Measuring the Difference Between Self-Reported and Actual Self-Regulated Learning Behaviours in University Students

Lina Bareišytė

s1966944

First Supervisor: Dr. Alieke van Dijk

Second Supervisor: Dr. Hannie Gijlers

Faculty of Behavioural, Management and Social Sciences

Department of Psychology

Specialization Learning Sciences

University of Twente

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Abstract

Self-regulation is a part of 21st century skills and plays a crucial role in this skill package as it is key for higher academic achievement. Good self-regulated learners among other things can plan, monitor, and reflect on their learning behaviour. Unfortunately, some students do not possess, are not aware about the possession, or tend to overestimate their possession of self-regulatory skills. Therefore, this mixed-design study hypothesized that university students will report greater self-regulatory behaviours than they will perform them in a think-aloud learning task, as well as that self-regulation will have a significant positive impact on academic achievement. Furthermore, studies have shown that students who are interested in a certain topic will display greater results and more self-regulatory learning behaviours during the task regarding that topic. Therefore, motivation was also taken into consideration for this research. The study conducted collected data from university students ($N = 26$), and had three main parts: self-report questionnaire, observation of self-regulation during reading comprehension learning task, and a domain knowledge test. The study found significant correlations between motivation and perceived seeking information and organization of the task factors. No other significant correlations have been detected. This study's findings and literature suggest that perceived and actual self-regulation, as well as the relationship between self-regulation and motivation should be investigated more in-depth as all of them are important parts of learning and higher education.

Measuring the Difference Between Self-Reported and Actual Self-Regulated Learning Behaviours in University Students

As time passes, changes are required to conform the needs of rapidly developing society, and yet learning is neglected as it is still book and memory-oriented (Dede, 2010). Modern classrooms and learning environments try to turn away from perennial learning methods and place an emphasis on improving complex communication and expert thinking skills (Dede, 2010). In order to help students become more productive and obtain educational success a great interest is placed on learning behaviours such as self-control, self-adjustment, working with others, goal-directed behaviours, and attitude (Dede, 2010; Mahboubeh, 2017; Scorza, Araya, Wuermli, & Betancourt, 2016). In the article by Funke, Fischer, and Holt (2018) these skills are referred to as 'non-cognitive', other texts tend to refer to them as "life skills" or "21st century skills" (Scorza et al., 2016). They not only include content important for everyday life, information and communication technology, and life-skills but also have a strong focus on learning and thinking (e.g. communication, collaboration, critical thinking) (Dede, 2010; Partnership for 21st Century Skills, 2006). These skills are meant to help students succeed throughout their academic careers, be able to study in an efficient way, and learn to adjust to context specific requirements of the modern society (Dede, 2010; Mahboubeh, 2017; Scorza et al., 2016).

One of the main components of the 21st century skills is self-regulation (Scorza et al., 2016). It is used by learners to help manage their learning activities (Azevedo & Cromley, 2004) "such as goal setting, self-monitoring, and self-evaluation" (Graham, Harris, & Reid, 1992, p. 1). Studies regarding self-regulation are conducted for various age-groups starting from kindergarten, up to university, and across the lifespan (Bodrova & Leong, 2008; Broadbent & Poon, 2015; Mullen & Hall, 2015; Pintrich, 2004). The focus of research mainly lies in younger students, since self-regulation is a good predictor of future academic success (Neuenschwander, Röthlisberger, Cimeli, & Roebers, 2012). Therefore, parents and teachers are keen on improving self-regulation of students from the very beginning of their academic careers (Bodrova & Leong, 2008; Neuenschwander et al., 2012). Studies have shown that students who engage in self-regulated learning are able to obtain and apply new information faster than their peers who do not engage in this type of behaviour (Duckworth & Carlson, 2013). Additionally, such students do well in school, are less likely to quit and often continue into higher education (Duckworth & Carlson, 2013). Older students who successfully finish school and enter universities are already expected to have developed these skills and be able

to apply them due to their education, age, and ability, thus, receive tasks with less guidance and are expected to engage more in self-study (Cleary, Dembitzer, & Kettler, 2015).

However, not all students obtain and develop self-regulatory skills at school, learn how to use them to achieve best results, or choose to engage in them when needed (Cleary, Dembitzer, & Kettler, 2015). Additionally, students of different ages tend to overestimate their abilities to learn and perform (Cassady, 2000; Porat, Blau, & Barak, 2018). Although, older students face less problems with overestimation of their capabilities, such behaviour is still prominent especially in lower achieving university students (Cassady, 2000) A lot of self-study that is expected in the university setting and a lack of self-regulatory skills may lead to inappropriate learning behaviours (Cassady, 2000; Wasylkiw, 2015). Sometimes students think that they have done enough or that their learning method is the best one. However, by using another strategy they could achieve the same result faster or learn a lot more information (Zimmerman, 1990). According to Cleary, Dembitzer, and Kettler (2015) sometimes students "do not know what they do not know" (p. 842), which is when they do not immerse themselves into certain behaviours which could lead to better learning or other positive outcomes. By being actively aware of the possession of self-regulatory skills and understanding how to use them, students engage in adaptive and strategic learning (Cleary, Dembitzer, & Kettler, 2015). Additionally, they try to plan, carry out, and reflect on their ability to use learning strategies and their effectiveness. However, even after reporting such learning activities students who engage in self-regulated learning while preparing for tests or exams do not necessarily do so during regular learning tasks (Cleary, Dembitzer, & Kettler, 2015). Thus, keeping in mind that overestimation of capabilities could play a role, to better understand university students' learning styles it is important to compare whether they actively engage in self-regulated learning behaviours or whether they only think that they do.

Hence, the aim of this study is to extend knowledge on self-reported self-regulatory behaviours in university students and to see whether it mirrors their actual behaviour. Outcomes could provide an insight whether students are able to correctly assess their study behaviour and whether specific actions should be taken to reduce the possible gap between perception and reality.

Self-Regulated Learning

According to Pintrich (2000) self-regulation "is an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control

their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (p. 453). To get a better overview of this idea a theoretical framework has been proposed for self-regulated learning, which involves four phases: *forethought, planning, and activation, monitoring, control, reaction and reflection* (see Figure 1; Pintrich, 2000). These phases are commonly used when describing self-regulation by other researchers as well (e.g., Zimmerman, 2000; Pintrich, 2004). According to a review on self-regulated learning the models proposed by Pintrich and Zimmerman are very similar based on four main criteria: background, definitions, components, and research (Puustinen & Pulkkinen, 2001). To better explain the theory for this research ideas from both models will be used.

Self-regulated learning according to Zimmerman (1998) is multidimensional, determined by context and expected outcomes. Meaning, that it can be influenced by various measures such as motivation and that it is composed of multiple different phases which should all be addressed for best results (Zimmerman, 1998). The first phase of self-regulated learning is used to prepare oneself for action - *forethought, planning, and activation* - it contains understanding why the information is necessary and/or important to learn, what is already known, activating prior knowledge by using prompts, and self-questioning (Pintrich, 2000; Schunk, 2005). Second phase includes *monitoring* which helps students with time and effort management, as well as creating a 'feeling of knowing' (Pintrich, 2000; Schunk, 2005). Students tend to experience such feeling when faced with materials studied in the past (Schunk, 2005). Third phase - *control* involves students choosing efficient strategies and switching in-between them, furthermore, it helps to stay motivated and encourages to seek help when needed (Pintrich, 2000; Schunk, 2005). The final one is *reaction and reflection*, which involves thinking back on the work that has been done and evaluating oneself, outcomes, time, and effort (Pintrich, 2000; Schunk, 2005).

A good self-regulator tends to engage into all main phases; however, they might happen cyclically, linearly, in a random order and not necessarily all at once (Pintrich, 2000; Schunk, 2005; Zimmerman, 1998). Students themselves can control into which behaviours they want to engage, although some may occur unknowingly (Pintrich, 2004). Additionally, throughout the process good self-regulators are actively aware about the relations between the use and application of learning strategies, and academic achievement (Zimmerman, 1990). Without this active engagement one cannot understand what information is still unclear or

missing and may not feel the need to go back through the phases again or use them simultaneously, which is usually what good self-regulated learners tend to do (Pintrich, 2000).

Phases	Cognition	Motivation/Affect	Behavior	Context
1)Forethought, Planning, and Activation	1)Target goal setting	1)Goal orientation adoption	1)Time and effort planning	1)Perceptions of task
	2)Prior content knowledge activation	2)Efficacy judgments	2)Planning for self-observations of behavior	2)Perceptions of context
	3)Metacognitive knowledge activation	3)Perceptions of task difficulty		
		4)Task value activation		
		5)Interest activation		
2)Monitoring	1)Metacognitive awareness and monitoring of cognition	1)Awareness and monitoring of motivation and affect	1)Awareness and monitoring of effort, time use, need for help	1)Monitoring changing task and context conditions
			2)Self-observation of behavior	
3)Control	1)Selection and adaptation of cognitive strategies for learning, thinking	1)Selection and adaptation of strategies for managing motivation and affect	1)Increase/decrease effort	1)Change or re-negotiate task
			2)Persist, give up	2)Change or leave context
			3)Help-seeking behavior	
4)Reaction and Reflection	1)Cognitive judgments	1)Affective reactions	1)Choice behavior	1)Evaluation of task
	2)Attributions	2)Attributions		2)Evaluation of context
Relevant Scales	Rehearsal Elaboration Organization Metacognitive Regulation	Mastery Self-talk Extrinsic Self-talk Relative Ability Self-talk Relevance Enhancement Situational Interest Enhancement Self-consequating	Effort Regulation Time/Study Environment Help-seeking	

Figure 1. Description of areas and phases of self-regulated learning (Wolters, Pintrich, & Karabenick, 2005).

Self-regulation in University Education

Most students who transition from schools to universities experience a shift of responsibility: from external – where everything is provided and one only needs to focus on learning the given materials, to internal – being personally responsible for planning, organizing, and learning (Wasylkiw, 2015). University students face increased classrooms, workloads, and other new challenges regarding work ethic. In a study done by Wasylkiw (2015) students have indicated that the main two problems which impaired their study performance were time management and self-regulation. Only students who before entering a university studied in advanced classrooms (e.g. International Baccalaureate Diploma Programme) which offered a higher workload or had job experience next to their education did not seem to face these problems because they have learned to manage their time and deal with a higher amount of study materials beforehand. However, these experiences are not very common amongst students. The majority report that they did not acquire both time

management and self-regulatory skills and thus, struggled throughout university, coming unprepared to exams, and submitting tasks late. Although, some students suggested that time management can be improved by creating a schedule, self-regulation becomes a more difficult issue to solve.

Upon arrival to the university students are expected to bring a package of skills (Wasylkiw, 2015). A comparison provided by the University of Regina (n.d.) between high school and university shows that university students are expected to be able to independently review materials, understand which information is important to study, and how they should do so to succeed. Additionally, it is stated that during lectures and tutorials students are only provided with key points and have to understand themselves whether they should take notes, what to write, how to study, and how to do so efficiently. Another important mention is that all studying is independently managed, students can decide for themselves whether to attend certain classes, how to divide their time, how, what, and where to study. The comparison gives the impression that students are provided with a lot more freedom for studying in the university, however, it is important to note that set deadlines for deliverables and/or exams are stricter, and that there are a lot more materials to be prepared for (University of Regina, n.d.). Students who do not possess these self-regulatory learning skills or are unable to obtain them fast risk dropping out or losing their scholarships (Wasylkiw, 2015).

Possession and appropriate use of self-regulatory skills in university education not only leads to higher achievement (Zimmerman & Bandura, 1994). It has been found that it increases ones perceived self-efficacy, confidence in personal goal setting, and motivation (Ruban & Reis, 2006; Zimmerman & Bandura, 1994). Students who engage in self-regulation tend to doubt themselves less and are willing to take on new challenges faster than their peers (Zimmerman & Bandura, 1994).

Students as Self-Regulated Learners

Students who are good at self-regulated learning think of what they want to learn (process goals) or achieve (product goals) whilst learning by setting goals (Kitsantas, 2002). To help achieve such goals students engage in strategic planning and observe the progress by self-monitoring (Graham, Harris, & Reid, 1992; Kitsantas, 2002). They evaluate what is going well, what could be improved, or think about how their learning process should be adjusted for similar problems faced in the future (Graham, Harris, & Reid, 1992; Kitsantas, 2002). If the outcomes of the learning process are obtained or along the way students notice little to no

progress they tend to self-evaluate and check whether certain learning strategies can be adjusted, changed, or whether guidance from others is required (Kitsantas, 2002; Zimmerman, 2000). Although as previously mentioned, these processes do not have to happen all at once, students must engage at least in some of them consciously or subconsciously to achieve positive results (Pintrich, 2000; Schunk, 2005; Zimmerman, 1998).

According to Zimmerman (1989) learning is not necessarily a fixed trait and can be altered and/or enhanced. Therefore, students who do not perform as well in comparison to their peers can engage into self-regulated learning activities, be able to improve the way they are learning, and achieve higher scores (Hernández-Barrios & Camargo-Uribe, 2017; Pintrich, 2004; Zimmerman, 2008). Furthermore, by immersing into self-regulatory activities students can create a link between the 'external' environment and their own thinking by setting goals, creating personalised meanings, and strategy use, which would help them to better remember and retain the information when needed (Broadbent & Poon, 2015; Pintrich, 2004).

Additionally, an important distinction should be made regarding the use of self-regulation. Some students may not engage into self-regulated learning because they do not possess these skills (availability deficiency), meanwhile, others might possess the necessary skills but be not aware how to correctly use them in certain contexts (production deficiency) (Veenman, Kok, & Blöte, 2005).

Current Study

The aim of the current study is to compare self-reported and actual self-regulatory behaviours in university students. A previous study done by Veenman, Prins, and Verheij (2003) has already investigated the differences between perceived and actual learning styles of university students. To explore deeper the concept of self-regulation the research question for this study is as follows: *To what extent is there a difference between self-reported and actual self-regulatory learning behaviours in university students?*

The study conducted is a mixed-methods research design and consists of three main parts. The first one is a self-report questionnaire that assesses students perceived self-regulation skills whilst studying, followed by a measurement to determine students' motivation towards a topic. The second part involves a think-aloud learning task. It is used to observe self-regulatory behaviours whilst studying. To help clarify what self-regulatory behaviours are reading comprehension is used. It has been found that good self-regulators use reading comprehension to better understand, monitor, and organize the task at hand (Paris &

Paris, 2001). Although it is not directly linked to academic achievement in university education, strategies used during reading comprehension help facilitate learning (Parmis, Bandalan, & Clerigo, 2020). The final part is a domain knowledge test to assess the information obtained during the learning task.

Hypotheses that will be addressed are as follows:

H1. Students report greater self-regulatory behaviours than they actually show these skills in a think-aloud learning task.

As mentioned previously, students tend to overestimate their learning abilities (Cassady, 2000; Porat, Blau, & Barak, 2018). Additionally, they report not possessing sufficient or being unable to use self-regulatory skills needed for the university education (Veenman, Kok, & Blöte, 2005; Wasylkiw, 2015). Thus, it is expected that students will reveal that they engage into greater amounts of self-regulatory learning behaviours than they will perform during the learning task.

H2.1. Students who report greater motivation scores to learn the given topic perform more self-regulatory learning behaviours.

When analysing perceived and actual self-regulation it is necessary to address motivation as it plays an important role (Zimmerman, 2008). Literature suggests that motivation positively affects self-regulation (Green, Nelson, Martin, & Marsh, 2006; Miller & Brickman, 2004). Therefore, it is expected that motivated students will report and engage into more self-regulatory learning behaviours.

H2.2. Students who report greater motivation to learn the given topic perform better in a domain knowledge test about it.

Self-regulation is closely related to motivation, students who show greater motivation for a certain topic tend to study better and harder for it rather than the ones who are not interested in the topic (Baumeister & Vohs, 2007; Wasylkiw, 2015). For that reason, it is expected that students who enjoy the topic more will perform better overall.

H3. Students who show more self-regulatory skills during the learning task achieve higher scores in the domain knowledge test.

Self-regulation is positively linked to academic achievement (Zimmerman, 1990). Therefore, it is predicted that students who show greater self-regulatory learning behaviours will perform better in a domain knowledge test compared to their peers.

Method

Participants

The study consisted of twenty-six university students (12 females; 14 males), ranging in age from 20 to 26 years (M = 21.58; SD = 1.36). All were recruited using availability sampling. Twenty-two students who volunteered to participate were following a bachelors study programme, four others were following a masters study programme. The sample included a variety of different nationalities (57.7% Lithuanian; 19.2% Dutch; 23.1% other). To ensure that all participants were provided with the same conditions, the study was conducted in English. Before starting with the study participants signed an informed consent form, as well as were informed verbally about the use of data collected. Participation was voluntary, and participants could withdraw from the study at any time.

Measures

Learning task

The learning task used in this study was based on a similar task created by Veenman, Prins, and Verheij (2003) and its aim was to help observe whether students engage into self-regulatory behaviours whilst studying. Participants were instructed to use the think-aloud method - verbalising thoughts or ideas which cross their mind while doing the learning task (Jääskeläinen, 2010). In case they fell silent, participants were encouraged to continue expressing their thoughts by the researcher (e.g. “I can see that you are busy with something, can you explain to me what you are doing?”). During this part participants were introduced to a learning task – an approximately 1000-word long text about Greenland sharks by O’Connor (2017), with additional pictures (see Appendix B). For this specific learning task no prior knowledge about the topic was required. The text was aimed at a general reader and it went in depth explaining about Greenland sharks and how their age can be determined based on their corneas. For this study, the text was adjusted by adding sub-headings and two explanatory pictures to create a resemblance to learning materials provided by universities and help the reader to easier navigate throughout the text. Students were given a maximum of 30 minutes

to read and study the text, however before the time ran out, they could indicate to the researcher that they were done preparing and could continue with the domain knowledge test early. After the learning task was finished, participants were asked to give a short summary on how they studied ("Please briefly explain how you studied the text").

Self-Regulation Strategy Inventory-Self-Report

To measure perceived self-regulation an adjusted Self-Regulation Strategy Inventory-Self-Report (SRSI-SR) was used (see Appendix A). The questionnaire is aimed to check whether students engage into self-regulated learning behaviours which are not directly observable by their teachers or supervisors (Cleary, Dembitzer, & Kettler, 2015). Originally created to measure perceived self-regulation of high-school students in a particular subject, it was adapted by Hernández-Barrios and Camargo-Uribe (2017) to fit university students. The translated and adapted version was used in this study. The questionnaire consists of 18 statements (e.g. "I do additional bibliographic searches to help me understand topics from class") and participants have to evaluate how much each of these statements fit to their study behaviour based on a four-point Likert scale, from 1 = *disagree* to 4 = *agree* (Hernández-Barrios & Camargo-Uribe, 2017). All statements are grouped into four different factors: maladaptive regulatory behaviour (MRB), managing environment and behaviour (MEB), seeking information (SI), and organization of the task (OT). The reliability of the adjusted version of SRSI-SR is $\alpha = 0.84$.

Motivation

To measure students' topic interest, a statement regarding motivation was posed "Please indicate how motivated you are to read about this topic". It measured one's motivation regarding the learning task on a scale from 0 = *not motivated* to 10 = *very motivated*.

Domain Knowledge Test

To measure students' domain knowledge on the topic of the text (e.g. Greenland sharks), a domain knowledge test was developed (see Appendix C). It was intended to measure what students have learned during the learning task and check whether their motivation for the task had any influence on achievement. The domain knowledge test consisted out of five multiple choice questions with one correct answer option (e.g. "What type of carbons help to determine the date of birth of the deceased?"), one multiple choice

question with two correct answer options (e.g. “Please tick that/those answer option(s) which according to the text explain why Greenland sharks have such a long lifespan.”) and one open question (e.g. “Please explain why is it impossible to determine the age of Greenland sharks in a similar way as for other sharks?”).

Procedure

The procedure for this research was one session which consisted of three main parts. Firstly, participants were asked to fill in a questionnaire containing some background questions (e.g. age, gender), followed by the adapted version of SRSI-SR questionnaire (see Appendix A), and a question regarding their motivation towards the topic. To complete the questionnaire participants had approximately 15 minutes.

After the questionnaire, an audio-recorded digital meeting between the participant and the researcher took place. During which each of the participants received a learning task about Greenland sharks (see Appendix B). For the digital meeting it was required to have a good internet connection, a computer or a mobile device with a working microphone and camera, as well as any additional materials participants wanted to use while studying for the domain knowledge test. Meetings were mainly conducted through audio-recorded Skype video-calls where the researcher introduced participants to the learning task at hand, answered questions, and observed the participants while they were preparing for the domain knowledge test.

The learning task was provided in a Word document offering the ability for participants to add personal notes or highlight important parts. Moreover, participants were allowed to use additional resources and/or materials to emulate their usual study procedure. They were given 30 minutes and instructed to study the text while using the think-aloud technique. If at any point during the learning task participants became silent, they were encouraged to continue expressing their thoughts by the researcher. Additionally, if participants were finished studying before reaching the 30-minute mark, they were able to continue with the domain knowledge test early.

Lastly, the domain knowledge test was conducted directly after participants were finished studying or the time ran out. To ensure that no cheating took place, the digital meeting with the researcher continued, however, voice recording was stopped. The domain knowledge test consisted of six multiple choice and one open question (see Appendix C). All questions in it were created based on the text about Greenland sharks. The domain knowledge

test did not have a time limit, moreover, participants were not allowed to use their notes or any other additional sources.

Data Analysis

Self-Regulation Strategy Inventory-Self-Report

The analysis of the adjusted version of SRSI-SR results was based on the explanation provided by Hernández-Barrios and Camargo-Uribe (2017). Means (*M*) and standard deviations (*SD*) for each of the four factors were calculated. They provided insights on student perceived self-regulatory learning behaviours. The minimum score one could receive for each of the factors was 5 and maximum was 20, except the factor seeking information for which minimum score was 3 and maximum 12.

Observation of the Learning Task

To determine the actual self-regulatory learning behaviours audio-recordings from digital meetings were transcribed and coded using an observation table (see Figure 2). It was created to help identify and code self-regulated learning behaviours, so that they could be compared with self-reported measures provided by SRSI-SR. The observation table was created based on self-regulated learning models by Pintrich (2000; 2004), Zimmerman (1989; 1998), and the SRSI-SR. However, the observation table mentions only three out of four phases. In the adjusted SRSI-SR questionnaire the self-regulated learning phase r*eaction and reflection* was not included. This phase for students usually occurs after submitting, while waiting, and upon receiving the results of a test or an assignment (Schutz, & Davis, 2000). Which is beyond the scope of this research.

Possible behaviours described in the observation table are explanations of each of the three phases: *forethought, planning, and activation* (e.g. “Thinks how it would be the best to study, before starting”)*, monitoring* (e.g. “Reflects on what is known and what one does not understand”), and *control* (e.g. “Searches for additional information”). In theories of self-regulated learning some behaviours are explained more precisely (e.g. “Asks questions regarding the task”) than others (e.g. “Monitors learning behaviour”), thus, to help indicate them faster, reading comprehension was used to explicate relevant self-regulatory behaviours related to the learning task at hand. Reading comprehension provides an explanation of clear, observable behaviour and plays an important role identifying self-regulated learning (Cirino et

al., 2017). For example, by using explanations provided by studies on self-regulation and reading comprehension both strong and poor readers can be addressed (Law, Chan, & Sachs, 2008; Mohammadi, Saeidi, & Ahangari, 2020). Good readers tend to engage in rehearsal and organization of the materials to help them understand the text better (Paris & Paris, 2001), meanwhile readers who have problems comprehending the text tend to slow down their reading pace and engage in other strategies to help them understand, such as re-reading or self-questioning (Law, Chan, & Sachs, 2008). Therefore, self-regulatory observable behaviours which can be explained by reading comprehension have been included into the observation table. For example, to explain one of self-regulatory behaviours "If something is not clear, continues to try to understand it" the theory of reading comprehension offers that students who want to better understand what they have read engage into: *Rephrasing*, *Paraphrasing, Summarizing, Re-reading*, and *Rehearsing* (Fotovatian & Shokrpour, 2007).

The observation table included a total of ten codes, all of which had at least one equivalent from the adjusted SRSI-SR. Some codes had more equivalents from the questionnaire because certain behaviours when explained in detail consisted of multiple possible scenarios (e.g. "Quickly regains focus after getting distracted" has six different links attached to it because a distraction can be caused by various different things and/or events). Each code was given one point if a corresponding action has been shown, for example, a repetition of a sentence while learning was awarded one point to the code "If something is not clear, continues to try to understand it". The minimum score one could receive for all codes was zero, the maximum score could not be set because there is no determined number on how many times one performs a certain behaviour.

Coded behaviours were grouped accordingly into four factors based on SRSI-SR. Means and standard deviations for each of them were calculated.

Phases	Behaviour	Link to the adjusted SRSI-SR questionnaire
Forethought, planning, activation	Thinks how it would be the best to study, before starting. For example, chooses to: - Repeat out loud - Highlight - Write notes	18. I think about how best to study before I begin studying 17. I use some method to keep my class material in order
Monitoring	Reflects on what is known and what one does not understand - Thinks what should be remembered	14. I plan in which order I will carry out my academic activities

	- Focus on keywords or phrases - Special aspects of the task	
	Monitors learning behaviour - Time - Effort - Evaluates what is going well, what is not	16. I make a schedule to help me organize my study time
Control	Assesses the progress - E.g. What have I learned? - E.g. Is there anything important that I have missed?	4. I try to forget about the topics that I have trouble learning (reversed question)
	Thinks whether the current learning strategy works - E.g. Note taking is too long of a process, switches to rehearsal	
	Reinforces oneself - Positive self-talk - Rewards	3. I give up or quit when I do not understand something (reversed question)
	Asks questions regarding the task	1. I ask my teacher questions when I do not understand something 2. I avoid asking questions in class about things I don't understand (reversed question)
	If something is not clear, continues to try to understand it by: - Rephrasing - Paraphrasing - Summarizing - Re-reading - Rehearsing - Looking at images	13. I investigate when I don't understand something about the tasks I have to do
	Quickly regains focus after getting distracted	5. I am easily distracted when I am studying (reversed question) 6. I try to study in a quiet place 7. I try to study in a place that has no distractions (e.g. noise, people talking) 8. I make sure that nobody disturbs me when I study

	9. I let others to interrupt me when I'm studying (reversed question)
	10. I finish all my academic activities before starting other activities
Searches for additional information	11. I do additional bibliographic searches to help me understand topics from class
	12. I am looking for complementary material to the topics seen in class
Coordinates time - Wants to continue with the test before the preparation time runs out - Finishes preparing on time	15. I coordinate my time according to the assigned academic activities

Figure 2. Observation table.

Domain Knowledge Test

To evaluate the domain knowledge test each question was awarded with points. Minimum points one could receive was zero and maximum points awarded for the domain knowledge test was nine. Correctly answered multiple choice question with one possible answer option was given one point. Multiple choice question with more than one answer option was given two points, however, if the participant chose only one correct answer option or chose more answers than were correct, he or she was awarded with one point. When none of the correct answer options were chosen one received zero points. The final open question if answered correctly was given two points: one for explaining how age is determined for Greenland sharks and one for explaining how it is determined in other sharks.

Results

The Relation Between Perceived and Actual Self-Regulation

Table 1 provides insights on minimum, maximum, mean (*M*) and standard deviation (*SD*) scores per factor based on SRSI-SR questionnaire. The minimum score one could receive was 1 and the maximum was 4. During the research only two factors seeking information and organization of the task received a maximum possible score. Scores of

perceived self-regulation varied in moderation. Participants on average showed relatively high scores for all factors.

Table 1.

Means (M), standard deviations (SD), minimum and maximum scores per SRSI-SR factor.

Factors	Minimum score	Maximum Score	M	SD
Self-Report MRB	1.75	3.50	2.72	0.53
Self-Report MEB	1.60	3.80	2.59	0.60
Self-Report SI	1.75	4.00	2.91	0.60
Self-Report OT	1.38	4.00	2.89	0.78

Table 2 reports scores received from the observation table per factor. The minimum score one could receive was zero and there was no set maximum score for the observations. Observed self-regulation showed a larger variety of scores. Especially seeking information and organization of the task factors showed large deviations between minimum and maximum scores. Observed managing environment and behaviour was the only factor which behaviours some participants did not show. Table 2 also demonstrates that all averages of behaviours performed were on a medium to low level compared to the maximum scores observed.

Table 2.

Means (M), standard deviations (SD), minimum and maximum scores per observed factor.

Factors	Minimum score	Maximum Score	M	SD
Observed MRB	0.25	3.75	1.99	1.00
Observed MEB	0	6.00	1.73	1.56
Observed SI	8.50	55.00	24.40	11.53
Observed OT	1.25	15.50	6.53	3.42

Correlation Analysis

To compare both perceived and actual self-regulation first a test of normality was performed. It showed that all factors were normally distributed except the observed managing

environment and behaviour ($p = 0.008$). Therefore, to determine the relation Spearman rank correlation was chosen to administer.

To see whether there is a statistical relationship between perceived and actual self-regulation, scores received from SRSI-SR questionnaire and perceived scores from the observation table per factor were paired in a correlation analysis (see Table 3). No statistically significant correlations between the pairs have been found ($p > 0.05$).

Table 3.

Spearman rank correlations between perceived and observed self-regulatory behaviours

		1	2	3	4	5	6	7	8
1.	Self-Report MRB	-							
2.	Self-Report MEB	.224	-						
3.	Self-Report SI	.450*	.186	-					
4.	Self-Report OT	.315	.514**	.333	-				
5.	Observed MRB	.115	-.379	-.336	-.377	-			
6.	Observed MEB	-.196	-.304	-.194	-.098	.271	-		
7.	Observed SI	-.101	-.383	-.177	-.154	.487*	.252	-	
8.	Observed OT	-.014	-.209	-.173	-.123	.385	.253	.626**	-

Note. *$p < .05$, **$p < .01$.

Observations per Factor

To gain insight on behaviours observed in the following explanations and examples per factor are provided. They present information on what types of behaviours were performed and how they were described by participants.

Maladaptive Regulatory Behaviour. MRB was reversed and focused on maladaptive behaviour. Participants who scored higher than the average mean during the learning task collected points mostly by asking questions about the learning task or assessing their progress. Questions asked were either about understanding the text "*Can I ask you a question? What is meant by the last sentence? Why is catching it is as welcomed as stepping in dog poop?*" (P8) or about the structure, content or criterion of the domain knowledge test "*I want to check what the criteria for the exam is. Is it open book, is it closed book?*" (P6). Assessing the progress involved going back through the memories/notes and thinking "*What do I have so far?*" (P2). Some participants even went back and questioned their knowledge about the topic "*What do they eat? I know, they eat fish, like shrimp, tiny other fishes, but not plankton. That is interesting, they are not like whales*." (P6).

Managing Environment and Behaviour. MEB focused on distractions, whether students were able to choose a suitable environment to study, did not get distracted or quickly regained focus after getting distracted. This is the only factor where some participants did not perform any behaviour related to the factor. The observed distractions were mainly caused by the cat of the researcher, during the digital meetings it would start meowing causing disturbances for the learning process of the participants or other outside noises "*Do you hear the dogs? I'll close the window.*" (P12). Other distractions occurred when searching for additional information online "*I'm just looking through the Wikipedia page and looking through the contents… And then go to the article about radiocarbon dating, then I might end up in a hole of Wikipedia for half an hour, when I need to study actually*." (P2). However, most of them did not take long to deal with "*Oh they also have a video, which is probably too long for now…*", "*Oh, that was a pop-up*." (P3).

Seeking Information. Perceived and observed SI focused on understanding better the information at hand by using different strategies and seeking complementary materials. Performed behaviours often included searching for additional information "*I'm looking up the definition for the eye, for the family of the shark. Because I don't know what that is*." (P5). Also, repeating and/or summarising words, phrases, or sentences "*So Heinemeier, Steffensen, Nielsen, Heinemeier, Steffensen, Nielsen, Heinemeier, Steffensen, Nielsen, Heinemeier, Steffensen, Nielsen.*" (P14) and translating "*I'm not sure what elusive means, so I'm going to translate it*" (P9).

Participants who performed information seeking behaviours had various approaches, some focused on remembering minor details within the text *"I read the whole article*

whatever is written there. Then, I start reading it again slowly, trying to pay attention to every little detail which might be important. Which might be a lot of. Try to write it down. Then in the end check all the details if from all the details I can make a story in my mind, then it means that it is pretty much done correctly." (P15), others - on the overall story "*I first read through the paragraph and then once for all and then I knew a bit of the story. So, I could come back and highlight what is important and if I thought... Highlight was not enough and I thought I should have summary, I did that. Then I did the story in my own words, I wrote it in my own words. So, then I could read over it and understand it more easily."* (P14).

Organization of the Task. Finally, OT focused on planning how to approach the learning task most effectively and manage time efficiently. Before starting with the learning task some participants thought what the most efficient way to study would be "*I went through the entire text to see how long it was. And maybe I'm thinking, maybe I should start making yellow*" (P14), others focused on what the domain knowledge test might consist of "*I think, right now, I will just write these three questions down because I'm not sure whether they will be important for later."* (P26). Performed behaviours involved planning "*Okay, now there are some references I'm not going to do anything with it. I'm going over it, once more now because I have 5 minutes left*." (P14), as well as a reflection on what is clear and what requires looking into "*I'm trying to figure out why isotopes are relevant for this whole thing. If they're talking about the sharks*." (P6).

The Effect of Motivation on Self-Regulation

To determine whether there is a relation between motivation and self-regulation first a test of normality was administered. It showed motivation scores as normally distributed (p = .001), meanwhile perceived and actual self-regulation scores were not ($p_{perceived}$ = .20; p_{actual} = .20). Thus, to test the relationship between variables Spearman rank correlation was used. It showed a positive correlation between motivation and perceived self-regulation (r_s = .502, p = .009). No significant correlation between motivation and actual self-regulation was found (p = 0.592). To explore motivation on perceived self-regulation deeper, Spearman rank correlation was administered to all four factors. It showed that only two factors were affected: seeking information and organization of the task (see Table 4).

Table 4.

Spearman rank correlation between motivation and perceived self-regulation factors

	1	2	3	4	5
1. Motivation	-				
2. Self-Report MRB	.268	-			
3. Self-Report MEB	.144	.224	-		
4. Self-Report SI	.395*	.450*	.186	-	
5. Self-Report OT	.447*	.315	.514**	.333	-

Note. *$p < .05$, **$p < .01$.

To predict perceived seeking information and organization of the task factors on motivation, two linear regression analyses were performed. The first one investigated the effect of perceived seeking information behaviours on motivation, $b = .47$, $t\ (24) = 4.44$, $p < .001$. It showed a significant regression equation ($F\ (1, 24) = 6.921$, $p = .015$, $R^2 = .224$). The second regression was used to predict motivation on perceived organization of the task $b = .40$, $t\ (24) = 3.06$, $p = .005$. It again showed a significant regression equation ($F\ (1, 24) = 4.637$, $p = .042$, $R^2 = .162$).

The Relation Between Motivation and Domain Knowledge Test Scores

To see whether there is an interaction between motivation and domain knowledge test scores a correlation analysis had to be administered. First a normality test was conducted. According to Shapiro-Wilk results were not significant ($p = 0.06$), meaning that the data was normally distributed, therefore Pearson correlation was chosen to conduct next. It showed a non-significant correlation between motivation and domain knowledge test results ($r = 0.06$, $p = 0.77$).

The Effect of Self-Regulation on Domain Knowledge Test Scores

To administer whether self-regulation has an influence on domain knowledge test scores two multiple regression analyses were carried out. The first one focused on predicting domain knowledge test scores based on all four factors of self-reported self-regulation. The second one investigated the relationship between domain knowledge test scores and observed self-regulation scores. Both multiple regression analyses showed no significant results ($F_{reported}\ (4, 21) = 0.163$, $p = 0.955$, $R^2 = 0.030$; $F_{observed}\ (4, 21) = 1.020$, $p = 0.420$, $R^2 = 0.163$).

Discussion

The aim of this study was to gain insights regarding perceived and actual self-regulatory learning behaviours in university students. In case of a possible gap it is important that universities address the problem by adjusting the curricula to help students transition easier to a more self-reliant way of studying (Cleary, Dembitzer, & Kettler, 2015). The research conducted was based on a design previously done by Veenman, Prins, and Verheij (2003), however, it had a more in-depth focus on self-regulation. Additionally, an observation table was created based on theory of self-regulatory learning by Pintrich (2004; 2004), Zimmerman (1989; 1998), and expanded upon using theory on reading comprehension. As reading comprehension provides examples of observable behaviours both of strong and poor readers (Law, Chan, & Sachs, 2008; Paris & Paris, 2001). Additionally, the study explored relationships between motivation and self-regulation, as well as motivation and learning outcomes. Such examinations were important to conduct because motivation has been shown to play a role on self-regulation and positively impact academic achievement (Miller & Brickman, 2004; Zimmerman, 1998). Therefore, it is interesting to see whether motivation will have an impact on both or at least one of the variables.

In the first hypothesis the study focused on relationships between self-reported and performed self-regulatory behaviours. It was expected that participants will report more self-regulatory learning behaviours than perform them. However, no significant relationship between the scores has been found. This might indicate that there is no relationship between perceived and actual self-regulation, nonetheless more research is required to prove that. A similar study which focuses on reported and performed attitudes in autonomous and control-oriented (e.g. people who are dependent on external influences) students show that autonomous students display more consistencies (Koestner, Bernieri, & Zuckerman, 1992). As previously mentioned, students need to be self-reliant to do well in university (Wasylkiw, 2015). Most participants in this study were older students, already accustomed to the student lifestyle, making them quite autonomous and thus, possibly aware of their behaviours. Which would give food for thought whether students are aware of their behaviours and are able to report them accurately. Hence, it might be interesting to investigate perceived and actual self-regulation among younger students.

The first part of the second hypothesis analysed the effect of motivation on self-regulation. It predicted that motivation could positively affect how much students engage into self-regulatory learning behaviours. Findings suggest that motivation influences perceived

seeking information and organization of the task behaviours. No other significant correlations between variables have been found. A study done by Wolters (1998) found that students reported engaging into cognition and help seeking behaviours amongst others (performance goals, environment) to defeat low motivation. Wolters (1998) described cognition as strategies that students engage in, to accomplish a task. They involve planning on how to study, take notes, and make flashcards which mainly correspond with the factor organization of the task from SRSI-SR as it involves similar criteria (see Appendix A). Meanwhile, help seeking behaviours described in the paper – asking friends or teachers for support and assistance when the task is difficult or unclear, are comparable to seeking information factor. Additionally, the paper noted that such behaviours increase as the task difficulty increases (Wolters, 1998). Therefore, a possible explanation for outcomes of this hypothesis could be that students can potentially understand and report how they would cope with the task at hand, however, when faced with a task they might not engage into the reported variety of self-regulatory behaviours as the task does not require them to do so. Meaning that if the domain knowledge test was too easy for some students they did not need to engage into certain behaviours and thus, did not show them. To sum up, findings suggest taking a closer look into motivation and its effect on performed self-regulation with increasing difficulty tasks.

The second part of the second hypothesis predicted that students who are more motivated about the topic presented in the learning task will obtain higher scores in a domain knowledge test about it. Which would indicate that motivation plays a role within self-regulation and achievement. Although after conducting the analysis no significant results have been found, other studies suggest that motivation plays a big role in academic achievement (e.g. Milner-Bolotin, 2001; Wolters, 1998). Such discrepancies indicate that motivation might not have been fully addressed as there is more to it than topic motivation alone (e.g. intrinsic, extrinsic) (Vallerand et al., 1992). A broader look should be taken to analyse the effect of motivation on domain knowledge test results. Additionally, it is important to address that received outcomes might have been affected because the research conducted was an extracurricular activity for students and they could participate voluntarily. It is important to consider that participants might not have taken the domain knowledge test as seriously as they would have an actual exam which is a part of their curriculum. Students who have reported high motivation about the topic at hand might not have been motivated to do well on the domain knowledge test and vice versa.

The final hypothesis proposed that students who engage more into self-regulatory learning behaviours will grasp the learning task better and achieve higher scores in a domain knowledge test. Such findings would go in line with a paper by Zimmerman (1990) stating that self-regulation is influenced by motivation, however, good self-regulators do not need to be interested in a topic to be motivated to study. Unfortunately, again, no significant results have been found. To achieve good scores, students must actively try to engage in self-regulatory learning behaviours (Mega, Ronconi, & De Beni, 2014). Aside from that, they must understand the task well, be mindful about their needs, recognize what they want to learn, and whether spending a lot of time on a task will align with their planning (McCann & Garcia, 1999). Although students showed self-regulatory behaviours it is possible that some of them did not engage into them enough, as much as they usually would, or did not engage in relevant activities which would be important to learn the task efficiently (e.g. goal-setting). Multiple participants did not spend a lot of time engaging and analysing the learning task and while it could possibly be their way of learning, it could also be their way of recognising that the outcome of the learning task does not have a direct impact on their future and thus, should not take a lot of energy. Due to the number of participants a couple of similar cases could have impacted the entire outcome. Measuring whether students engage into as many self-regulatory behaviours as they usually would, could be difficult, however, using graded exams from a university curriculum might put additional pressure to try and perform well.

Limitations

Outcomes of this research might have been influenced by several reasons. One of them is that during this research the COVID-19 pandemic took place and due to it both participants and the researcher to ensure safety had to stay in lockdown. This led to an inability to choose where to study and certain distractions which could have been avoided by participants in regular conditions took place (e.g. pets at home, outside noises, family members). Distractions are common when learning from home and they can impede the amount of effort one puts in order to complete a task (Sharma, Dick, Chin, & Land, 2007). Conditions faced during this research had influence on factors of maladaptive regulatory behaviour and managing environment and behaviour as they both included observations regarding distractions which might occur whilst studying. Therefore, some factors were better represented than others.

Second limitation encountered during the study was the length and the timing of the learning task. Some students reported that they were more used to studying larger amounts of

information with no time restrictions, which led to them changing their learning strategies from their usual to more time-friendly ones. This, again, might have influenced the final outcomes.

Third limitation that should be addressed is regarding the adjusted SRSI-SR. A confirmatory factor analysis was conducted to see whether factors load accordingly to the questionnaire as the adjusted version was translated from Spanish to English by the researcher. However, factors did not load accordingly which means that questions might have not fully represented constructs at hand. Although the original questionnaire and its factors are verified and a confirmatory analysis is unnecessary, something might have been lost in translation and thus, affected the outcomes of this research.

Recommendations

For future studies, an adjusted version of this research should be considered involving a graded domain knowledge test at the end which is part of students' curriculum in the university. As it has been found that students put more effort and perform better during important tests (Cole, Bergin, & Whittaker, 2008). This could provide a more precise insight on study behaviour as graded exams would encourage to perform well. Additionally, grading could help involving all four phases of self-regulated learning. As the final phase *reaction and reflection* was not addressed during this research and it is an important part of self-regulated learning (Pintrich, 2000). Good self-regulated learners after reviewing past mistakes tend to adjust their ways of learning and improve their learning performance for the future (Pintrich, 2000). Thus, by allowing participants to reflect on how they performed during the domain knowledge test, insights could be gained on what went well and what behaviours students would change to perform better next time.

Another idea for future research would be to address the study of Koestner, Bernieri, and Zuckerman (1992). Their study focused on attitude-behaviour correlations and involved the differences between autonomous and control-oriented students. Suggesting that these traits can determine whether one acts accordingly to the perception of oneself. This idea could be used to understand whether autonomy helps university students to correctly perceive the level of self-regulation in learning and be able to report it accurately.

Final suggestion is regarding the impact of motivation on self-regulation. To further assess the effect of motivation on self-regulation it would be interesting to apply the increasing difficulty task idea by Wolters (1998) and use it whilst observing students. This

way it would be possible to compare the effect of motivation on perceived and actual differences between self-regulatory learning behaviours. Such research would help to better understand whether motivation increases when faced with a difficult task and whether there is a possible decrease in motivation and self-regulatory learning behaviours when the task gets too difficult (Capa, Audiffren, & Ragot, 2008; Rakes & Dunn, 2010).

Conclusion

The study conducted was meant to provide insights on perceived and actual self-regulated learning, as well as address whether topic motivation has influence on self-regulation and domain knowledge test results. Significant positive relationships between motivation, perceived seeking information, and perceived organization of the task factors have been found. Indicating that motivation at least partially plays a role upon perceived self-regulation. These findings propose to look deeper into the effect of motivation on self-regulation as it has only been addressed to an extent and requires more in-depth look. Although, no other significant results regarding posed hypotheses were found this research gives food for thought and suggests continuing investigating the topic of self-reported and actual self-regulation. To sum up, self-regulation is an important part of learning and should not be taken lightly, it has been found that self-regulation is partially affected by motivation and suggested that these relationships should be continued to explore.

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Appendix A

Self-Regulation Strategy Inventory—Self-Report questionnaire (Cleary, 2006), translated and adapted to university students (Hernández-Barrios, & Camargo-Uribe, 2017).

A. Maladaptive regulatory behaviour (Factor I)

1. I ask my teacher questions when I do not understand something*
2. I avoid asking questions in class about things I don't understand
3. I give up or quit when I do not understand something
4. I try to forget about the topics that I have trouble learning
5. I am easily distracted when I am studying

B. Managing environment and behaviour (Factor II)

6. I try to study in a quiet place
7. I try to study in a place that has no distractions (e.g. noise, people talking)
8. I make sure that nobody disturbs me when I study
9. I let others to interrupt me when I'm studying*
10. I finish all my academic activities before starting other activities

C. Seeking information (Factor III)

11. I do additional bibliographic searches to help me understand topics from class
12. I am looking for complementary material to the topics seen in class
13. I investigate when I don't understand something about the tasks I have to do

D. Organization of the task (Factor IV)

14. I plan in which order I will carry out my academic activities
15. I coordinate my time according to the assigned academic activities
16. I make a schedule to help me organize my study time
17. I use some method to keep my class material in order
18. I think about how best to study before I begin studying

* *Reversed question*

Appendix B

Learning Task, text by O'Connor (2017)

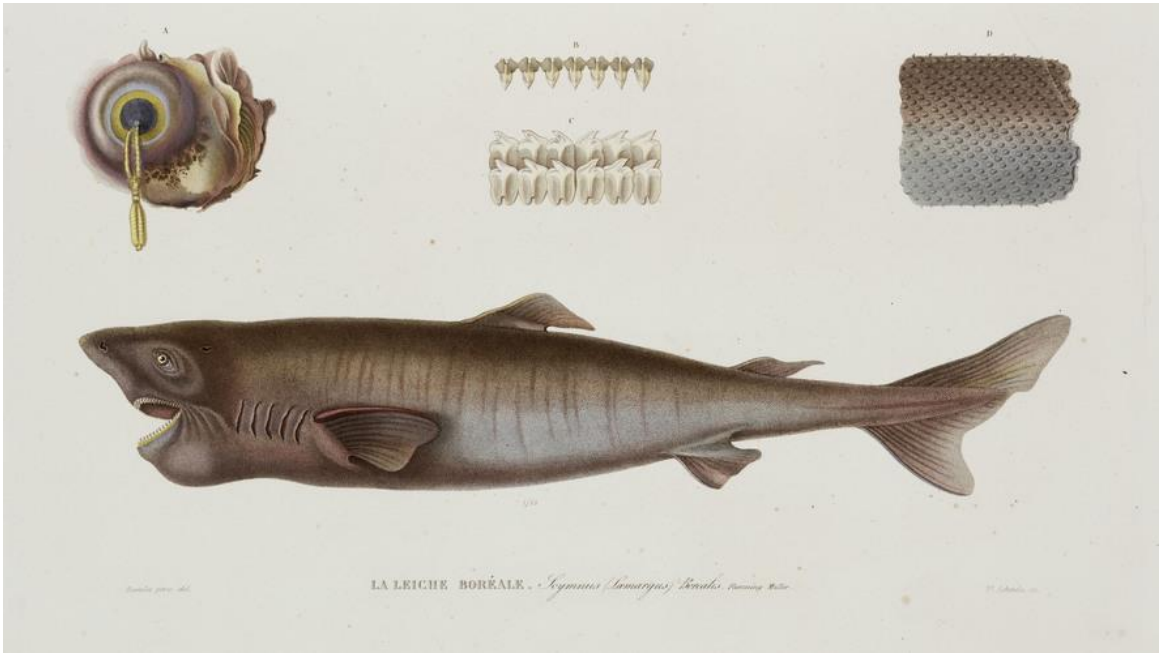
The Strange and Gruesome Story of the Greenland Shark, the Longest-Living Vertebrate on Earth

Not the prince charming you were looking for…

Greenland sharks are among nature's least elegant inventions. Lumpish, with stunted pectoral fins that they use for ponderously slow swimming in cold and dark Arctic waters, they have blunt snouts and gaping mouths that give them an unfortunate, dull-witted appearance. Many live with worm-like parasites that dangle repulsively from their corneas. They belong, appropriately enough, to the family *Squalidae*, and appear as willing to gorge on fresh halibut as on rotting polar bear carcasses. Once widely hunted for their liver oil, today they are considered bycatch. For some fishermen, a biologist recently told me, netting a Greenland shark is about as welcome as stepping in dog poop.

Questions yet to be answered

And yet the species has an undeniable magnetism. It is among the world's largest predatory sharks, growing up to eighteen feet in length, but also among its most elusive. Its life history is a black box, one that researchers have spent decades trying in vain to peer inside. Where do Greenland sharks mate? What is their global range and population structure? And, most enticing of all, how long do they live? A study begun in the nineteen-thirties suggested that the species' lifespan might well be extraordinary, based on the slow growth rate of a single shark that a scientist was lucky enough to catch twice. Verifying this, however, proved nearly impossible. To determine age in other sharks, biologists count the growth rings on their fin spines and vertebrae. But Greenland sharks have no hard tissues in their bodies; even their vertebrae are soft. The longevity question seemed unanswerable.



Picture 1. A lithograph of a Greenland shark, showing its eyes, teeth and skin (picture from an article by Davis, 2016).

Eye – the determinant of age

The mystery might have lingered were it not for the work of three Danish scientists—a physicist named Jan Heinemeier and two marine biologists, John Fleng Steffensen and Julius Nielsen. Nine years ago, Heinemeier and four of his colleagues published a paper on lens crystallines, a class of proteins found in the human eye. Like all organic molecules, crystallines contain carbon, including trace amounts of the radioactive isotope carbon-14. Unlike other proteins, which undergo constant recycling and replenishment, crystallines remain stable throughout a person's life; they are envelopes sealed at birth, their contents an artifact from the womb. And, if crystallines are the envelopes, then carbon-14 is the postmark. The isotope has always occurred naturally on Earth, formed wherever incoming cosmic rays strike the atmosphere, but some of the current supply also comes from nuclear-weapons tests. The level fluctuates from year to year, and that means that every given time period has its own carbon-14 signature. (There was a particularly huge spike, called the bomb pulse, in the nuke-happy heyday of the fifties and sixties.) Experimenting on cadavers' lenses, Heinemeier found that he could measure how much carbon-14 they contained and use it to determine the deceased's date of birth.

Another trip to Greenland

Heinemeier's paper made no mention of Greenland sharks. In 2009, Heinemeier received a request from Steffensen, who had recently travelled to Greenland and confronted the longevity puzzle. Was there a way, Steffensen asked, to use the sharks' soft vertebrae for

carbon dating? Heinemeier suggested that Steffensen should return to Greenland and bring back some lenses. But there was a problem. Though sharks do possess crystallines in their eyes, acquiring enough samples for a rigorous study was an expensive and logistically tricky proposition; at first, Steffensen managed to get just two. Hearing this at one of Steffensen's lectures, Nielsen, a young biology student, proposed a solution. He had spent the summer in Greenland, working on research vessels for the Greenland Institute of Natural Resources, and it occurred to him that the trawlers' unwanted bycatch was a biological goldmine. Over the next five years, as Nielsen completed a master's and then a doctorate at the University of Copenhagen, he and a group of research trawlers and local fishermen harvested eyes from twenty-eight Greenland sharks.

Longest living shark is expected to be nearly six centuries old!

Nielsen and his collaborators published their results in August of last year. Using Heinemeier's method, they found that the smallest of the sharks they caught—those around seven feet long—were born after the bomb pulse, while the largest animals were born well before it. With the help of a mathematical model that linked size with age, they estimated that one sixteen-foot female was at least two hundred and seventy-two years old, and possibly as much as five hundred and twelve years old. Because it is difficult to establish background carbon-14 levels in the ocean, and because Nielsen and his colleagues didn't know which part of the ocean the sharks had been born in, the figure was inexact. Still, it firmly established Greenland sharks as the longest-living vertebrates on Earth. In theory, the biggest ones could be nearly six centuries old.

Picture 2. Greenland shark (picture from an article by Weisberger, 2017)

How do they do it?

The question now is how the sharks do it. Increasingly, scientists are searching the natural world for the genetic and behavioral mechanisms that endow creatures with their special abilities—that make elephants virtually immune to cancer, say, or axolotls capable of regenerating a lost limb. There may be Greenland sharks alive today that were born before Christopher Columbus; the species is not even thought to reach sexual maturity until around a hundred and fifty years of age. Why? The answer likely has to do with a very slow metabolism and the cold waters that they inhabit. But for now, Nielsen said, it's yet another mystery. "I'm just the messenger on this," he told me. "I have no idea."

Appendix C

Test (correct answers are in bold)

Questions

1. What type of carbons help to determine the date of birth of the deceased?

a) Carbon 16
b) Carbon 14
c) Bomb pulse
d) Crystallines

2. How were most of the shark eyes acquired for the research?

a) Steffensen went to Greenland and collected the eyes himself
b) Nielsen collected the eyes during the summer in Greenland and offered to sacrifice them for the research
c) Nielsen together with local fishermen collected shark eyes for the research
d) Nielsen together with Heinemeier collected shark eyes for the upcoming 5 years

3. According to the text, which of these statements is incorrect?

a) Elephants are immune to cancer
b) The longest living shark is two hundred and seventy-two years old
c) Greenland sharks are the longest-living vertebrates on Earth
d) Crystallines can be found in a human eye

4. A study begun in the nineteen-thirties suggested that the species' lifespan might well be extraordinary. Why is that?

a) Greenland sharks are difficult to catch
b) Slow metabolism
c) Slow growth rate
d) They live in cold waters

5. Which of these qualities does not belong to a Greenland shark?

a) Blunt snout
b) It is one of the largest predatory sharks
c) Gaping mouth
d) White underside

6. Please tick that/those answer option(s) which according to the text explain why Greenland sharks have such a long lifespan.

- ☐ **Slow metabolism**
- ☐ Secluded waters that they live in
- ☐ They do not have any other natural predators
- ☐ Fast metabolism
- ☐ **They live in cold water**

7. The given passage goes in depth talking about a different approach on how to determine the age of Greenland sharks. Please explain why is it impossible to determine the age of Greenland sharks in a similar way as for other sharks?

To determine age in other sharks, biologists count the growth rings on their fin spines and vertebrae. But Greenland sharks have no hard tissues in their bodies; even their vertebrae are soft.