Learning and Instruction 56 (2018) 10–19

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc

Primary knowledge enhances performance and motivation in reasoning

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1. Introduction

1.1. Issues in learning normative logic as secondary knowledge

Learning at school demands conscious efforts, motivation (often extrinsic) and time. The main aim of formal education is to teach culturally important knowledge which would be very difficult to learn by oneself or by simple social interactions (Sweller, 2015). Students are asked to apply rules in a logical way which may be different from the kind of logic they are using every day (Stanovich & West, 2000). They must be able to implement a strict specific grammar rule, to demonstrate a mathematical theorem, to solve physics equations, to apply scientific reasoning and so on. Despite logic being omnipresent, it is not necessarily taught as such and the context of its learning is neglected: for example, in Johnson-Laird's 573 pages book "How we reason" (2006), there is nothing about learning to reason. One issue is that logical problems are not engaging first:

If A, then B.

B.

A?

When they are faced with that kind of problem, students tend to sense a trap in the question leading them to disengage from the task (De Neys & Feremans, 2013; Evans, 2005; Johnson, Tubau, & De Neys, 2016). The logical reasoning expected from high schools to universities is indeed a complex field to master. It is rather intriguing that so few people consider its learning: many works are concerned with computer programing (Barker-Plummer, Barwise, & Etchemendy, 2008) or medical reasoning (Barrows, 1994), but very few deal with a comprehensive learning of logic that could be of interest to people from all walks of life. A hundred years ago, we were already intrigued by the difficulty to teach and to learn logic (Carroll, 1896).

Learning is a complicated process and several approaches seek to find ways to facilitate it. For example, the cognitive load theory specifies that the cognitive load should not exceed working memory capacity (Paas, Renkl, & Sweller, 2003; Sweller, Ayres, & Kalyuga, 2011). Nevertheless, according to the desirable difficulties theory, this cognitive load should be sufficient enough to promote learners' engagement as much, if not more, than the learners' performances (Bjork & Bjork, 2011; Chi & Wylie, 2014). The present research provides a novel idea that could be used in the design of educational materials. But learning skills also come from the individuals' intentions.

Because learning academic knowledge is a long and difficult process, it requires motivation (Ellis, 2008). But whatever the field of learning, even when learners are motivated to learn, it is not uncommon for them to get demotivated along the way and to give up learning. The main concern of teachers and parents is therefore to foster motivation, pleasure in learning and engagement in learning tasks (Braver et al., 2014; Cosnefroy, Nurra, & Dessus, 2016). Given the importance of logic (mostly abstract logic) in our current societies (Markovits & Lortie-Forgues, 2011) and the difficulties in engaging learners durably in learning, it is essential to investigate which factors influence this emotional and cognitive engagement.

1.2. Reasoning with conditionals contents

Logical problems can take different forms (De Neys & Bonnefon, 2013). Conditional rules and their inferences can be considered as syllogisms. Conditional problems as "if A, then B" imply four inference types: *Modus Ponens* (*MP*) "A. B?", *Modus Tollens* (*MT*) "No B. A?", Affirmation of the Consequent (AC) "B. A?" and Denial of the Antecedent (DA) "No A. B?". According to the logical norms, *MP* and *MT* are valid inferences where *MP* is true and *MT* is false whereas AC and DA are invalid inferences where the answer cannot be given with certainty. Almost everyone can solve *MP*, the majority of individuals solves *MT*, but even less succeed AC and DA (little resistance to invalid inferences) (De Neys, Schaeken, & d'Ydewalle, 2005; Evans, Handley, Neilens, & Over, 2007; Newstead, Handley, Harley, Wright, & Farrelly, 2004).

It is well-known that logical problems' content influences individuals' responses. If the problem is abstract, *i.e.* it does not represent anything realistic (particularly, involving letters or numbers; Evans et al., 2007), the reasoning process is more difficult. Thus, one is inclined to answer "yes" to the example "if A, then B; B. A?", thinking that the link between A and B is bidirectional (Dominowski, 1995; Evans, Handley, & Bacon, 2009). If the example above is presented in more concrete terms such as:

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https://doi.org/10.1016/j.learninstruc.2018.02.007
Received 20 September 2017; Received in revised form 23 January 2018; Accepted 27 February 2018

If someone wants to find the length of a right triangle's side, then he uses the Pythagoras theorem.

Jack uses the Pythagoras theorem.

Does that mean he wants to find the length of a right triangle's side?

The reasoning process is then easier (Dominowski, 1995). Indeed, one can imagine other reasons why Jack would use the Pythagoras theorem: he may want to prove that a triangle is a right triangle or not. It thus invalidates the necessity of the antecedent through counter-examples (De Neys & Everaerts, 2008; De Neys et al., 2005). The effect of logical problems' content and the importance of prior knowledge about the problem's context can lead to higher performances (deontic tasks, Cosmides & Tooby, 2004; Evans, 2005; Markovits, 1986; the increase of counter-examples or more complete mental models, Johnson-Laird, 2005) or to completely bias individuals' responses (De Neys & Feremans, 2013; De Neys, 2006; Evans, 2005; Handley, Newstead, & Trippas, 2011; Morsanyi & Handley, 2012). This bias effect can be explained by the dual models approach (Evans & Frankish, 2009; Stanovich & West, 2000) when the heuristic, automatic, rapid and cheaper in cognitive resources responses of system 1 conflict with the analytical, conscious, slow and very expensive in cognitive resources responses of system 2. Such conflict detection is then necessary for the system 2 to inhibit the system 1 response and then to generate its own response (De Neys & Bonnefon, 2013). System 1 is considered universal, supporting survival whereas system 2 is more personal utility directed (Stanovich & West, 2000). Numerous studies also showed that adding a cognitive load, with a Dot Memory Task for example (De Neys, 2006; Trémolière, Gagnon, & Blanchette, 2017), increases the number of heuristic responses in logical problems: the cognitive resources in working memory are used to process the added cognitive load and thus are less available to reason consciously. The number of heuristic responses can be reduced if the capacity of working memory is significant (De Neys, 2006; Newstead et al., 2004; Stanovich & West, 2000). However, the respective implications of the two systems are not clear when it comes to conditionals (Bonnefon, Eid, Vautier, & Jmel, 2008). Literature is extremely extensive about logical problems' content, but no research, as far as we know, has linked logical reasoning with the evolutionary approach about knowledge learning.

1.3. What type of knowledge we acquire inside and outside schools and how we acquire it

We do not reason in the same way in everyday life and in schools. Our reasoning in everyday life is to be effective in a limited time with incomplete and doubtful information (heuristics) (Morsanyi & Handley, 2008). These strategies are far different from those that must be used in schools, logic requiring more conscious thought, efforts and time (analytical). The strategies used in everyday life are more linked to biologically primary knowledge whereas other strategies are linked to biologically secondary knowledge. The classical normative logic is secondary knowledge because we did not evolve to be logical (Stanovich, West, & Toplak, 2011), we learn to be effective most of the time (Geary & Bjorklund, 2000). According to a recent theory in evolutionary educational psychology (Geary, 2007, 2008, 2012; Geary & Berch, 2015, 2016), human beings evolved specifically to acquire primary knowledge distributed in folk psychology (*e.g.*, self-awareness, face recognition, facial expressions, language, group dynamics, theory of mind), folk biology (*e.g.*, fauna, flora, food) and folk physics (*e.g.*, navigation). This acquisition is easy, unconscious and fast contrary to secondary knowledge (*e.g.*, mathematics, grammar, every academic disciplines) for which our brain did not have enough time to evolve. The ease of acquisition of primary knowledge is linked to their essential function in the survival of our species: for example, it is directly useful to be able to recognize kin or to be able to spot the best food (Kaplan, Hill, Lancaster, & Hurtado, 2000). Primary knowledge is generalizable whereas secondary knowledge is very difficult to generalize and is rather specific (Tricot & Sweller, 2014). Additionally, individuals are intrinsically motivated to engage in task that involve primary knowledge acquisition while extrinsic motivation is often required to learn secondary knowledge (Geary & Berch, 2016).

The recent massive accumulation of secondary knowledge made schools indispensable for individuals to be adapted regarding our societies' demands which are not the same as those of our ancestors' (Richerson & Boyd, 2005). The motivational feature of primary knowledge is therefore an essential asset to be promoted in learning. Moreover, secondary knowledge is built on primary knowledge. For example, learning to read (secondary knowledge) is based on sound segmentation (primary knowledge). Primary knowledge facilitates the acquisition of secondary knowledge, particularly through the use of primary mechanisms that increase working memory capacity and reduce the impact of cognitive load promoting learning (Glenberg, Goldberg, & Zhu, 2011; Kirschner, Paas, & Kirschner, 2011; Paas & Ayres, 2014; Paas & Sweller, 2012; Ping & Goldin-Meadow, 2010; Van Gog, Paas, Marcus, Ayres, & Sweller, 2009; Youssef, Ayres, & Sweller, 2012). Indeed, human cognitive architecture and the knowledge acquisition process are supposed to have evolved in a similar way to biological structures (Sweller & Sweller, 2006). The limited working memory constrains the learning of new information for which the human being is not adapted. Thus, reducing cognitive load through instructions should promote learning. That is the main claim of the cognitive load theory (Sweller et al., 2011). Until recently, the limited capacity of working memory was thought to apply to the acquisition of all kinds of information (Paas & Sweller, 2012). But, as our system evolved to easily process primary knowledge, the cost in working memory is minimized. The processing of primary knowledge, even extremely complex, does not imply working memory cost (e.g. speaking is a complex activity combining motor skills, sounds, gesture, etc.). However, when an individual is faced with secondary knowledge, she or he doesn't have the abilities inspired by genetics to automatically assimilate information. The cognitive load theory then applies only to secondary knowledge (Sweller, 2008).

2. Present study

As far as we know, no study investigated the influence of primary and secondary knowledge content on individuals' performance and motivation in a reasoning task. In this paper, our aim is to test whether the effortful and motivating nature of primary knowledge could facilitate performance and engagement in a reasoning task (involving normative rules as secondary knowledge), challenging the evolutionary model of knowledge. To this end, we conducted two experiments. Each participant was faced with conditional problems involving primary knowledge content (food) or secondary knowledge content (grammatical rules). Problems involved unknown words so that familiarity and prior knowledge did not influence responses. As a matter of fact, our participants spend more time learning and applying secondary knowledge such as grammatical rules than dealing with how to process food so that it can be eaten (Beck & Richard, 2010; Guichemerre, 2011) and, in any case, none of them found the themes used familiar from near or far. Problems had thus the same level of abstraction with a shade of primary or secondary knowledge. As in studies in logical reasoning, we assessed participants' performance. We also wanted to include important factors in learning such as emotional and cognitive engagement, confidence in given responses and the perceived cognitive load. The main goal was to highlight that primary knowledge positively influence those variables comparing to secondary knowledge (Hypothesis 1).

In order to challenge the evolutionary model of knowledge, we also manipulated the added or extrinsic cognitive load of the tasks. Indeed, secondary knowledge is supposed to consume cognitive resources whereas primary knowledge is not. Thus, adding an additional cognitive load with a second task should impede secondary content to a