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Thymio II, a robot that grows wiser with children*

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Abstract— **Thymio II is a small robot developed for education. It aims at offering a wide public the possibility to understand the basics of robotics and programming. To achieve this, it aims at being appealing to a large age range and serve as a medium for several types of activities. In this study, we tested it in five different workshops of the EPFL Robotics Festival with various activities. The workshops target different age groups and the participants can control the robot via different means: built-in buttons, graphical programming and text programming. At the end of the activities, participants were asked to fill a short survey to give their impressions about the robot, their appreciation of the tasks and their motivations to take part. We could show through this feedback that Thymio II appeals to young children as much as to teenagers, to both girls and boys, and allows them to have fun and learn new things.**

Fig. 1: The Thymio II robot.

I. INTRODUCTION

Robots are often considered to be a promising tool for education [1] [2] [3]. Many initiatives to use robots in schools or to encourage young people to get interested to technology were developed [4] [5]. Their qualities that are often put forward are: they fascinate children, they attract their attention and motivation, and they enable the exploration of multiple disciplines. Thus, robots could be appropriate to teach technology- or science-related topics to young children. Technology is indeed underrepresented in schools at a young age [6] [7].

Our group's response on this problematic is the Thymio II robot (shown in Fig. 1). After discussions with teachers and evaluation of our first robot destined to children [8], we decided to to propose a low-cost, yet programmable robot for children. It seemed important to us that the robot also offers learning opportunities for children of a wide age range. This is somewhat opposed to what some experts of the toy industry advised us: in their opinion, a toy should target a very precise segment of the market, and can certainly not span over a range of 10 years. "Buyers need and want change as they move through life. Toy manufacturers use this to market toys for different ages of children, and also state the specific age segment on the packaging of the toy." [9]. We, on the other hand, see the educational robot as a tool, much like a computer. This tool can be the medium for different types of activities destined to different age groups, to both genders, or to teach different subjects. Therefore the tasks can evolve with the child and become more and more complex as she or he grows and learns.

In this paper we evaluate Thymio II in different activities, from the point of view of the users. We try to understand if Thymio II is usable and acceptable for different age groups, and both genders.

A. Existing Robots

Many robots have been developed for children. The most widely used ones are:

- The Bee-bot, which targets very young children and has a minimalistic interface [10].
- The LEGO Mindstorms, which is used in the Roberta program, the First Lego League and many schools. It allows programming with a graphical interface but it requires the child to be able to read. According to the LEGO website, it targets middle and high school [11].
- The LEGO WeDo, a simpler version of a programmable LEGO construction. This one has a much more limited set of possibilities, an targets elementary schools (children aged seven to twelve) [12].
- The Arduino platform is quite appreciated for its flexibility, in highschool or university [13]. It is a more complex platform, not adapted for very young children, unless a specific exercise is developed.

None of these platforms is as usable and interesting for young children as for teenagers. In those examples, a robot is made more accessible to children by making it simpler and limiting the number of sensors and actuators. We find this approach detrimental to learning, as in our opinion the whole concept of a sensory-motor loop and reactive behavior is a key aspect of robotics. People who want to have an interesting platform for young children often end

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up using more complex boards to develop a base that fits their needs [14]. In the next section, we describe our own platform and how we tried to make it accessible for users of all ages, while keeping a certain complexity.

B. The Thymio II Robot

Thymio II is a small (10 cm) mobile robot destined to children. The École Polytechnique Fédérale de Lausanne (EPFL) developed its concept in collaboration with designers from the École Cantonal d'Arts de Lausanne (écal) in 2010. The project took advantage of the ease-of-use of the Aseba framework [15], that had also been developed at EPFL by Dr. Stéphane Magnenat, now with Eidgenössische Technische Hochschule Zürich (ETH). Both Aseba and Thymio II continue to be improved in a joint effort between ETH, EPFL and Mobsya, the association responsible for the production and distribution of Thymio II.

The robot comes with pre-programmed behaviors for beginners, and more advanced users can program it through a Visual Programming Language (VPL) or through a more common scripting language. The pre-programmed behaviors offer an illustration of the possibilities of the Thymio II, as well as some classic robotic behaviors. For example, there is obstacle avoidance, line following, reaction to free-fall or shocks, etc. Then, the VPL allows users to program by associating cards representing events together with cards representing actions[1]. Albeit it allows more possibilities than the pre-programmed behaviors, this graphical language still has limitations compared to the complete Aseba scripting language. With the latter, users can do more advanced programming[2]. The software is open source and available for different platforms: Linux, Windows and Mac OS.

To make it interesting to program, we gave Thymio II a wide range of sensors and actuators:

- infrared proximity sensors, in the front, the back and underneath the robot
- a 3-axis accelerometer
- 5 capacitive touch buttons
- an infrared receiver for remote control
- a microphone
- a micro-SD card slot
- a temperature sensor
- two direct-current motors
- a speaker
- 39 LEDs placed all over the robot

This set of components, while limited to keep a low price, allows for many interesting experiments. The robot is currently sold for less than 100 CHF (approximately 105 USD). Thymio II's hardware is open as well, as we want to encourage users to learn and to look into how things work. Several schools in the region of EPFL have started using it and many people have also acquired one for their personal use. To date, more than 2,000 units have been produced and sold. The Robotics Festival, that we describe in the next section, has strongly contributed to its popularity in the French-speaking part of Switzerland.

[1]see `https://aseba.wikidot.com/en:thymiovpl`

[2]see `https://aseba.wikidot.com/en:asebalanguage`

C. The Robotics Festival

Thymio II has been used in workshops at the EPFL Robotics Festival since 2011 [16]. This Festival is a yearly event on a single day, that consists of demonstrations, workshops, exhibitions, contests and shows about robotics. It started in 2008 and targets a wide public: families, hobbyists, people who are not specialists of the field. The entrance is free, as are most workshops. The 2013 edition is estimated to have attracted around 17,000 visitors. Children can take part in several workshops on different topics: soldering, construction, programming, electronics and many others. They do not demand entrance fees unless the children can take their construction or robot back home. This year, we proposed five different activities around Thymio II. We took this opportunity to conduct a survey among the participants, to evaluate the robot's potential as a tool for education in different age groups.

II. SURVEY

A. Context of the activities

The data presented in this work was collected during the 2013 edition of the EPFL Robotics Festival. Five different workshops were centered on Thymio II, as summarized in TABLE I. The activities as well as the age targets were different.

1) Workshop A: Discover Thymio II while playing: This workshop was intended for the youngest visitors. It did not involve any computers and did not require any programming skills. The children used the pre-programmed behaviors of Thymio II, and the buttons as the primary input for orders.

The pedagogical objectives were to get children acquainted with the experimental approach. They had to make observations and tests around the robot, deduce some rules, and then use those rules to find solutions to some challenges.

When they entered the workshop, they first received a robot. They had to fill a table with what the robot did in the different pre-programmed behaviors through observation and experimentation, and formalized those observations as rules. After that, they solved a few challenges such as *Thymio II should move around the table without making any of the wooden pieces fall! Which mode will you choose?* At the end, they discovered possible physical extensions to Thymio II (building blocks, trailers or pencils) and had the robot draw on a sheet of paper or built a circuit for it.

2) Workshop B: Travel through space with Thymio II: Like in workshop A, no computers were involved. This activity targeted children who already knew the pre-programmed behaviors of Thymio II.

Children started by summarizing what they knew of the robot's behaviors and filled a table together. Then they formed groups of two and received challenges to solve in a limited time. The six challenges revolved around the topic of the 2013 Robotics Festival: space. The tasks were the following: *Get out of the mother ship through a tunnel*,

TABLE I: The five Festival workshops with Thymio II

Workshop name	Advised age	description	participants/available slots	Abbreviation
Discover Thymio II while playing	4 to 8	Focus on discovering how a robot reacts to different inputs, what it can perceive, and what it can do.	179/180	A
Travel through space with Thymio II	6 to 9	This workshop revolved around the topic of space, which was the theme of the 2013 Festival. It focused on solving challenges with Thymio II.	108/108	B
Graphical programming with Thymio II	8 to 11	Introduction to how a robot works (sensory-motor loop) and how to use the VPL to program Thymio.	100/100	C
Introduction to programming with Thymio II	12 to 15	Introduction to robotics and the sensory-motor loop, focus on the text-based programing language through a step-by-step tutorial.	75/80	D
Advanced programming with Thymio II	14 to 18	For more experienced user. Increasingly complex challenges to achieve a more complex beavior.	36/40	E

Travel around the craters of the Moon, *Cross a vertiginous bridge*, *Destroy the asteroids* and *Build a pulley and raise the flag*.

3) Workshop C: Graphical programming with Thymio II: At the age targeted in this activity children usually have some experience with computers and mice and know how to read, though not very fast. But they are not familiar with english terms nor comfortable with typing on a keyboard. The VPL lets them program the robot by using only the mouse by associating images.

The goal of this workshop was to teach some concepts of robotics: the sensory-motor loop, the purpose of a program and of a programming language.

This activity started whithout computer. First children could play with Thymio II and test its behaviors. Then the group discussed what the robot could perceive and how it could act. The *sensors* and *actuators* were explained and listed. It showed that with the same hardware, Thymio II could have different behaviors. The notion of *program* was established, children were shown how they could build a program/ behavior themselves by using a computer and a specific *language*. They saw the *events* and *actions* cards used in VPL, and related them with the list of sensors and actuators prepared previously. Only then they took place at a computer. After some examples of combinations of events and actions, they played in the VPL interface. Finally, they were given a few challenges to solve, such as *Program Thymio II to move while it is on the table and stop whenever you lift it*.

4) Workshop D: Introduction to programming with Thymio II: In workshop D, the objectives were quite similar to workshop C's, but the participants had to be more comfortable with typing and english vocabulary as the programming language taught was text-based.

The explanations started with the notions of *program* and *sensory-motor loop*, followed by the syntax and keywords of the Aseba programming language. Each participant was sitting at a computer and followed the examples on their own robot. After that, they followed a step-by-step tutorial with examples illustrating events, conditions, use of sensors/ actuators or variables.

5) Workshop E: Advanced programming with Thymio II: This workshop was for more advanced users who wanted to deepen their knowledge.

After a short summary of the language, participants worked on increasingly complex challenges. They had to think of a solution, plan it and program by themselves. Assistants gave hints and explanations. For example, the following challenges were given: *Make Thymio move, stop on the black lines, count the grey ones* etc.

At the end of each of those workshops, participants were asked to fill a short survey about their age, gender, motivation to the festival, appreciation of the activity and success at it. With these questions, we aim at determining whether each activity was adapted, interesting and motivating for the advised age range.

B. Demographic profile

The workshops did not all offer the same number of slots for participants, but all of them were nearly full. In general, the Robotics Festival attracts many children from six to thirteen years old. We see in Fig. 2 that people mostly followed the advice on the age for the workshops. It has to be noted though that not all participants answered the survey.

In addition, the attendants of the Robotics Festival's workshops and shows were in average 34% girls and women. For the Thymio II workshops, the proportion of girls depends on the type of activity and probably on the age of participants. The link with the age is difficult to make because of the lower number of older respondents. However, when looking at the proportion of girls by workshop in TABLE II, it is quite clear that workshop E attracted less girls than other workshops. We do not know if this is because of the topic of the workshop, the fact that it is destined to experienced people or because of the advised age.

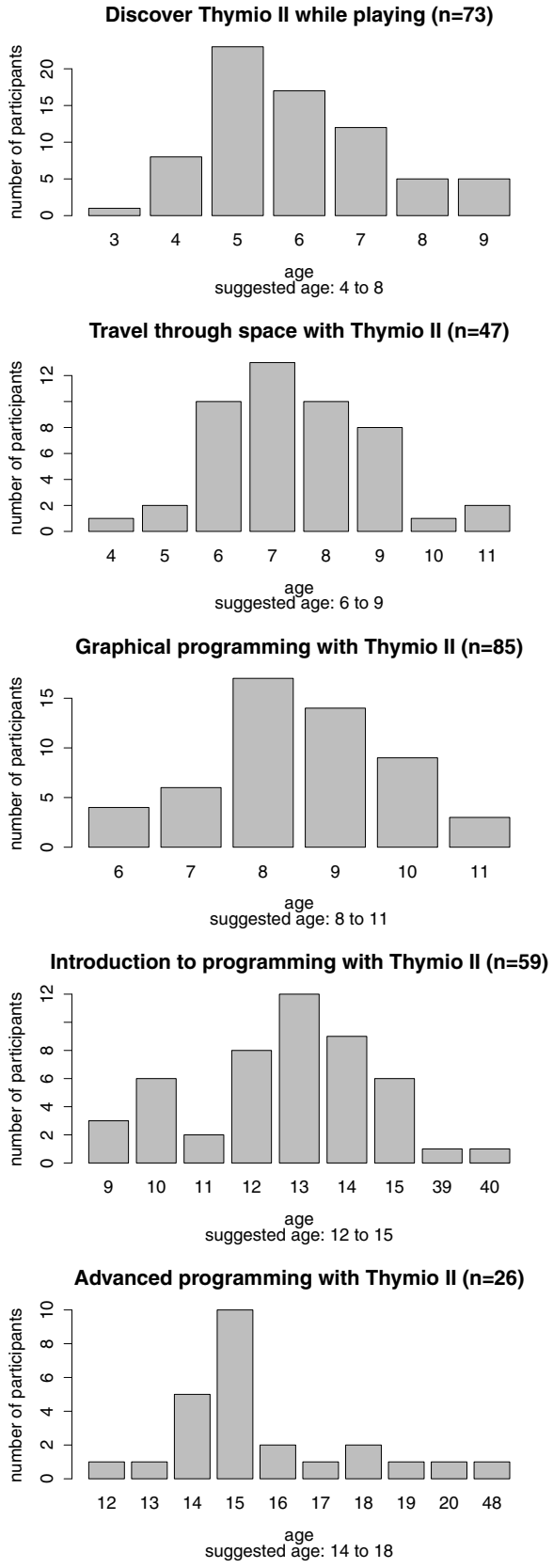

Fig. 2: Age distribution in the different workshops.

TABLE II: Number of boys and girls in the respondents

Workshop	Boys	Girls	% of girls
A	46	25	35%
B	34	14	29%
C	52	30	37%
D	44	15	25%
E	24	2	8%

This is not the first time that Thymio II workshops are proposed to visitors. In average 53% of the respondents have already attended the Festival, and 27% of them have already taken part in a Thymio II workshop. The proportion of new visitors to the festival is not linked with the age, gender or workshop type. We notice however that older attendants came to a Thymio II workshop for the first time, probably because previously there were no workshops targeted for them. We know from 2012 data that the Robotics Festival's adult visitors have mostly a higher education background (48%), and many are, themselves or through a parent or friend, related to EPFL (44%). Therefore, this survey is not representative of the general population, but probably has a positive attitude towards robots and technology.

C. Motivation to attend

To understand the goals and reasons to attend of the different age groups and genders, we asked a few questions about their motivation to come to the festival and their decision to pick a particular workshop.

To the question *Why did you come to the festival today?*, most respondents replied *to have fun discovering robots*. However, among the younger ones (3-6), *because my parents decided to come* is prominent, while the older ones give importance to *because later I want to work in a technical field*, as illustrated in Fig. 3a. We see that young children are brought by the motivation of their parents, and as they grow older they start to see an interest of the event for their future career. This effect is reflected in the workshop proportions (see Fig. 3b). This motivation is also different between girls and boys: girls show nearly no interest in working in a technical field later (see Fig. 3c). Instead, their main motivation is to have fun and discover robots, followed by the fact that their parents brought them. This effect is observed even if we remove the respondents older than 14, where there are nearly no girls.

When asked about their primary goal in coming to the festival, the respondents mention mostly *to learn new things* and *to have fun*. On this question there is no difference in the answers of boys and girls, and a correlation with the age is not clear either. However, we saw that people with different goals chose different workshops (Fig. 4). The workshop A, having the word *play* in its title, attracted indeed more children who wanted to *have fun*, while the two workshops based on text programming (D and E) attracted a majority of children who wanted to *learn*.

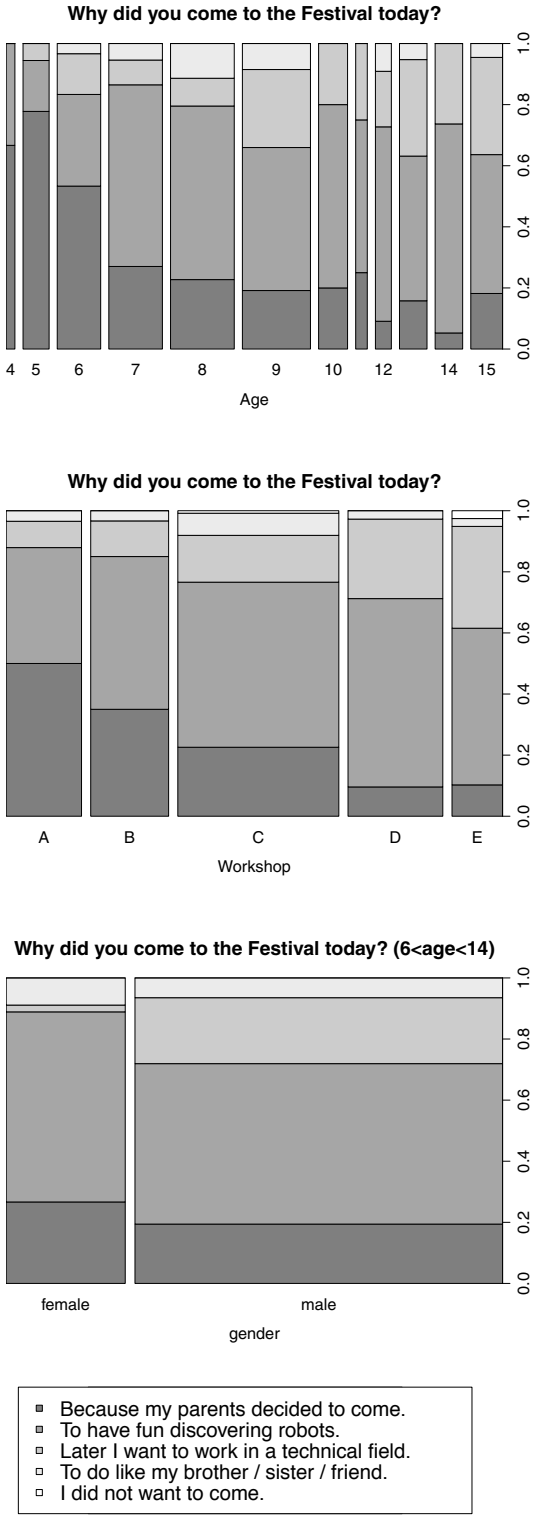

Fig. 3: The motivation to visit the Festival is influenced by age and gender.

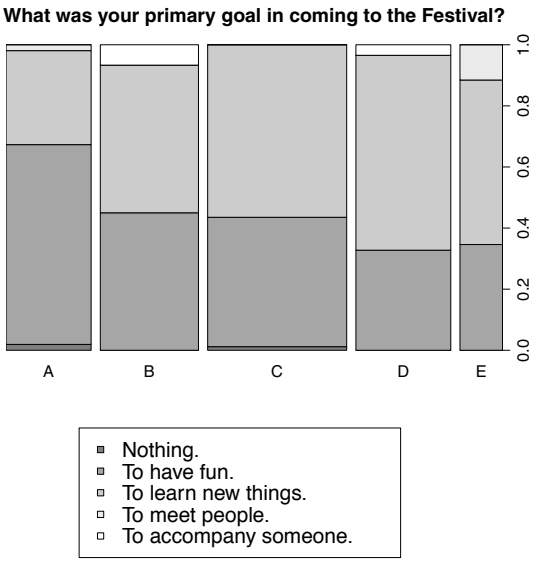

Fig. 4: Primary goal of the visitors, by workshop.

III. RESULTS

In this section, we try to understand if the activities were appreciated, and why. We move on to evaluate if the activities were adapted for the participants by looking at their confidence at solving the tasks. Finally we evaluate the controllability of the robots itself through its button interface, the VPL and the scripting language.

Throughout the workshops and after the day of the Festival, we received extremely positive feedback. When participants were asked if their primary goal had been fulfilled (*to learn new things* and *to play* as seen in Sec. II-C), 85 % replied *very much*, 14 % *a little* and less than 1 % said *not at all*. This answer does not correlate with age, gender or workshop type.

A. Appreciation

Participants were then asked what they appreciated about the activity they took part in. As the content of the workshops were different, we will treat this result by workshop. We see that in workshop A (Fig. 5), mostly the fact that they *could play* was appreciated with a little bit of *instructions and challenges were stimulating*. Workshops B and C were also appreciated quite a bit for the fact that participants could *play* but much less than A. The importance of the challenges stays at a similar level but *I learnt things that will be useful later* becomes as important as the play. The importance of learning is also there for workshops D and E, but the play loses importance while the stimulating challenges become primordial, especially for E. There is no hint that the gender impacts the appreciation.

What we see here, is that a wide range of children with different ages and motivations really appreciated the workshops based on the same robot, because the content and activities were adapted to their motivations. It confirms that our robot can be a tool for different purposes, and is attractive for a wide age range.

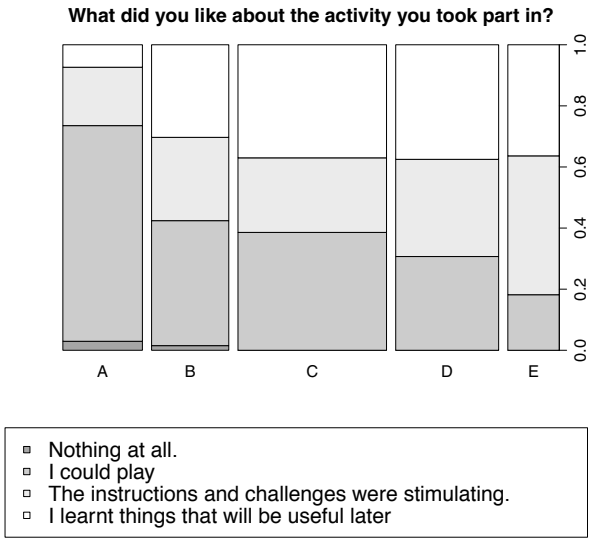

Fig. 5: Aspects the visitors appreciated.

Fig. 6: Most participants feel they succeeded very much in the tasks.

B. Confidence and success

With the following questions we investigate the feeling of aptitude and perceived complexity of the tasks by the participants. This should allow us to check whether the content of the workshops is appropriate for the advised age range.

The first question was *Did you succeed with the challenges?* In all workshops except E, there is a majority of *very much* (77%). In E the answers are mostly *a little* (see Fig. 6). Indeed, in this workshop, the scope of the challenges is wider and covers many more programming concepts. The work in that particular workshop was more independent. Interestingly, in this workshop also, *instructions and challenges were stimulating* was the most mentioned appreciated aspect. People felt that they had not yet fully succeeded with the challenges, but this actually motivated them. We note also that only three people answered that they *did not succeed at all*, and they were all three seven

Fig. 7: They activities are perceived as quite easy.

year-old children, in the workshops C and D, which were intended for older kids.

We then asked if the activity was too difficult; most respondents answered *Not at all* (70%). In that case, we see that for the workshops D and E, there is also an important proportion of *a little too difficult* (Fig. 7). The reason is probably that the text-based programming language, which offers advanced capabilities, is more complex than VPL or the pre-programmed behaviors. After only one and a half hour of use (the duration of these workshops), the users do not feel yet confident with the syntax and keywords. However, these results present an encouraging fact: with the same robot, very young children found it easy and fun to perform tasks, while teenagers appreciated that there were more challenging.

For both questions, the response of males and females are very similar.

C. Controllability

Finally, in order to evaluate the robot itself and the interaction that the children have with it, we asked them about the robot's controllability. As the contents of the workshops were different, the way children controlled the robots also changed. In workshops A and B, children gave orders to the robots through the buttons, in C they programmed through the VPL, and in D and E they used the scripting language. Thus, we asked them different questions related to the tasks performed during the workshops and to the way through which they controlled the robots. The questions were:

- *Is it easy to know which button to press, for example so that Thymio II follows a track?* for A and B
- *Is it easy to know which cards to use, for example so that Thymio II stops moving when you hit it?* for C
- *Is it easy to know which keywords to use, for example so that Thymio II stops moving at the edge of the table?* for D and E.

We see that in the case of A, B and C there are more than 50 % of *very easy* (see Fig. 8). The button interface and cards of the VPL seem easily understood. The scripting language seems to be perceived as more complex. In workshops D

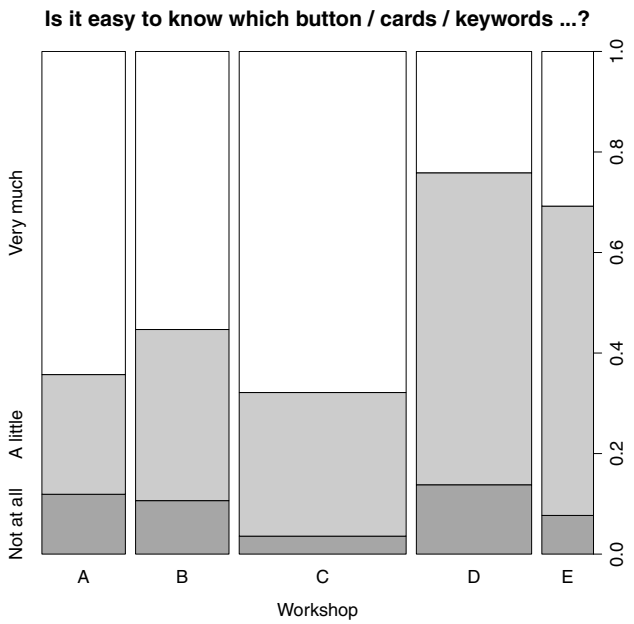

Fig. 8: The buttons and VPL are seen as quite understandable, while the script language is more challenging.

and E most participants find it moderately easy to understand which keywords to use. This result is expected as the buttons interface and the VPL were designed for children, while the Aseba language was created primarily for research. We see however that it is not dismissed as *very difficult* by teenagers; they still manage to understand the gist of it in a one and a half hour workshop.

IV. CONCLUSIONS

In this work we used the Thymio II robot in workshops with children of different age groups and for different activities. The workshops took place during the 2013 edition of the Robotics Festival, which attracts many children, but probably biased towards a positive attitude on robotics. The main motivations of the participants are *to have fun discovering robots* in general, with an important *because my parents decided to come* response from the youngest visitors and a lot of *because later I want to work in a technical field* from the older ones. Similarly the main goals are *to have fun* and *to learn new things*.

Most visitors feel their goals are attained, whether girls or boys, young or old. Participants appreciated a lot that they could *play*, especially in the workshop A. Many also felt they had *learnt things that will be useful later* and in the text-based programming workshops they liked that *the activities were challenging and motivating*

In general the activities and the robots were perceived as accessible by all age groups. The programming language is seen as a bit more complex, but in a positive way.

In conclusion, these results give us a good hint that our Thymio II robot

- appeals to a wide age range and both genders,
- can be successfully used as a medium for different types of activities,
- provides different control interfaces that were validated in the target age groups,
- gives users a feeling that they learnt something useful,
- can be at the center of activities that are simple and encouraging for younger pupils, as well as challenging for more advanced pupils.

Now that these basic requirements have been validated, we will pursue this research by addressing another side of the user studies: that of teachers. Indeed, we think that a good tool for education needs also to come within a good framework, for which it is primordial to understand the needs and constraints of the educators.

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