Studying the adaptation of robot's strategies in an educational task

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ABSTRACT

The present paper describes a set of experiments in child-robot interaction that will be conducted within the EASEL project. Our proposed experimental setup is an inquiry-learning task based on the Piagetian Balance Beam.

Keywords

Child-Robot Interaction; education; learning

1. INTRODUCTION

Children nowadays are using interactive technology such as smart phones or tablets on a regular basis. Even from the age of 4, they are able to operate smart devices without any help [10] for both entertainment and educational purposes. Introducing technology in classrooms has gained great interest as it provides access to a much wider set of learning resources and allows for individualized learning [2]. Numerous technologies have been developed and employed in an attempt to make learning environments more engaging and empower the learning experiences for all learners; the effectiveness of these new technological resources has been tested in the context of a class, where they have been shown to improve learning speed, engagement and attention without a complex process of adaptation [23].

As robots gain popularity, it is only natural to explore their potential impact in educational scenarios [14]. In deed, robots' social abilities and skills make them relevant for peer-to-peer interaction [6] as they may influence children's knowledge acquisition. For example, the role assumed by the robot (peer or tutor) has been examined in [3, 26]. The presence of a robot (compared to a screen) may account for higher learning gains [13, 11]. Similarly, dynamic adaptation and personalization of the robot's behaviour to children between 3-5 years-old suggested that children are able to learn new words and show significant increase in valence [7]. Positive impact and higher learning gain in long-term interactions seem to also be affected by the robots' social components [18] and affective responses [12]. Despite the fact that not all studies were able to show significant results in knowledge acquisition, most of them highlight increased engagement and positive attitude, making them suitable for effective tutors or peers, as they seem to promote interest and pedagogical achievement [8].

Along these guidelines, and within the context of the EU FP7 project *Expressive Agents for Symbiotic Education and Learning* (EASEL), we aim to find new solutions that would enhance learning through a system promoting adaptation to the children's needs. The EASEL project aims at exploring and developing a theoretical understanding of Human-Robot Symbiotic Interactions (HRSI), capitalized in the domain of tutoring. The main goal of EASEL is to deliver a Synthetic Tutor Assistant (STA) that guides learners through interactive science-based learning paradigms. The theoretical approach and expected impact of the project is described in [17] whereas the underlying architecture is presented in [24].

Adjusting to the skills and progress of individual students helps to maintain the process of learning acquisition. It is essential that a task remains challenging enough, as too easy or too difficult tasks may lead to loss of interest and motivation or the development of learned helplessness [1]. The latter refers to the creation of maladaptive passivity shown in people and animals who experienced a series of randomly assorted, negative events and who accepted that reinforcers

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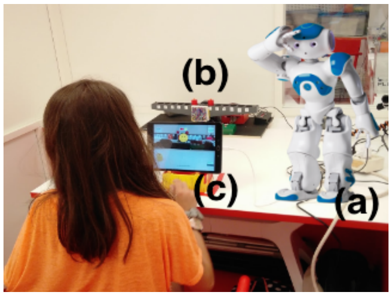

Figure 1: Example of an interaction. The robot (a) interacts with a child in the balance beam educational task. The child places various weights on the Smart Balance Beam (b) and predicts where the scale will fall using the easelscope (c). (Image has been edited to represent the new setup.)

cannot be controlled. In order to prevent such feeling of helplessness, we need to ensure that students believe that they can be effective in controlling the relevant events within the learning process [19].

Regulating the difficulty of a task is what we call *shaping the landscape of success* and it is similar to *scaffolding*, a technique based on helping the learner cross Vygotsky's *Zone of Proximal Development* (ZPD) which indicates the difference between what a learner can do with and without external help [25].

This approach can be paired with Constructivism techniques, which see the teacher as someone who does not provide the learner with the correct solutions, but through the usage of hints and directions helps the learner arrive at the conclusion himself. It defends the idea of learning through making and the use of technology-enhanced environments [15], instead of learning via direct instruction. The role of a constructivist teacher is closer to a guide than to the classical teacher [22], what enhances the importance of engagement during the class.

Here, the robot will assume a role similar to that of a constructivist teacher in a science-based educational task. We plan to adjust the parameters of the learning scenario and the robot's strategies on the basis of an online analysis of learner's cognitive and emotional state (Learner Model) and assess if such adaptive strategies facilitate learning, compared to predefined ones.

2. METHODOLOGY

We designed an interaction scenario based on an inquiry–learning task that allows students to ask questions, make discoveries and investigate solutions. Usually, discoveries are guided through the help of a *facilitator*; here, the humanoid robot Nao will be guiding the interaction. The task aims at teaching children about the multiplicative relation between weights and distance (i.e., the "torque rule"), based on the Piagetian Balance Beam [9] and the principles proposed by Siegler [20, 21]. Children will interact with the Nao, using the Smart Balance Beam (SBB) and the EASELscope, as shown in Figure 1. The interaction will take place at two schools in Barcelona (Spain), where approximately 80 eight year-old children will participate.

2.1 The Balance Beam physics task

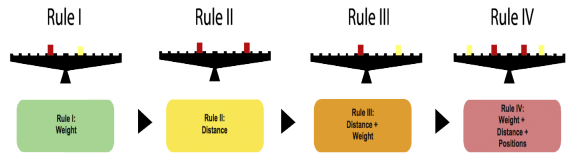

Figure 2: Schematic illustration of the four rules assessed by Siegler [20]. At each developmental stage one or both dimensions (i.e., weight and distance) are considered. For instance, Rule I exclusively considers the weight, whereas Rule IV considers both weights and distance from the fulcrum.

Children will be asked to place different weights on the two sides of the Smart Balance Beam (SBB). They are then asked to predict the behaviour of the beam: will it stay in equilibrium, tip to the left, or tip to the right followed by an estimation of their level of confidence regarding their answer (previous results on confidence be found in [4]). The role of the robot is to encourage the students, help them get through a series of puzzle tasks and provide feedback. The puzzles provided have four levels of difficulty, matching Siegler's rules (Figure 2):

- Level I: different weights are placed at the same distance from the centre of the balance.
- Level II: same weights are placed at different distances from the centre of the balance.
- Level III: different weights are placed at different distances from the centre of the balance.
- Level IV: follows the principles of Level III, however now the number of weights at each side varies.

The usage of the balance beam task in the present work constitutes a simple inquiry learning task where children's performance can be fully described in terms of the application of a hierarchy of rules of increasing complexity that can be operationally controlled.

We propose two experimental conditions in which the behavior of the robot is modulated: in the *Fixed/Reactive* condition, the robot behaves in a predefined way, employing fixed strategies of content presentation. In the *Adaptive* condition, the learner's current cognitive and emotional state define the strategies (for example level adaptation) that will be employed by the robot. The experimental protocol will consist of three sections: a pre- assessment phase, the intervention phase (the balance beam task with the Fixed or Adaptive conditions) and a post-assessment.

2.2 Data Collection

Prior to the intervention (pre-assessment phase), children will be asked to predict the outcome of a predefined configuration of the scale without providing feedback about their answer. This questionnaire will allow us to understand each child's initial level of understanding regarding the task and the weight-distance relations.

During the interaction, information about the emotional state of the child will be assessed through the Scene Analyzer

[27], a module that allows for the automatic classification of facial expressions and speech probability. Possible mistakes in reproducing a given configuration will be acquired by the smart balance beam, followed by the child's performance, confidence level and reaction times acquired by the EASELscope. Video analysis will allow us to perform an offline evaluation of the overall interaction.

After the intervention, and similar to the pre-assessment phase, children will be asked to predict the outcome of a predefined configuration of the scale. This part will allow us to evaluate any possible improvement compared to the pre-assessment questionnaire. Additionally, following the methodological approaches suggested in [5], we will evaluate the task itself and the interaction between the child and the robot using validated questionnaires, such as the Fun Toolkit [16] combined with semi-structured interviews.

3. DISCUSSION AND CONCLUSION

The focus of this study is to explore the effect of adaptation of a robot's strategies in an educational task. We propose two conditions, one in which the robot adapts its strategies and educational content to the child based on its cognitive and emotional state, versus one in which information is provided in a predefined/fixed way. We expect that children in the adaptive condition will perform better compared to the fixed one.

One of the main problems we may face is novelty effect, as the kids could focus more on the robot's movements and behaviour than the content of the task. In the future, a long-term study would allow us to overcome this issue.

4. ACKNOWLEDGMENTS

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5. REFERENCES

[1] L. Y. Abramson, M. E. Seligman, and J. D. Teasdale. Learned helplessness in humans: Critique and reformulation. *Journal of abnormal psychology*, 87(1):49, 1978.

[2] D. Atkins, J. Bennett, J. Brown, A. Chopra, C. Dede, B. Fishman, and B. Williams. Transforming american education: Learning powered by technology. *Learning*, 114, 2010.

[3] M. Blancas, V. Vouloutsi, K. Grechuta, and P. F. Verschure. Effects of the robot's role on human-robot interaction in an educational scenario. In *Conference on Biomimetic and Biohybrid Systems*, pages 391–402. Springer, 2015.

[4] M. Blancas, V. Vouloutsi, R. Zucca, and P. F. Verschure. Considering students' confidence when building a synthetic tutoring system. Paper presented at the conference New Friends, 2016.

[5] V. Charisi, D. Davison, D. Reidsma, and V. Evers. Children and robots : A preliminary review of methodological approaches in learning settings. In *2nd Workshop on Evaluating Child Robot Interaction âĂŞ HRI 2016 1(2)*, 2016.

[6] T. Fong, I. Nourbakhsh, and K. Dautenhahn. A survey of socially interactive robots. *Robotics and autonomous systems*, 42(3):143–166, 2003.

[7] G. Gordon, S. Spaulding, J. K. Westlund, J. J. Lee, L. Plummer, M. Martinez, M. Das, and C. Breazeal. Affective personalization of a social robot tutor for children's second language skills. In *Proceedings of the Thirtieth AAAI Conference on Artificial Intelligence*, pages 3951–3957. AAAI Press, 2016.

[8] J.-H. Han, M.-H. Jo, V. Jones, and J.-H. Jo. Comparative study on the educational use of home robots for children. *Journal of Information Processing Systems*, 4(4):159–168, 2008.

[9] B. Inhelder and J. Piaget. *The growth of logical thinking from childhood to adolescence: An essay on the construction of formal operational structures.* Basic Books, 1958.

[10] H. K. Kabali, M. M. Irigoyen, R. Nunez-Davis, J. G. Budacki, S. H. Mohanty, K. P. Leister, and R. L. Bonner. Exposure and use of mobile media devices by young children. *Pediatrics*, 136(6):1044–1050, 2015.

[11] J. Kennedy, P. Baxter, and T. Belpaeme. The robot who tried too hard: Social behaviour of a robot tutor can negatively affect child learning. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, pages 67–74. ACM, 2015.

[12] I. Leite, C. Martinho, A. Pereira, and A. Paiva. icat: an affective game buddy based on anticipatory mechanisms. In *Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems-Volume 3*, pages 1229–1232. International Foundation for Autonomous Agents and Multiagent Systems, 2008.

[13] D. Leyzberg, S. Spaulding, M. Toneva, and B. Scassellati. The physical presence of a robot tutor increases cognitive learning gains. 2012.

[14] O. Mubin, C. J. Stevens, S. Shahid, A. Al Mahmud, and J.-J. Dong. A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, 1:209–0015, 2013.

[15] S. Papert. *Mindstorms: Children, computers, and powerful ideas.* Basic Books, Inc., 1980.

[16] J. C. Read and S. MacFarlane. Using the fun toolkit and other survey methods to gather opinions in child computer interaction. In *Proceedings of the 2006 conference on Interaction design and children*, pages 81–88. ACM, 2006.

[17] D. Reidsma, V. Charisi, D. Davison, F. Wijnen, J. van der Meij, V. Evers, D. Cameron, S. Fernando, R. Moore, T. Prescott, et al. The easel project: Towards educational human-robot symbiotic interaction. In *Conference on Biomimetic and Biohybrid Systems*, pages 297–306. Springer, 2016.

[18] M. Saerbeck, T. Schut, C. Bartneck, and M. D. Janse. Expressive robots in education: varying the degree of social supportive behavior of a robotic tutor. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1613–1622. ACM, 2010.

[19] M. E. Seligman. Learned helplessness. *Annual review of medicine*, 23(1):407–412, 1972.

[20] R. S. Siegler. Three aspects of cognitive development. *Cognitive psychology*, 8(4):481–520, 1976.

[21] R. S. Siegler and Z. Chen. Developmental differences

in rule learning: A microgenetic analysis. *Cognitive Psychology*, 36(3):273–310, 1998.

[22] L. Steffe and J. Gale. *Constructivism in education.* 1995.

[23] K. Swan, M. v. â. Hooft, A. Kratcoski, and D. Unger. Uses and effects of mobile computing devices in k–8 classrooms. *Journal of Research on Technology in Education*, 38(1):99–112, 2005.

[24] V. Vouloutsi, M. Blancas, R. Zucca, P. Omedas, D. Reidsma, D. Davison, V. Charisi, F. Wijnen, J. van der Meij, V. Evers, et al. Towards a synthetic tutor assistant: the easel project and its architecture. In *Conference on Biomimetic and Biohybrid Systems*, pages 353–364. Springer, 2016.

[25] L. S. Vygotsky. *Mind in society: The development of higher psychological processes.* Harvard university press, 1980.

[26] C. Zaga, M. Lohse, K. P. Truong, and V. Evers. The effect of a robotâĂŹs social character on childrenâĂŹs task engagement: Peer versus tutor. In *International Conference on Social Robotics*, pages 704–713. Springer, 2015.

[27] A. Zaraki, D. Mazzei, M. Giuliani, and D. De Rossi. Designing and evaluating a social gaze-control system for a humanoid robot. *Human-Machine Systems, IEEE Transactions on*, 44(2):157–168, 2014.