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INTERVENTION STUDY

An Evolutionary Approach to Motivation and Learning: Differentiating Biologically Primary and Secondary Knowledge

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Abstract
The ubiquity of formal education in modern nations is often accompanied by an assumption that students' motivation for learning is innate and self-sustaining. The latter is true for most children in domains (e.g., language) that are universal and have a deep evolutionary history, but this does not extend to learning in evolutionarily novel domains (e.g., mathematics). Learning in evolutionarily novel domains requires more cognitive effort and thus is less motivating. The current study tested the associated hypothesis that learning will feel easier and more motivating for evolutionarily relevant (e.g., "mother," "food") than evolutionarily novel (e.g., "computer," "gravity") word pairs and that a growth mindset emphasizing the importance of effort in learning might moderate this effect. Specifically, 144 adults were presented with 32 word pairs (half evolutionarily relevant and half evolutionarily novel) and were randomly assigned to a growth mindset or a control condition. Evolutionarily relevant words were better remembered than evolutionarily novel words ($d=0.65$), and the learning was reported as more enjoyable ($d=0.49$), more interesting ($d=0.38$), as well as less difficult ($d=-0.96$) and effortful ($d=-0.78$). Although the growth mindset intervention fostered a mindset belief, compared to the control condition, it did not lead to improved recall performance or changes in motivational beliefs. These results are consistent with the prediction of higher motivation and better learning of evolutionarily relevant words and concepts than for evolutionarily novel words and concepts. Implications for future research and educational practice are discussed.

Keywords Motivation · Evolution · Learning · Biologically primary knowledge · Biologically secondary knowledge

Motivation contributes to children's learning in school, and thus, it is not surprising that motivation theories are at the heart of modern theories of educational

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psychology (Deci et al., 1991; Wigfield & Eccles, 2000). Contemporary theories of motivation portray it as “the energy [students] bring to [school related] tasks, the beliefs, values, and goals that determine which tasks they pursue and their persistence in achieving them, and the standards they set to determine when a task has been accomplished” (Wentzel & Wigfied, 2007, p. 1). The development of motivation for learning emerges during the preschool years (see also Geary & Xu, 2022a; Wigfield et al., 2015; Wigfield et al., 2015) and often in the context of social play (Gray, 2011; Moll & Tomasello, 2007). Although it may seem logical that motivation to learn should continue into formal education settings, this is not typically the case. Children’s motivation for school learning declines as the knowledge taught in school becomes more complex (Wigfield et al., 2006). In other words, there is not a domain-general motivational bias to learn, but the domains in which children’s learning motivation is stronger or weaker are not fully understood.

An evolutionary perspective has been proposed to explain this variation in learning motivation (Geary, 1995; Geary & Xu, 2022a; Marsh et al., 2021). It has been suggested that children are motivated to engage in activities, such as social play or exploration of the environment, that support the development to universal forms of knowledge, such as language and the location of important things (e.g., water source) in the ecology. The motivation to engage in these types of activities does not, in theory, extend to the activities that promote academic learning and are often in conflict with them (Geary, 2024). The present study assessed the hypothesis that learning potentially evolutionary-relevant (e.g., survival-related) will be easier (i.e., greater accuracy), more motivating, and less effortful than learning evolutionarily novel information. A related aim was to determine if framing the learning in a growth mindset emphasizing on effort investment differentially influenced learning and motivation across these evolutionarily relevant and evolutionarily novel conditions.

An Evolutionary Distinction of Knowledge and Motivation

Geary (2008; see also Geary & Xu, 2022b for broader literature) proposed an evolutionary framework that distinguishes biologically secondary knowledge and skills learned in schools from those acquired nearly automatically during development (e.g., language, face recognition). The biologically primary knowledge associated with the latter emerges through a combination of built-in scaffolds to ensure its learning and a motivation to engage the species-typical (e.g., social play) activities that enhance these abilities and adapt them to local conditions (e.g., the local language). These built-in cognitive and motivational biases do not extend to most academic domains, such as physics and mathematics, and thus, these require more explicit, organized instruction (Paas & Sweller, 2012; Sweller et al., 2019). The evolutionary novelty of these domains also explains why the motivation to learn them declines during schooling (Gnambs & Hanfstingl, 2016; Gottfried et al., 2001; Spinath & Spinath, 2005).

The basic idea is that the combination of built-in cognitive and motivational biases results in the universal emergence of biologically primary cognitive domains organized as folk psychology, folk biology, and folk physics (Atran, 1998; Geary, 2005; Gelman, 2003; Leslie et al., 2004; Wellman, 2017; Wellman & Gelman, 1992). These abilities support the development and maintenance of social relationships (folk psychology), knowledge about other species in the ecology (e.g., edible plants, folk biology), and the ability to navigate and use objects as tools (folk physics). These abilities have a deep evolutionary history, in contrast with the more recent emergence of formal education about 5000 years ago (Eskelson, 2020). Indeed, universal education slowly emerged across many parts of Europe and globally over the past 400 years (Goldin, 1999) (Ramirez & Boli, 1987), and universal education in some Western contexts was not achieved until well into the nineteenth century and sometimes the early twentieth century and remains to be achieved in some parts of the world today (Goldin, 1999). In the context of schooling, children eventually learn biologically secondary knowledge, such as reading and mathematics.

The demands of modern schooling and modern economies result in an evolutionary mismatch between primary knowledge and motivational systems and the secondary knowledge needed to be successful in the modern world (Bjorklund, 2022). Still, aspects of primary knowledge and motivation can at times be used to facilitate engagement in secondary learning (Alipour et al., 2023; Paas & Sweller, 2012). Embedded in logical problem-solving training context, Lespiau and Tricot (2018, 2019) conducted a series of experiments in university and secondary school students. These studies consistently showed that participants scored higher for logical problems infused with primary knowledge content in comparison to problems infused with secondary knowledge content. Furthermore, they also reported higher motivation and less perceived cognitive load when solving problems with primary content. They largely replicated the same pattern of findings in statistical problems (e.g., Lespiau & Tricot, 2022b).

Except for one small study on mathematics learning (Alipour et al., 2023), there are (to our knowledge) no studies that contrast learning in the context of primary and secondary content other than logic and statistics, for example language learning. Spoken language is a key part of folk psychology and essential to developing survival-related social networks in traditional contexts. Reading skills are secondary knowledge and are built onto the language system but are not needed in traditional contexts and have only recently become universally important in modern contexts (Geary, 2002). Learning and remembering written vocabulary words are directly influenced by the evolutionary salience of the meaning of these words. Nairne (2022; 2013) showed that adults' memory for nouns representing animate, living things (e.g., predator) is better remembered than those representing inanimate, non-living things (e.g., book). The results support the hypothesis that the human memory system is biased towards fitness-based events and things. Although Nairne and colleagues' studies were based on a vocabulary-related task, the experiment was not based on an authentic learning task specifically. In other studies, the animacy principle was subject to word learning tasks including foreign words—Swahili words paired with English translations (VanArsdall et al., 2015) or nonwords (Laurino & Kaczer, 2019). In both studies, participants (undergraduate students) could produce the Swahili or nonword translation better for animate as compared to inanimate words.

While the studies on animacy are indeed relevant to the primary versus secondary knowledge distinction, the focus there is more specifically on remembering nouns representing things that are living (e.g., animals) or non-living (e.g., furniture, or tools) as examples of evolutionarily relevant and novel information. A more complete and direct assessment of the evolutionary distinction should be based on a vocabulary task with words more widely reflecting both the biologically primary and biologically secondary knowledge types (Geary & Bjorklund, 2000). It is worth noting that such a vocabulary learning task is based on paired words consisting of a native word matched with a nonword (De Groot & Keijzer, 2000), which also resembles aspects of paired-associate learning tasks (Karantzoulis et al., 2011), presented in the form of word pairs (Rohwer & Litrownik, 1983), or visual imagery pairs (Pressley & Levin, 1977). The word association paradigm invokes a "stimulus–response" type of mental process, thus enables examining learning of the memorization (Rohwer & Litrownik, 1983), including the extent to which nonwords representing different knowledge types can be recalled. Such tasks allow the learning process (e.g., the cognitive load, the motivational aspects) to be directly contrasted between different knowledge content by using words directly presenting those concepts. Furthermore, this task affords control over possible confounds of task variations compared to some other tasks we considered. For example, it is possible to balance task elements based on word features such as letter lengths, syllables, and word abstract/concreteness (De Groot & Keijzer, 2000). With such a study, it is then possible to assess the motivation associated with learning words from different knowledge categories. It is expected that compared to words presenting biologically secondary knowledge, words representing biologically primary knowledge would be better recalled and learned with greater enjoyment and possibly with less perceived cognitive load (e.g., less effort and less difficulty).

The effortful learning follows from the lack of built-in cognitive scaffolds and motivational biases to facilitate secondary knowledge learning; in the context of animacy research, one scaffold is the bias to attend to living things that in turn facilitates learning about them. The learning of secondary knowledge requires more effort, which in addition to the novel content contributes to reduced motivation (Bjorklund, 2022; Geary & Bjorklund, 2000). Thus, from an evolutionary perspective, explicitly or implicitly promoting motivation and effortful engagement in learning might be more important for secondary than primary learning. This lies at the heart of growth mindset (Burnette et al., 2022; Yeager et al., 2019), a motivational belief that emphasizes the importance of effort investment in achieving academic proficiency. While some students believe their abilities can be improved with perseverance and practice, others believe their abilities are fixed and further effort will not make a difference. These beliefs are respectively called "growth" or "fixed" mindset. Learners with a growth mindset are more likely to adopt more positive attitudes towards learning, whereas learners with a fixed mindset develop maladaptive motivations and behaviors including lower effort during learning. The concept of mindset and its roles in motivation and learning have been extensively studied in the last few decades (Canning & Limeri, 2023; Dweck & Leggett, 1988). It was shown that fostering a growth mindset can have a positive effect on motivation and reduce learners' perceived effort and difficulty for physics learning, a biologically secondary knowledge domain (Xu et al., 2021). It is expected that a growth mindset intervention will be more effective for effortful learning and thus more important for learning words representing biologically secondary knowledge compared to words representing biologically primary knowledge.

Present Study

The present study thus aims to empirically investigate the effect of knowledge types on motivation and learning performance based on a novel vocabulary learning task, and the effect of an effort-inducing motivation intervention (growth mindset) on the motivation and learning outcomes based on different knowledge types. It is predicted that participants will perform better, experience more motivation, and less cognitive demands when learning words with a biologically primary content as compared to words with a biologically secondary content. It is also predicted that the growth mindset intervention will be more effective for biologically secondary word learning than biologically primary word learning.

Method

Participants and Design

The study applied a randomized controlled trial design and was based on data collected from 144 first year psychology bachelor students attending a Dutch university. The mean age was 21.08 ($SD = 3.1$) years (18 men, 123 women, and three choosing not to identify their gender). The experiment was based on a two-way within and between-factor mixed design. The within factor was evolutionary context embedded in a learning task, distinguishing biologically primary knowledge and biologically secondary knowledge. The between factor distinguished a growth mindset intervention ($n = 72$) or a control condition ($n = 72$), randomized across participants.

The current sample size exceeded the 48 participants that were minimally required, based on an a priori power calculation for a mixed design ANOVA analysis, with a medium effect size of Cohen's $d = 0.5$ (or $f = 0.25$), for power = 80%, and type I error rate = 5%.

Learning Task

The learning task contained 32 pairs of Dutch-fictional words, presented to learners sequentially in eight lists of four word pairs (Table 1). The goal of the task was to learn the fictional ('foreign') words. The Dutch (native) words that appeared in the learning task were selected in terms of the number of syllables, abstract (e.g., sad) or concrete (e.g., fruit) word (Brysbaert et al., 2014), number of letters contained in the word (De Groot & Keijzer, 2000), and frequency (Baayen et al., 1996). The full details of Dutch word construction are presented in Table 1. The fictional words were constructed with random letters with comparable lengths (six to seven letters) with two syllables.

The learning task consisted of a total of eight study lists. In each list, there were four Dutch-fictional word pairs. Each word pair was automatically shown on the screen for 8 s. The word pairs within each list were repeated four times in

Table 1 Word lists and knowledge type presented during learning task

Study list 1 (primary concepts)				Study list 2 (secondary concept)			
Dutch-fictional	English	Abstract/concrete	Frequency (per million)	Dutch-fictional	English	Abstract/concrete	Frequency (per million)
1 Vlinder-bumqit	Butterfly	5.00	10	5 Telefoon-kodeiss	Telephone	4.87	84
2 Liefde-breefje	Love	1.87	170	6 Grammatica-wotsuit	Grammer	1.87	6
3 Peer-miftee	Pear	4.87	10	7 Paraplu-nufrijg	Umbrella	4.80	9
4 Wraak-ellaan	Revenge	1.93	18	8 Vermenigvuldiging-klaspert	Multiplication	3.07	1
Study list 3 (primary concepts)				Study list 4 (secondary concepts)			
Dutch-fictional	English	Abstract/concrete	Frequency (per million)	Dutch-fictional	English	Abstract/concrete	Frequency (per million)
9 Haar-morees	Hair	4.73	97	13 Krant-kodiel	Newspaper	4.93	117
10 Vijand-plarker	Enemy	2.73	60	14 Zwaartekracht-pardaan	Gravity	3.07	6
11 Moeder-zappel	Mother	3.00	596	15 Auto-soeluup	Car	5.00	208
12 Gevaar-bekaar	Danger	2.73	116	16 Geschiedenis-strokit	History	1.86	137
Study list 5 (primary concepts)				Study list 6 (secondary concepts)			
Dutch-fictional	English	Abstract/concrete	Frequency (per million)	Dutch-fictional	English	Abstract/concrete	Frequency (per million)
17 Kikker-schomik	Frog	4.93	9	21 Computer-jedoek	Computer	4.67	49
18 Gunst-aaluuk	Favor	2.00	22	22 Werkwoord-bisdalf	Verb	1.73	4
19 Citroen-geschak	Lemon	4.87	11	23 Kraan-karsing	Crane	4.87	14
20 Haat-bijnjert	Hate	1.67	37	24 Wiskunde-muspert	Mathematics	2.53	11
Study list 7 (primary concepts)				Study list 8 (secondary concepts)			
Dutch–fictional	English	Abstract/concrete	Frequency (per million)	Dutch–fictional	English	Abstract/concrete	Frequency (per million)
25 Lichaam-ipseel	Body	4.47	292	29 Boek-voliekt	Book	4.93	387
26 Vriend-rufoen	Friend	2.40	284	30 Atoom-plokerts	Atom	2.60	7
27 Vader-boddelt	Father	3.13	576	31 Tram-stoger	Tram	4.67	20
28 Dreiging-spodent	Threat	2.47	16	32 Eeuw-fileek	Century	2.33	229

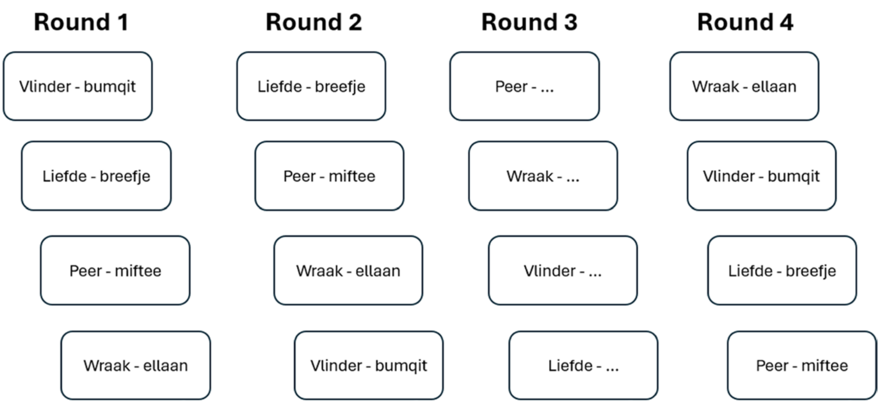
Note. Word ratings representing the degree of abstractness/concreteness were extracted from Brysbaert et al. (2014), with 1 representing an abstract word and 5 representing a concrete word. Word frequency was extracted from the Dutch vocabulary Corpus CELEX (Baayen et al., 1996). There was no statistically significant difference between words representing knowledge types in terms of abstractness/concreteness ($t = -0.68$, $p = 0.50$, $d = -0.24$; $M = 3.30$, $SD = 1.28$ for primary knowledge words; $M = 3.61$, $SD = 1.32$ for secondary knowledge words), nor word frequency ($t = 1.15$, $p = 0.26$, $d = 0.41$; $M = 145.54$, $SD = 195.54$ for primary knowledge words; $M = 80.56$, $SD = 110.90$ for secondary knowledge words) a Latin-square fashion (see Fig. 1 for illustration of word pairs presented in one study cycle for list 1). In the first, second, and fourth rounds, the word pairs were presented; while in the third round, only the Dutch word was presented, with a prompt for the participant to type in the corresponding fictional word. The learning phases concluded after all eight study lists with a total of 32 word pairs were shown.

Experimental Conditions

Two experimental conditions were implemented: the evolutionary knowledge type distinctions (within factors) and growth mindset intervention (between factors).

Evolutionary Knowledge Type Distinction

The evolutionary contexts were embedded in the learning task by way of counterbalancing equal numbers of word pairs across each context. There were four lists of 16 words representing primary objects (e.g., mother) and concepts (e.g., love), and another four lists representing 16 secondary objects (e.g., computer) or concepts (e.g., gravity; see Table 1). In total, there were eight themes for primary knowledge and eight themes for secondary knowledge (see Appendix Table S1). They were broadly comparable to those used in previous research investigating biological knowledge types (e.g., Lespiau & Tricot, 2018; Lespiau & Tricot, 2022a).



Note. This figure demonstrates the presentation sequence of the word pairs in Study List 1 (see Table 1 for all study lists). Each word pair was presented for 8 seconds each, thus in total 32 seconds in each round.

Fig. 1 An illustration of the presentation of study list 1 during the learning phase

Growth Mindset Intervention

In both the growth mindset and its control conditions, the participants performed reading and writing tasks (Appendix) adapted from previous research (Xu et al., 2021). The tasks were designed to be similar across intervention and control conditions. In particular, the reading tasks contained comparable lengths of texts and numbers of illustrative images.

Growth Mindset Condition Tasks A growth mindset intervention was presented to the learners in the form of a text to read and a writing task. The reading text concerned scientific explanations on brain functions and the importance of effort and persistence when learning new knowledge. The writing task instructed the participants to write a short motivating letter to a student who is struggling to learn to reinforce the growth mindset text.

Control Condition Tasks The control group completed comparable reading and writing tasks. The reading task provided a scientific explanation of cognitive functions but not specific to learning situations, nor concepts related to growth mindset (e.g., effortful practice). After reading the text, participants were asked to produce a short-written summary of it.

Measurements

During and after the learning task, participants reported measures regarding motivational beliefs, cognitive load perceptions, and learning performance.

Growth Mindset Belief

Growth mindset belief (Dweck, 2000) was measured on a six-point Likert scale ("No matter who you are, you can significantly change your intelligence level," ranging from "completely disagree" to "completely agree"). Participants reported growth mindset belief twice, once before the growth mindset intervention ($\alpha = 0.85$) and afterwards ($\alpha = 0.91$).

Enjoyment and Interest

Single-item ratings of enjoyment and interest (Lespiau & Tricot, 2018) were assessed during the vocabulary task on nine-point Likert response scales ("not at all" to "very much"). After each vocabulary list, the participants rated the extent to which they enjoyed and were interested in the words they just studied. In total, there were eight items rated for enjoyment (test–retest reliability ICC = 0.96) and eight items rated for interest (ICC = 0.97).

Cognitive Load Perceptions

Cognitive load perceptions (Paas, 1992) were assessed with single-item ratings of perceived mental effort and difficulty during the vocabulary task using nine-point Likert response scales (from “not at all” to “very much”). After each vocabulary list, the participants rated the extent to which they perceived their mental effort and found it difficult for learning the words they were just presented with. In total, there were eight items rated for mental effort (ICC = 0.94) and eight items rated for difficulty (ICC = 0.91).

Learning Performance

Learning performance was measured via recall of the words from the learning task. After the learning task was completed, the native (Dutch) version of the word was given as a prompt for the participants to fill in the fictional version of the word. The order was randomized between primary and secondary knowledge words. Each correctly spelled word was awarded one point with a maximum possible score of 32 for the performance measure (ICC = 0.91).

Procedure

The main phases of the experiment are illustrated in Fig. 2. The experiment was implemented online through Limesurvey (Limesurvey GmbH n.d.). Participants signed up for the study through the university experiment recruitment portal. To increase participation, an online lottery was offered in the form of a gift voucher worth 50 euro. The participants and experimenter joined the experimental session via MS Teams. A link to the study was shared by the experimenter with the participants. The participants worked independently on their own computers. The assignment of the experiment’s link was randomized in terms of growth mindset intervention or control conditions. At the start of the experiment, the participants were first presented with an example of the word learning task. Then, they filled out questionnaire items on growth mindset both before and after they received growth mindset intervention or control task (see “Growth Mindset Intervention” for details). Afterwards, participants completed the learning task with embedded biological primary and secondary knowledge contexts (see “Learning Task” and “Evolutionary Knowledge Type Distinction” under the “Experimental Conditions” section for details). They also completed motivation and cognitive load questionnaire items for each of the eight-word learning lists throughout the learning phase. In the last step, they completed a recall test on the words learned in the learning task (see “Learning Performance” for details).

Ethical guidelines were followed, and approval was obtained from the institutional ethical committee review board.

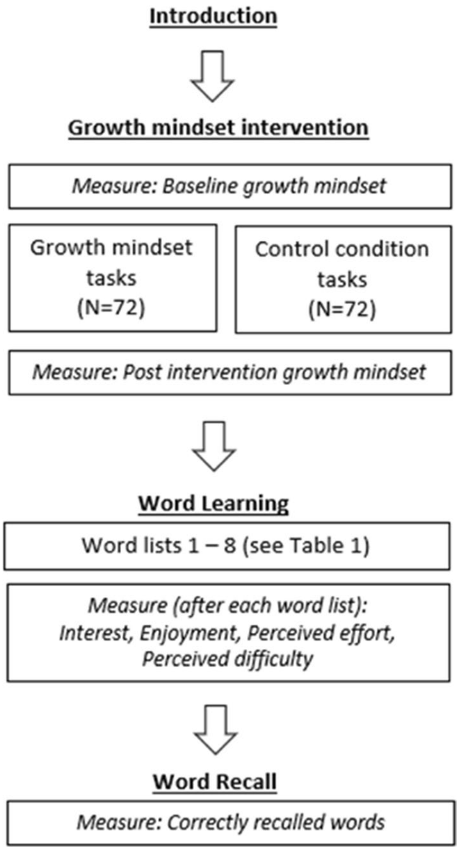


Fig. 2 Experimental phases

Results

The Interaction Between Knowledge Type and Growth Mindset

Firstly, an independent sample *t*-test was used to check whether participants were randomized across conditions. Results showed that in comparison to the control condition, participants in the growth mindset intervention condition had higher baseline growth mindset beliefs (t (142) = −2.90, $p = 0.004$, $d = 0.48$; $M = 3.4$, $SD = 0.7$ for control condition; $M = 3.76$, $SD = 0.78$ for growth mindset condition). Thus, baseline growth mindset was included as a covariate in subsequent analyses involving growth mindset intervention factor. Furthermore, a potential interaction was checked for between baseline growth mindset and intervention. Controlling for baseline growth mindset, the interaction term in an ANCOVA showed that the effect of the growth mindset was not affected by the baseline growth mindset (F (1, 140) = 0.62, $p = 0.434$); thus, this interaction was not included in subsequent analyses.

Then, to asesses the interaction effect between the two main experimental factors, a mixed ANCOVA was used to test whether the effect of growth mindset intervention is dependent on knowledge types. Results indicated there were no significant interaction effects (also see means, marginal means in Table 2), including for interest ($F(1, 141) = 2.52$, $p = 0.115$), enjoyment ($F(1, 141) = 2.39$, $p = 0.124$), perceived difficulty ($F(1, 141) = 2.37$, $p = 0.126$), perceived effort ($F(1, 141) = 0.09$, $p = 769$), or recall performance ($F(1, 140) = 1.38$, $p = 0.243$).

Since there was no interaction effect between growth mindset intervention and knowledge type in any of the dependent variables, the following result sections proceeded to present the analysis of the effects of knowledge type and growth mindset intervention separately, without the interaction term. The analysis for growth mindset intervention was based on one-way ANCOVA. The analysis for knowledge type was based on the paired sample *t*-test (equivalent to one-way ANOVA when no covariate is included).

The Effect of Knowledge Type

Paired sample *t*-tests showed that in comparison to secondary knowledge words (Table 3), participants rated learning primary knowledge words as more interesting ($t = 4.53$, $p < 0.001$, $d = 0.38$; $M = 4.56$, $SD = 1.79$ for primary knowledge words; $M = 4.32$, $SD = 1.80$ for secondary knowledge words), more enjoyable ($t = 5.83$, $p < 0.001$, $d = 0.49$; $M = 4.51$, $SD = 1.72$ for primary knowledge words; $M = 4.13$, $SD = 1.72$ for secondary knowledge words), and experienced less difficulty ($t = -11.48$, $p < 0.001$, $d = -0.96$; $M = 4.89$, $SD = 1.41$ for primary knowledge words; $M = 5.65$, $SD = 1.49$ for secondary knowledge words) and less effort ($t = -9.35$, $p < 0.001$, $d = -0.78$; $M = 5.38$, $SD = 1.49$ for primary knowledge words; $M = 5.89$, $SD = 1.45$ for secondary knowledge words). They also recalled more primary knowledge words than secondary knowledge words ($t = 5.85$, $p < 0.001$, $d = 0.49$; $M = 7.29$, $SD = 3.99$ for primary knowledge words; $M = 6.08$, $SD = 4.17$ for secondary knowledge words).

The Effect of Fostering Growth Mindset

Further ANCOVA analyses revealed no differences across the growth mindset and control groups for the outcomes (Table 4), including interest ($F(1, 141) = 1.02$, $p = 0.315$, $d = 0.27$, $M = 4.20$, $SD = 1.63$ for control condition; $M = 4.68$, $SD = 1.87$ for growth mindset condition), enjoyment ($F(1, 141) = 1.58$, $p = 0.211$, $d = 0.29$, $M = 4.08$, $SD = 1.52$ for control condition; $M = 4.56$, $SD = 1.79$ for growth mindset condition), difficulty ($F(1, 141) = 0.97$, $p = 0.325$, d $= -0.07$, $M = 5.32$, $SD = 1.26$ for control condition; $M = 5.22$, $SD = 1.52$ for growth mindset condition), mental effort ($F(1, 141) = 0.47$, $p = 0.496$, $d = 0.02$, $M = 5.62$, $SD = 1.39$ for control condition; $M = 5.65$, $SD = 1.49$ for growth mindset condition), or word recall performance ($F(1, 140) = 0.24$, $p = 0.623$, $d = 0.05$, $M = 13.15$, $SD = 7.82$ for control condition; $M = 13.57$, $SD = 7.77$ for growth mindset condition).

Table 2 Means, marginal means, and interaction effect between growth mindset condition and knowledge type condition

Outcome variables	Evolution distinction	Marginal means			Control condition			Mindset condition			Mixed ANCOVA interaction effect (knowledge type × mindset intervention)			
		N	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*df1*	*df2*	*F*	*p*
Interest	Marginal means	144			72	4.20	1.63	72	4.68	1.87				
	Primary	144	4.56	1.79	72	4.36	1.69	72	4.76	1.87	1	141	2.515	0.115
	Secondary	144	4.32	1.8	72	4.04	1.64	72	4.60	1.91				
Enjoyment	Marginal means	144			72	4.08	1.52	72	4.56	1.79				
	Primary	144	4.51	1.72	72	4.32	1.64	72	4.70	1.78	1	141	2.389	0.124
	Secondary	144	4.13	1.72	72	3.85	1.53	72	4.42	1.85				
Perceived difficulty	Marginal means	144			72	5.32	1.26	72	5.22	1.52				
	Primary	144	4.89	1.41	72	4.90	1.27	72	4.88	1.54	1	141	2.368	0.126
	Secondary	144	5.65	1.49	72	5.75	1.37	72	5.56	1.59				
Perceived effort	Marginal means	144			72	5.62	1.39	72	5.65	1.49				
	Primary	144	5.38	1.49	72	5.32	1.41	72	5.44	1.57	1	141	0.087	0.769
	Secondary	144	5.89	1.45	72	5.92	1.44	72	5.85	1.48				
Recall performance	Marginal means	143			71	13.15	7.82	72	13.57	7.77				
	Primary	143	7.29	3.99	71	7.27	4.01	72	7.30	3.99	1	140	1.377	0.243
	Secondary	143	6.08	4.17	71	5.88	4.27	72	6.26	4.08				

Note. Baseline growth mindset belief was included as a covariate

Table 3 Outcomes by knowledge types

Outcome variables	Evolutionary distinction	*N*	Mean	*SD*	Cohen's *d*	Paired sample *t*-test		
						t	*df*	*p*
Interest	Primary	144	4.56	1.79	0.38	4.53	143	< 0.001
	Secondary	144	4.32	1.80				
Enjoyment	Primary	144	4.51	1.72	0.49	5.83	143	< 0.001
	Secondary	144	4.13	1.72				
Perceived difficulty	Primary	144	4.89	1.41	− 0.96	− 11.48	143	< 0.001
	Secondary	144	5.65	1.49				
Perceived effort	Primary	144	5.38	1.49	− 0.78	− 9.35	143	< 0.001
	Secondary	144	5.89	1.45				
Recall performance	Primary	143	7.29	3.99	0.49	5.86	142	< 0.001
	Secondary	143	6.08	4.17				

Discussion

An evolutionary approach to learning predicts differences in the ease of and motivation to learn evolutionarily relevant or biologically primary knowledge and evolutionarily novel or biologically secondary knowledge (Geary, 2008). The latter largely refers to knowledge and skills needed to be successful in developed economies and largely taught through organized schooling. Results from the current experimental study confirmed these predictions for adults' learning of vocabulary with evolutionarily relevant versus evolutionarily novel content. We further hypothesized that a motivation intervention focused on increasing growth mindset and effort investment would benefit secondary knowledge vocabulary learning more than primary vocabulary learning, but this was not supported by the findings of this study.

Participants found vocabularies representing primary knowledge categories to be more interesting, more enjoyable to learn, and less difficult and effortful compared to learning vocabularies representing secondary knowledge. Moreover, primary knowledge words also were recalled better than secondary knowledge words. These results are consistent with previous research based on logic learning (Lespiau & Tricot, 2019) and also to some extent for statistics learning (Lespiau & Tricot, 2022b). Since the biologically primary knowledge concerns fitness and survival-related activities, the current findings are also in agreement with the literature in survival processing where words associated with living things are often better recalled than words associated with non-living things (Nairne, 2022; VanArsdall et al., 2015). The present study broadens the scope of living/non-living concepts to include more broadly defined primary and secondary knowledge types and further generalizes the knowledge distinction from logic/statistics to vocabulary learning. The present study suggests a promising approach to utilize the motivational and cognitive advantages of primary knowledge to design language learning instruction for adults. For example, it may be more motivating to learn vocabularies when the curricula first present primary knowledge content (Lespiau & Tricot, 2022a) and perhaps also set contexts

Table 4 Outcomes by a growth mindset intervention

	Control			Mindset			Cohen's *d*	ANCOVA*			
	N	Mean	*SD*	*N*	Mean	*SD*		*df1*	*df2*	*F*	*p*
Growth mindset post-intervention	72	3.46	0.72	72	4.22	0.94	0.91	1	141	22.87	< 0.001
Interest	72	4.20	1.63	72	4.68	1.87	0.27	1	141	1.02	0.315
Enjoyment	72	4.08	1.52	72	4.56	1.79	0.29	1	141	1.58	0.211
Perceived difficulty	72	5.32	1.26	72	5.22	1.52	−0.07	1	141	0.97	0.325
Perceived effort	72	5.62	1.39	72	5.65	1.49	0.02	1	141	0.47	0.496
Recall performance*	71	13.15	7.82	72	13.57	7.77	0.05	1	140	0.24	0.623

Note: For ANCOVA analysis, baseline growth mindset belief was included as a covariate

*The recall performance was the sum score from the primary knowledge content and secondary knowledge content related to these themes (Nairne, 2022; see also studies using survival versus nonsurvival contexts Nairne et al., 2019; Nairne & Pandeirada, 2010; Raymaekers et al., 2014).

Despite of the hypothesis that a growth mindset intervention focusing on effort investment may be especially beneficial for learning vocabularies representing biologically secondary knowledge, results showed no difference in motivation and performance between the intervention and control conditions for learning associated with either knowledge types. It was also predicted that an intervention focusing on the importance of effortful practice would reduce the perceived cognitive load of secondary knowledge learning. This hypothesis was not supported in the current study. The finding is inconsistent with a previous experimental study where a growth mindset intervention increased motivation and performance and lowered perceived cognitive load for a learning task based on a physics topic (Xu et al., 2021). We refer to this study specifically, because most growth mindset research has been based on semester-long interventions (Burnette et al., 2022; Macnamara & Burgoyne, 2022) rather than short-term experiments.

Although both the previous study (Xu et al., 2021) and the current one were based on Dutch samples, there are important differences. The earlier study was based on a sample of vocational secondary education students and a physics topic learning task (i.e., about the Doppler effect) whereas the current study was based on a sample of academic university participants and a vocabulary learning task. In the Netherlands, vocational education is less selective academically than university education, like the institution where participants in the current study were enrolled. Thus, it is possible that the growth mindset intervention was less effective for the more academically advanced participants in the current study. University students presumably are well aware of the importance of effort and persistence which has enabled them to attend a prestigious university. In fact, this is also suggested by recent growth mindset literature that such an intervention is more effective for students who come from less advantaged background and who are performing less well (Burnette et al., 2022). Thus, this may explain, from a short intervention, why in the current study sample, the effect of the growth mindset intervention did not differentiate between learning vocabularies across biologically primary and secondary knowledge categories.

In terms of broad educational implications, an interesting point is whether the motivating nature of biologically primary knowledge can be used to formulate educational approaches in ways to make secondary knowledge learning intrinsically motivating (Bjorklund, 2022), for example, incorporating "productive failure" as a method of learning that guides children to learn by self-exploration (Kapur, 2016; Niu et al., 2021). The notion of productive failure is in line with the features of primary knowledge according to the evolutionary theoretical framework. This idea has sparked interesting debates as to whether this is a beneficial practice (Kirschner et al., 2006; Sweller, 2022). In his review, Bjorklund examined relevant literature and specifically suggested "guided play" as more beneficial than both direct instruction and play without any guidance (Bjorklund, 2022), at least for young children. However, "play" and "exploration" are not the only approaches that have an evolutionary basis. In evolutionary context, it has also been shown that learning can be improved from incorporating primary knowledge skills such as human motor systems involving body movement and hand gestures (Choi et al., 2014; Ginns & King, 2021).

In sum, the present study contributes to the developing field of evolutionary educational psychology, which is already showing promise to better understand and improve academic learning and instruction. We also note that many studies, if not all, are lab-based, short-term experimental research. As such short-term experiments may fundamentally differ from regular curricula learning, the field can benefit from future more classroom-based, intervention research (see Alipour et al., 2023).

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Declarations

Conflict of Interest The authors declare no competing interests.

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