on effort attribution, skill development and effort engagement are likely to be increased compared to those without a growth mindset, and thus more effective and deep learning can be expected. Therefore, we anticipate that learners in the growth mindset condition should outperform learners in the control condition on a transfer test. In addition, the learners in the growth mindset condition are expected to perform better on retention, because deep learning such as transfer requires successful construction of knowledge schemas. The building blocks of schemas would involve processing of initially more fragmented elements of information, and this can be reflected by retention.

Hypothesis 5. Following Hypotheses 2 and 4, cognitive load perceptions function as mediators for the pathway between growth mindset induction and learning performance (as illustrated in Figure 1): the growth mindset induction should lead to lower perceived intrinsic and extraneous loads and foster learning, resulting in better learning performance. Perceptions of intrinsic and extraneous load, jointly, are hypothesized to mediate the effects growth mindset induction have on retention and transfer.

<insert figure 1 here>

Method

Participants and Experimental Design

The current study was based on 138 10th grade students recruited from two similar public high schools. Although the original sample consisted of 140 students, two participants were excluded because they did not complete the experiment. Their average age was 16 years

(*SD* = 0.74). There were 50 boys and 84 girls; four students reported their gender as "other". A two group (experimental vs. control) between-subjects design was employed. The distribution of participants in experimental and control groups were equal in both schools because randomisation of experimental conditions was made for each experimental session (n = 69 in the growth mindset condition and n = 69 in the control condition).

The current sample size exceeded the 128 participants that were minimally required, based on an *a priori* power calculation for an effect size of Cohen's d = 0.5 (or f = 0.25), for power = 80%, and type I error rate = 5%.

Since the present study is he first that we are aware of to experimentally investigate the effect of growth mindset, there is no reference of a precise effect size for power analysis. While a recent meta-analysis (Sisk et al., 2018) based on 43 intervention studies showed a small Cohen's d of 0.08, an earlier meta-analysis (Lazowski & Hulleman, 2016) showed a larger effect (Cohen's d = 0.56) based on a lower number of primary studies (k = 6). Furthermore, the effect size should be expected to be larger in well-controlled lab settings (Hulleman & Cordray, 2009) such as ours. Also, recent meta-analyses examining affective aspects of instructional design (Brom et al., 2018; Ginns, Martin, & Marsh, 2013) based on similar learning tasks have reported Cohen's d values of around 0.5 in terms of cognitive load and performance. Summing up, information from various sources of relevant prior research, we aimed to recruit a sample size meeting the above power value. The sample sizes for other possible effect sizes would have been 352 for d = 0.3 (or f = 0.15), and 3142 for d = 0.1 (or f = 0.05).

Growth Mindset Induction

Students in the growth mindset and control conditions performed reading and writing tasks (adapted from Yeager et al., 2016). In the growth mindset condition, students read about brain function and malleability of intelligence in the form of a scientific article titled “You Can Grow your Intelligence”. Then, they were asked to write a letter to an imagined student who struggled with learning a difficult subject. The writing task was a self-persuasion strategy called “saying is believing” (Aronson, 1999), which has been shown to be effective in encouraging participants to adopt a growth mindset belief (Yeager et al., 2016). Students in the control condition read an article of similar length thematizing general brain functioning titled ‘The Neuron, Building Block of the Brain’. The article in the control condition did not talk about malleability of intelligence. Afterwards, participants in the control condition were asked to write a summary of what they read (“Please write down a short summary about ‘The Neuron, Building Block of the Brain’ ”). The materials used in both conditions are presented in Appendix A.

Learning Material

Participants in both conditions performed the same learning task, which was adapted from Fiorella and Mayer (2014). The learning task covered the topic of how sound travels, i.e., the Doppler effect, which was presented through a multimedia instructional message consisting of two single-sided pages of text and illustrations. The text was approximately 500 words with three pictures that were used to help understand the lesson (see Appendix B). Physics teachers of the participating schools were consulted to ensure that the students had not been taught the Doppler effect at the time of the study. Thus, the participants in the experiment were likely to be novices in the subject area.

Measures

Prior knowledge. Prior knowledge regarding the Doppler effect, was assessed with one item requiring learners to self-rate their knowledge base: “How much knowledge do you already have of the Doppler effect?”. The same question has been used to assess prior knowledge on the Doppler effect in previous research (Fiorella & Mayer, 2013, 2014). Learners were asked to indicate their answer on a nine-point Likert scale from (1) very little to (9) very much. The mean was 1.83 (SD = 1.16), confirming low prior knowledge on the topic.

Learning performance. Learning performance was assessed with one open-ended question for retention and three open-ended questions for transfer (adapted from Fiorella & Mayer, 2014). The retention questions focused on reproducing what was presented in the lesson (Mayer, 2014b) by asking students to “Explain how the Doppler Effect works”. The transfer questions focused on scenarios where the students needed to apply the knowledge learnt during the task in a different and novel situation. For example, “A ship is at sea. The wind is picking up and there are many waves. Every second, another wave arrives at the prow of the ship. Now imagine the ship starts navigating against the direction of the waves. What will happen with the time between two waves that arrive at the prow? Explain your answer.”.

The responses to the retention and transfer questions were scored based on the idea units mentioned by students (for full details see rubrics presented in Appendix C). For the retention questions, there were a total of 10 possible idea units extracted from the lesson. The mentioning of each idea unit in the retention question was awarded a score of one. The rentention socre was based on the sum of all scores awarded based on the number of idea units mentioned in the answer. For the transfer questions, there were three idea units in transfer qeustion 1, two idea units in transfer question 2 and one idea unit in transfer question 3. A score point of one was awarded for each correctly answered idea unit.

Two raters independently rated answers to these questions from a randomly selected subset of 25% of the participants. The inter-rater agreement was measured in the form of Pearson's correlation coefficient (r), suitable for continuous measures. Inter-rater reliability was $r = .91$ for retention and $r = .98$ for transfer, indicating a high level of inter-rater agreement. One rater therefore completed the questions from the remaining 75% of the participants.

Growth mindset. Mindset beliefs were measured by using the Implicit Theory of Intelligence Scale questionnaire (Dweck, 2000). This questionnaire consists of four items on a growth mindset (e.g., “No matter who you are, you can significantly change your intelligence level.”) and four items on a fixed mindset (e.g., “You have a certain amount of intelligence, and you can’t really do much to change it.”). Participants rated the statements using a six-point Likert scale from (1) completely disagree to (6) completely agree. Since the eight items measure a single mindset construct at opposite poles (Blackwell, Trzesniewski, & Dweck, 2007), fixed mindset items were reverse coded and combined with growth mindset items into a single scale representing growth mindset. The highest possible rating score was 48. A higher number represented a stronger orientation towards a growth mindset. The internal consistency indices were high: Cronbach’s $\alpha = 0.92$; $\Omega = 0.92$ at baseline and Cronbach’s $\alpha = 0.93$; $\Omega = 0.93$ for the manipulation check.

Mastery goal orientation. Mastery achievement goal orientation was measured with three items that were adapted from the Achievement Goal Questionnaire–Revised (Elliot &

Murayama, 2008) (e.g., "My goal is to learn as much as possible"). The items were directly translated into the native language of the participants without changing the content. The wording 'material' and 'content of the course' were replaced with 'Doppler effect', since that was the content of the offered learning material. Response options were based on a five-point Likert scale from (1) strongly disagree to (5) strongly agree. Items were summed to represent a scale of mastery goal orientation, with a highest possible score of 15. The internal consistency indices were good (Cronbach's $\alpha = 0.82$; $\Omega = 0.84$).

Cognitive load perception. Learner's cognitive load perceptions were measured in terms of intrinsic load and extraneous load, using items based on the psychometrically validated Cognitive Load Index scale (Leppink, Paas, Van der Vleuten, Van Gog, & Van Merriënboer, 2013). The items were adapted to specifically address our learning task as the original items referred to a complete course over a semester. The scale measures intrinsic load with three items (e.g., "The text that I just read was very complex") and three items on extraneous load (e.g., "The text was full of unclear language"). However, since the intrinsic load dimension focuses primarily on situations where overly complex cognitive load is experienced, two items (adapted from Klepsch, Schmitz, & Seufert, 2017) were added to measure intrinsic load ("The Doppler effect was easy to learn" and "When reading the text, I had to retain many things simultaneously in my mind") that covered also lower levels of complexity to allow for better differentiation of a wider range of intrinsic cognitive load perceptions (both high and low). All items were rated on an eleven-point Likert scale from (0) not at all to (10) totally. The three components show good consistency reliability for each domain (Cronbach's $\alpha = 0.87$, $\Omega = 0.87$ for intrinsic load; Cronbach's $\alpha = 0.66$, $\Omega = 0.73$ for extraneous load). Sum scores of each of the three cognitive load measures were created (including germane load – see below).

Although the instrument itself does have a subscale on germane load (Cronbach's α = 0.95, Ω = 0.95; Sum scores = 30), in our opinion the item descriptions do not reflect precisely the definition of germane load (e.g., "The text really helped me to increase my knowledge and understanding of the Doppler effect"), which was pointed out by the authors (Leppink, Paas, Van Gog, van Der Vleuten, & Van Merrienboer, 2014). Accordingly, while the result was reported for this scale, it was not interpreted.

All the measurement scales as well as performance test questions were translated into the language spoken by the participants with assistance from a professional translator and reviewed by those co-authors who are also native speakers of the language.

Procedure

The experiment was conducted during seven mentor sessions in the students' usual classroom setting. Each session consisted of 11 to 25 participants. For each session, the experimenter prepared an equal number of envelopes for participants in the experimental and case conditions. These envelopes contained the briefing letter and paper-based study materials for growth mindset and control conditions. Before the experiment started, the experimenter randomly placed these envelopes on the classroom desks, thus randomising the experimental conditions. As the participants stepping into the classroom, the experimenter collected the signed consent forms of both the participants and their parents. Then the students were asked to randomly choose a desk to sit at, thus further ensuring the randomisation of the experimental conditions. The experimenter gave the participants a brief introduction to the experiment. The students filled in their email address on a separate sheet to participate in a raffle in which two persons from the study could win a gift card prize of € 30. On the desk there were already a pencil and eraser. Although each set of materials was marked by a unique identification number, the number itself did not reveal the experimental condition to the experimenter. Thus, neither the experimenter nor the participants were aware of the experimental condition. In particular, the experimenter was able to remain blind to the conditions, because no questions or situations arose that were content specific to the experimental conditions or exposed and influenced the randomisation process. Furthermore, both raters of the performance tests were also able to remain blind to the experimental condition, because it was possible to separate the performance test pages from the pages which could reveal the experimental conditions.

The experiment was executed in phases. Each phase was paced by the experimenter, making sure that all participants spent the same amount of time on the tasks. The participants were asked to take out the materials for each phase when instructed by the experimenter while the materials of the remaining phases were kept sealed in the envelop.

During the first phase, the participants were given five minutes to complete information regarding demographics, prior knowledge and rated items measuring a growth mindset. The second phase was timed to last for 10 minutes. Participants in the growth mindset condition completed reading and writing tasks primed to induce a growth mindset; those in the control condition completed the corresponding reading and writing assignments that functioned as control tasks. At the end of phase two, participants in both groups rated items on mindset again as a manipulation check. The third phase was timed to last 12 minutes. The participants first rated items on mastery goal orientation and then studied a lesson on the Doppler effect. During the last phase, participants rated their cognitive load perceptions on the lesson from the previous phase, then completed the retention test and the transfer tests. The performance tests were timed individually. The last phase lasted for 18 minutes in total. The entire experiment lasted approximately 45 minutes. Ethical guidelines were followed and approval was obtained from the institutional ethical committee review board.

Fidelity Check

For intervention studies, it is important that a high degree of fidelity is maintained such that the participants responded accordingly as required by the experimental procedure (O'Donnell, 2008). The fidelity check was performed to verify that, during the experimental phase, the growth mindset and control tasks were indeed performed by the participants as instructed. For the growth mindset condition, we calculated the percentage of participants who actually wrote down text to a fellow student who struggled to learn a difficult subject (100%, 69 out of 69) and the percentage of participants who mentioned making an effort for a difficult subject to the fellow student they wrote to (77%, 53 out of 69 participants). For the control condition, we calculated the percentage of participants who actually wrote the summary from the proceeding article they read (99%, 68 out of 69 participants). Based on the randomly selected 25% (34 out of 138 participants) of the sample, the rating agreement between the two raters was 100% (17 out of 17) for the growth mindset condition with respect to writing to a fellow student, 88% (15 out of 17) for the growth mindset condition mentioning making an effort for a difficult subject, and 100% for the control condition (17 out of 17).

Furthermore, it is reasonable to assume that the participants were engaged in the experimental activities, as a result of the following activities: the experimental phase was timed by the experimenter, during which the participants only had access to material from this particular phase of the study. All participants spent the same amount of time working on the reading and writing tasks designated for this particular phase of the study. The desks they worked on were kept in order with only paper material of the study, an eraser and a pencil. The room was kept quiet by the experimenter. Given these procedures, it is likely that the participants were indeed engaged with the intervention materials handed to them.

Analysis

ANOVA and ANCOVA analyses were conducted in SPSS 25. To control for potential type I errors as a result of multiple testing, we used R to calculate adjusted *p*-values based on Benjamini-Hochberg's FDR method (Benjamini & Hochberg, 1995). Specifically, we chose to adjust the *p* values of the main outcomes, which are intrinsic load, extraneous load, mastery goal, retention and transfer outcomes. Mediation analysis was performed in Mplus 7.4.

Results

Table 1 presents descriptive statistics including means and standard deviations for the two experimental conditions as well as information on scale distribution and effect sizes measured by Cohen's *d*, univariate analysis of variance (ANOVA) and univariate analysis of covariance (ANCOVA) with prior knowledge as a covariate. Correlations among all variables are presented in Table 2. One-way ANOVA was used to compare differences between growth mindset and control groups regarding age, gender, prior knowledge, baseline growth mindset belief, as well as the manipulation check and mastery goal orientation. ANCOVA was used for outcomes on cognitive load and learning performance. Prior knowledge was used as a covariate, because of its relevance in cognitive load perceptions and learning performance (O. Chen, Kalyuga, & Sweller, 2017). Including relevant covariates can reduce the unexplained variance in the outcome variables, thus increase statistical power (Kahan, Jairath, Doré, & Morris, 2014).

Measurements of all scales had skewness and kurtosis statistics between -2 and 2, indicating approximate normal distribution (Gravetter & Wallnau, 2012). A one-way ANOVA showed no statistically significant group differences in terms of participants' gender, $F(1, 136) = 0.1$, *n.s.* $\eta_p^2 < 0.01$, age, $F(1, 136) = 2.6$, *ns.*, $\eta_p^2 < 0.02$, prior growth mindset, $F(1, 136) = 0.89$, *n.s.*, $\eta_p^2 = 0.01$, or prior knowledge, $F(1, 136) = 0.34$, *n.s.*, $\eta_p^2 < 0.01$.

Manipulation Check (Hypothesis 1)

A one-way ANOVA confirmed that participants in the growth mindset condition rated higher growth mindset belief compared to participants in the control condition, Cohen's $d = 1.01$ (Table 1), $F(1, 135) = 35.94$, $p = 0.00000002$, $\eta_p^2 = 0.21$. Furthermore, between the baseline and the manipulation check, there was also a greater increase of the growth mindset belief in the experimental group: $F(1, 135) = 52.21$, $p = 0.00000000003$, $\eta_p^2 = 0.28$. The findings show that in line with our expectations, the growth mindset induction led to higher scores in the mindset-condition for the learners in the experimental condition.

Cognitive Load (Hypothesis 2)

One-way ANCOVA analysis revealed that participants in the experimental group reported a lower level of intrinsic load, Cohen's $d = -0.32$ (Table 1), $F(1, 135) = 4.19$, $p = 0.04$, $p_{FDR} = 0.05$, $\eta_p^2 = 0.03$, and a lower level of extraneous load, Cohen's $d = -0.66$ (Table 1), $F(1, 135) = 14.94$, $p = 0.0002$, $p_{FDR} = 0.03$, $\eta_p^2 = 0.1$ than participants in the control condition. Additional analysis included the interaction between prior knowledge and experimental condition. Result showed that the effect of intervention was not dependent on the level of prior knowledge, neither for intrinsic cognitive load, $F(1, 134) = 0.29$, $p = 0.86$, $\eta_p^2 = 0.0002$, nor for extraneous cognitive load $F(1, 134) = 0.30$, $p = 0.59$, $\eta_p^2 = 0.002$. This result confirms the hypothesis that the growth mindset induction led to lower intrinsic and extraneous load perceptions.

There was no effect of condition on measurement of germane load, Cohen's $d = 0.25$ (Table 1), $F(1, 135) = 1.95$, $p = 0.16$, $\eta_p^2 = 0.01$. However, due to the discrepancy between the measurement items and the definition of the germane load, this result is not interpreted.

Mastery Goal Orientation (Hypothesis 3)

ANCOVA results showed that the mindset condition group indicated a higher mastery goal orientation, with an effect size of 0.31 (Table 1), $F(1, 135) = 3.82$, $p = 0.05$, $p_{FDR} = 0.05$, $\eta_p^2 = 0.027$. Further analysis adding an interaction term to the ANCOVA indicated that the effect of the experimental condition on mastery goal orientation was dependent on prior knowledge, $F(1, 134) = 56.14$, $p = 0.003$, $\eta_p^2 = 0.06$. Stratified post-hoc ANOVA analysis was performed by level of prior knowledge. For those reporting "very little" prior knowledge (n = 81; rated 1 on a scale between 1 to 9) there was no difference in mastery goal orientation between experimental and control conditions, $F(1, 79) = 1.37$, $p = 0.25$, $\eta_p^2 = 0.02$. For those reporting some level of prior knowledge (n = 57; rated between 2 and 6 on a scale between 1 to 9) there was a statistically significant difference in mastery goal orientation between the two groups, $F(1, 55) = 24.30$, $p = 0.000008$, $\eta_p^2 = 0.31$. The participant in the growth mindset induction condition reported higher mastery goal orientation (mean = 12.15) than those in the control condition (mean = 9.13) with an effect size Cohen's $d = 1.24$ (see Figure 2). This result partially confirms the hypothesis that the growth mindset induction led to a higher endorsement of mastery goals, but only for those who reported to have some level of prior knowledge.

<insert Figure 2 here>

Performance Outcome (Hypothesis 4)

According to the one-way ANCOVA results, the growth mindset experimental group participants outperformed the control group participants both on the retention test, $F(1, 135)$

= 5.58, p = 0.02, p_{FDR} = 0.03, η_p^2 = 0.04 and the transfer test, $F(1, 135)$ = 5.47, p = 0.02, p_{FDR} = 0.03, η_p^2 = 0.04. Additionally analysis included an interaction term indicated that the experimental condition did not depend on prior knowledge, neither for retention $F(1, 134)$ = 1.29, p = 0.26, η_p^2 = 0.01, nor for transfer $F(1, 134)$ = 0.18, p = 0.67, η_p^2 = 0.001. These findings indicate that Hypothesis 4 was confirmed and that a growth mindset induction indeed produced expected beneficial effects on learning.

Cognitive Load as Mediators (Hypothesis 5)

Mediation analysis was performed in order to demonstrate the indirect effect of cognitive load perceptions on the relationship between a growth mindset induction and learning performance. The regression coefficients of the mediation model (Figure 1) are presented in Table 3. For retention performance, none of the cognitive load perception variables mediated the effect of the growth mindset induction. However, for transfer performance, the total combined indirect effect was statistically significant (indirect effect β = 0.16, Table 4). Furthermore, the effect of the growth mindset induction became statistically nonsignificant after controlling for cognitive load variables (β = 0.24, $p > 0.05$, Table 3). This finding suggests that cognitive load perceptions completely mediated the effect of growth mindset on transfer, whereas for retention, there was a direct effect of the growth mindset induction that was not mediated by cognitive load perceptions.

Discussion

The present study demonstrated that in a randomised controlled setting, promoting a growth mindset leads to a higher growth mindset belief, stronger mastery goal orientation, lowered perception of intrinsic and extraneous loads, and better retention and transfer performance. Furthermore, the mediation pathway by which a growth mindset induction benefits learning was supported by mediation analysis: the cognitive load perceptions jointly mediated the effect of growth mindset induction on transfer performance.

Mindset Induction

The manipulation check in the present study indicated that the growth mindset induction was successful. Participants in the growth mindset induction condition reported a higher growth mindset belief compared to those in the control condition. In the growth mindset condition, the students were asked to read an article on how intelligence can grow through an explanation of brain functions, then they wrote to an imaginary fellow student who struggles in learning a difficult subject. This strategy has been shown to be successful in previous studies (Aronson, 1999; Yeager et al., 2016). The participants in the control condition performed comparable activities that consisted of reading an article only about brain function and then writing a summary of the article. Having the control group performing similar tasks makes the comparison of outcomes more comparable in terms of the type of activities and time spent on those activities during the experiment.

Effect on a Mastery Goal

The participants in the growth mindset group who reported relatively more prior knowledge on the learning topic rated a higher mastery goal orientation after the mindset induction phase. This result is largely consistent with many previous studies showing that a growth mindset is inducive to adaptation of mastery learning goals (Blackwell et al., 2007; Dinger & Dickhäuser, 2013). Although previous research conducted in observational, longitudinal settings showed that a mastery goal could mediate the effect of a growth mindset on performance (Blackwell et al., 2007), in the present study a mastery goal orientation was not associated with either cognitive load, nor performances (Table 2). This result might be due to the fact that achievement goals are relatively stable, trait like constructs (G. Chen, Gully, Whiteman, & Kilcullen, 2000) thus do not directly affect changes in cognitive processes occurring in the short term such as in the present study. Thus, the increase in mastery goal orientation observed in the growth mindset group is likely to represent short term fluctuation, which may not be associated with short term learning gains. It is also possible that follow up measures assessing retention of knowledge might show more pronounced differences in learning performance.

Further research is warranted regarding the finding that the effect of the growth mindset induction on mastery approach goal adoption was stronger for those who reported relatively higher level of prior knowledge. This may be a result of the way in which the persuasion task was formulated. The writing task in the growth mindset induction material suggested that the participants could write about growth mindset in reference to a supposedly difficult learning subject such as the Doppler effect. If a participant knew about the subject, it is more likely that they were able to make a stronger connection with the growth mindset in terms of a knowledge mastery orientation. However, the prior knowledge was not objectively assessed and the current study has already controlled for prior knowledge to a large extent by making sure that the Doppler effect had not been taught to the participants in school. Future study comparing learners with more differentiated levels of prior knowledge may provide more information in terms of the effect of growth mindset on mastery approach goal orientation.

Effect on Cognitive Load Perceptions

Although the two experimental groups in the present study learnt the same lesson, learners in the growth mindset induction group reported lower perceived intrinsic and extraneous cognitive loads. This is in line with our hypothesis that an adaptation of a growth mindset leads to reduced perception of intrinsic and extraneous loads. Although such a relationship was previously investigated by using an observational design (Cook et al., 2017), the finding from the current study offers a stronger causal inference based on a randomised, double blind experimental design, employing an active control group. Moreover, while the previous study (Cook et al., 2017) was not based on a learning task, the present study has stronger ecological validity because it was based on learning a lesson that is similar to the curriculum taught in secondary schools.

Effect on Learning Performance

Many previous school-based interventions have tested the implementation of growth mindset training during school semesters and looked at global academic achievement in terms of grades. The present study is one of the first to show that instilling a mindset belief in learners can indeed benefit learning both in terms of retention and transfer. The effect sizes we observed in terms of Cohen's *d* were 0.33 for retention and 0.39 for transfer. Both were larger than what was reported in a previous meta-analysis based on 43 studies ($d = 0.08$) (Sisk et al., 2018). One reason for the large difference in effect size could be that the present study was a randomised, single session experimental study, whereas the intervention studies included in the meta-analysis were field interventions that usually last for weeks or even months. Even with multiple training sessions, it is possible that the effect of an intervention becomes attenuated during the course of time. Furthermore, the mindset induction task in the present study was performed immediately prior to learning, thus the change in mindset was still salient enough to have an impact on learning. Furthermore, in intervention studies the achievement is typically measured by the global grade point average summarising grades from all the school subjects. The present study was based on a single lesson on a topic in physics and used specific measures of learning. It is possible that the growth mindset intervention is more effective for certain subjects with specific measures, but less for others. In future research, it may be fruitful to identify the subjects that respond to mindset interventions in effective ways.

It is important to note that, achievement measures such as grade point average used in interventions are relevant but not equivalent to the performance indicators such as retention and transfer used in the present experimental research. There are however similarities to a certain extent. For example, course grades make up the grade point average and these measures reflect in part retention and transfer of the knowledge the students have learnt during the course of a semester. However, when used as an outcome measure of an intervention, grade point average measures may also reflect factors that undermine the fidelity of the intervention, such as when participation was undermined by a low compliance rate. While this is an issue difficult to monitor in large scale online interventions, it is much better controlled in experimental settings. Furthermore, prior knowledge has shown to be an important factor affecting learning (Kalyuga, 2005). While prior knowledge is typically well controlled in experimental research, for intervention studies it is not the case. This is because in most courses taught in schools the students usually would have different levels of prior knowledge on the subjects they are taught, at least more so in comparison in relation to an experimental study where the prior knowledge is often controlled for. Such factors may explain why the effects observed in intervention studies are smaller and make it less applicable to directly compare the effects observed in different research settings (also see Hulleman & Cordray, 2006).

Furthermore, it is important to note that the magnitude of effect sizes (see Funder & Ozer, 2019 for an in-depth discussion on effect size) are not directly comparable across experimental and intervention research. One of the reasons leading to the moderate effect observed in intervention studies could be due to the lower degree of intervention compliance.

Fidelity checks of the present study indicated that almost all participants followed instructions and completed the manipulation tasks. Nevertheless, this is not necessarily the case in intervention studies. Growth mindset interventions are often implemented on a large scale, and often delivered online, with the participants completing the intervention tasks unsupervised. It thus may well be the case that the true effect of the intervention is in fact higher than observed in the current literature.

It was found that the growth mindset affected transfer performance indirectly via the mediation through cognitive load. This indicates that cognitive load plays an important role as a cognitive process indicator of learning. According to the tripartite classification based on cognitive load theory (Sweller et al., 2019), intrinsic and extraneous loads jointly take up resources in working memory during learning. However, recent theoretical development has indicated that affective factors such as emotion can narrow or widen the scope of working memory, and thus affect learning (Jan L. Plass & Kalyuga, 2019). Although the present study did not directly measure emotion, a construct such as intrinsic motivation is closely related to mastery goal orientation (Harackiewicz & Elliot, 1993) and fosters positive emotions (Pekrun, 2006). Attribution styles which are associated with a growth mindset belief, are also proposed to be associated with distinct emotional responses (Weiner, 2018). It is possible that the difference in perceived cognitive load and its mediating effects on performance observed in the present study can be further explained by emotional processes. Emotional states may directly impact the availability of cognitive resources, hence leading to more efficient learning and consequently better performance.

Limitations and Future Directions

The present study has several limitations. First, the present study translated original scales into the native language of the participants and some were adapted to the specific learning context of the current study. Although the translation and adaptation have been executed with great attention to detail, future psychometric studies are needed to determine and improve the measurement precision and validity by investigating the psychometric comparability of the scales across language and learning contexts.

The intrinsic and extraneous loads were both rated fairly low by the participants (lower than the mid-point). This could result in smaller variability in the data in terms of the range of cognitive load perceptions existing in the data. Although we were able to detect differences in those cognitive loads across experimental conditions, it is possible that the statistical power will be further strengthened if the cognitive load demand increases thus allowing the experimental effects to be observed with smaller samples. Future research could examine the effect of a growth mindset induction for learning tasks that differentiate intrinsic load and assesses whether a growth mindset is more effective for a high intrinsic load task.

The present study focused on subjective reports of cognitive load measures. It is worth noting that the intrinsic and extraneous loads were positively correlated, indicating that the learners did not completely distinguish the two loads. While CLT theory hypothesised an additive relationship between intrinsic and extraneous load (Sweller, Ayres, & Kalyuga, 2011), this does not necessarily imply a methodical limitation in the subjective questionnaire of cognitive load. It could be difficult for novice learners to distinguish the sources of experienced cognitive loads, due to their limited prior knowledge in the subject matter. Based on the finding, subjectively rated cognitive loads mediated the effect of a growth mindset on learning which implies that learners' reported cognitive loads may provide useful feedback for instructional designers. Such information can assist in designing instructional materials that reduce perceptions of intrinsic and extraneous cognitive loads. Future studies could further investigate the conditions under which subjective perceptions of cognitive load could affect learners' use of cognitive resources during learning.

It should be noted that the person perspective in the writing task for growth mindset group was directed towards a third person – an unspecific fellow student, whereas in the control group the writing task was not person specific. The person perspective has been shown to be of relevance to learning in previous research, with a first person perspective being the most effective for learning (Fiorella, van Gog, Hoogerheide, & Mayer, 2017; Hoogerheide, Renkl, Fiorella, Paas, & van Gog, 2018). Nevertheless, since the issue of person perspective was not relevant to the actual learning task in the present study, the effect might be minimal. Future studies may further clarify the role of person perspective during mindset induction.

Intervention studies have shown that certain subpopulations of students benefit more from having a growth mindset, such as those not doing well academically and at a disadvantage in terms of socio-economic background (Dweck & Yeager, 2019; Miller, 2019). Future experimental studies may incorporate different learner groups in the research design to better understand the underlying learning process in order to design potentially more effective interventions.

In the present study, the lesson in the learning task was a physics subject. It is possible that students may have different growth mindset beliefs for other school subjects. For example, previous research has shown that motivation beliefs such as achievement goals and attributional beliefs are domain specific (Bong, 2004). In a Korean student sample, Bong (2004) found that achievement goal orientations in math and language was correlated at 0.36 whereas ability attribution was uncorrelated in the two subjects. This implies that increases in motivation in one subject does not necessarily mean an increase in another subject. It would be informative to investigate whether growth mindset interventions benefit different school subjects equally effectively.

Although the present study focused on the effect of growth mindset on attribution and mastery goal orientation and learning performance, it is possible that changes in attribution and goal orientations could also affect mindset beliefs, especially when learners experience success and failure. Similarly, it is also informative to study these relationships through longitudinal designs, where measures on growth mindset, attribution and goal orientations are repeatedly assessed, thus enabling inferences on causal ordering. Although the validity of causal inference is undoubtedly strong under randomised controlled trails, well designed longitudinal studies can also offer useful insights in terms of the reciprocal ordering of the variables under investigation (Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005).

Historically the formulation of growth mindset theories is based on an attribution-centric view, with malleability of ability essentially functioning as a moderator on how attribution can influence motivational tendencies. It may be possible to create contexts where learning scenarios could prime different attributions to the learning experience. From an instructional design perspective, it may also be interesting to design learning tasks that vary in terms of cognitive demand, i.e. intrinsic cognitive load. It may be the case that learners exposed to tasks imposing less cognitive demand experience a higher sense of control and confidence, and therefore attribute their learning experience more to factors related to their own ability compared to learners exposed to tasks imposing more cognitive demand. If this is indeed the case, prolonged exposure to difficult tasks might lead to lower growth mindset on ability. This may be in itself an interesting approach to test the effect of attribution on mindset, and also provide interesting information regarding the design of instructional messages in combination with motivational strategies on effort beliefs such as growth mindset.

Implications

The present study shows the effectiveness of inducing a growth mindset belief prior to learning a short lesson. Given that the growth mindset induction was placed immediately prior to the learning phase, it may be fruitful for future interventions targeting mindset to embed the training session in closer proximity with the learning activities of the students, in order to have an effect. For example, mindset training could be tailored to specific courses, taking advantage of existing instructional principles that could reduce perceived cognitive load and promote motivation. Coincidentally Dweck and Yeager (2019) advocated that future research should explore avenues that can make growth mindset more lasting by way of creating an "environment with instructional tasks and practices that foster a growth mindset" (p.10, Dweck & Yeager, 2019). They indicated that "current direct-to-student programs do not tell us about the full potential of growth-mindset concepts and practices to enhance motivation and learning" (p.11) and that "we are extremely interested in how mindsets can be integrated into rigorous learning curricula" (p.12). They in particular discussed how teachers can be an influential factor in delivering the growth mindset practice in the classroom. Although it is still up to future research to show how growth mindset tasks can be incorporated into classroom teaching, our study showed that introducing a growth mindset immediately prior to learning can enhance learning performance for a short lesson.

Emotional design, for example, is a design principle which aims to enhance learner motivation and emotion (Jan L Plass & Kaplan, 2016). This design principle has been shown to be effective for reducing perceived cognitive load and foster learning (Brom et al., 2018). Strategies to enhance a growth mindset could also be based on instructional design of course materials. For example, courses on physics could include interesting and relevant stories based on struggles of well-known scholars in the subject. Modelling examples could be used in videos to show struggling learners the failure-success process of other learners' experience. These strategies allow a transmission of mindset beliefs in more integrated and ecological ways with regard to the course the students learn and thus could prove to be more effective.

The mediating effect of cognitive load on learning shown in the present study indicates that learning can also benefit from a reduction in cognitive load. Load reduction is an important strategy in designing effective learning and instruction (Martin & Evans, 2018). Although the present study focused on a growth mindset belief, it is possible that the effect of interventions such as growth mindset beliefs could vary during different learning conditions. Further studies should assess the effectiveness of growth mindset intervention conditions with different levels of intrinsic and extraneous loads.

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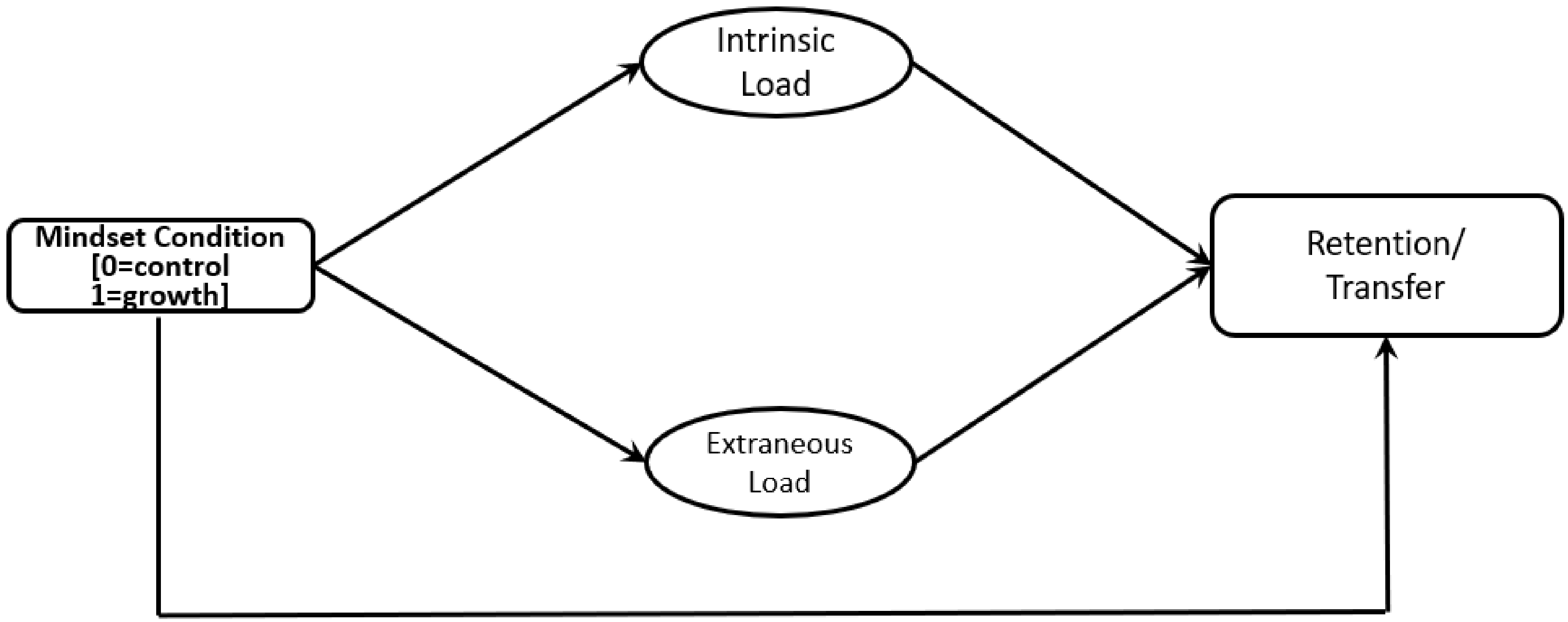

Figure 1. Mediation path diagram of perceived cognitive load on the relationship between mindset condition and performance outcomes.

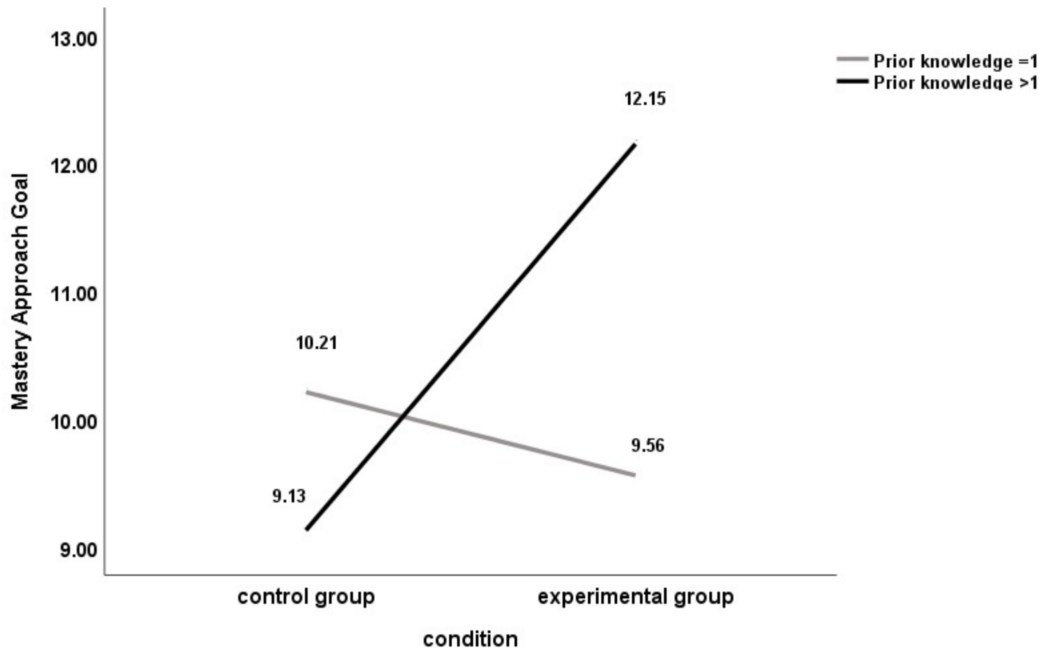

Figure 2. Means of mastery performance approach goal orientations for experimental and control group, by level of prior knowledge.

Table 1.

Descriptive Statistics and Results on the Effect of the Intervention Using Analysis of Variance

	Experimental		Control							
	M	*(SD)*	*M*	*(SD)*	skew	kurtosis	min	max	Cohen d	ANCOVA
Prior knowledge	4.73	1.97	4.91	2.03	0.33	-0.56	1.00	10.00	-0.09	NA
Growth mindset baseline	30.29	8.13	28.99	8.04	-0.53	-0.29	8.00	47.00	0.16	0.18
Growth mindset check	35.58	7.01	28.12	7.75	-0.48	0.03	8.00	47.00	1.01	***0.92***
Mastery goal	10.54	2.61	9.73	2.55	-0.72	0.14	3.00	15.00	0.31	**0.33**
Intrinsic cognitive load	13.07	9.25	15.91	8.51	0.76	0.27	1.00	42.00	-0.32	**-0.35**
Extraneous cognitive load	3.84	3.31	6.61	4.93	0.98	0.50	0.00	20.00	-0.66	***-0.64***
Germane cognitive load	27.83	8.72	25.49	9.76	-0.94	0.32	0.00	40.00	0.25	0.25
Comprehension	5.41	2.39	4.52	2.99	0.23	-0.22	0.00	13.00	0.33	**0.34**
Transfer	3.46	1.25	2.97	1.31	-0.35	-0.05	0.00	6.00	0.39	**0.39**

Note. Italics and bold: $p < .01$; bold: $p < .05$; numbers in columns ANCOVA are intervention effects on the metric of standardised outcome measures, with prior knowledge as a covariate.

Table 2.

Correlation Matrix

		1	2	3	4	5	6	7	8	9
prior knowledge	1	1.00								
prior growth mindset	2	0.15	1.00							
post manipulation growth mindset	3	0.10	***0.75***	1.00						
mastery goal	4	0.16	0.15	**0.17**	1.00					
intrinsic cognitive load	5	***-0.22***	***-0.21***	***-0.29***	-0.06	1.00				
extraneous cognitive load	6	-0.04	***-0.26***	***-0.43***	-0.15	***0.65***	1.00			
germane cognitive load	7	-0.14	***0.32***	***0.35***	0.10	-0.09	***-0.30***	1.00		
comprehension	8	***0.33***	0.08	0.08	0.00	-0.06	0.05	-0.03	1.00	
transfer	9	0.12	0.13	0.13	0.02	***-0.32***	***-0.30***	**0.19**	***0.37***	1.00

Note. Italics and bold: $p < .01$; bold: $p < .05$; underscored: $p < 0.1$

Table 3.

Regression Estimates from the Mediation Model

	Intrinsic load		Extraneous load		Retention		Transfer	
	β	s.e.	β	s.e.	β	s.e.	β	s.e.
Condition	**-0.34**	0.17	***-0.63***	0.17	***0.47***	0.19	0.24	0.16
Prior knowledge	***-0.23***	0.08	-0.05	0.07	***0.34***	0.08	0.08	0.10
intrinsic load					-0.07	0.10	-0.19	0.11
extraneous load					0.18	0.11	-0.14	0.09

Note. Italics and bold: $p < .01$; bold: $p < .05$; underscored: $p < 0.1$; β is standardised regression coefficients with standardised outcome variables.

Table 4.

Mediation Effect Estimates

Outcome: Retention			bootstrapped confidence interval	
	β	s.e.	2.50%	97.50%
Total indirect effect from condition	-0.09	0.08	-0.28	0.03
Specific indirect effect from condition				
condition -> intrinsic load -> comprehension	0.02	0.04	-0.03	0.15
condition -> extraneouos load -> comprehension	-0.12	0.09	-0.34	0.01
Outcome: Transfer			bootstrapped confidence interval	
	β	s.e.	2.50%	97.50%
Total indirect effect from condition	***0.15***	0.06	0.04	0.29
Specific indirect effect from condition				
condition -> intrinsic load -> transfer	0.06	0.05	0.00	0.22
condition -> extraneous load -> transfer	0.09	0.06	-0.01	0.22

Note. Italics and bold: $p < .01$; bold: $p < .05$; underscored: $p < 0.1$; β is standardised regression coefficients with standarsed outcome variables; values in bootstrapped confidence intervals were based on 1000 bootsrap draws.