Specifying and testing the design rationale of social robots for behavior change in children

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Abstract

We are developing a social robot that helps children with diabetes Type 1 to acquire self-management skills and routines. There is a diversity of Behavior Change Techniques (BCTs) and guidelines that seem to be useful for the development of such support, but it is not yet clear how to work out the techniques into concrete robot support functions and behaviors. The situated Cognitive Engineering (sCE) methodology provides guidance for the design and evaluation of such functions and behaviors, but doesn’t provide a univocal specification method of the theoretical and empirical justification. This paper presents an extension of sCE: a formal template that describes the relations between support objectives, behavior change theory, design specifications and evaluation outcomes, called situated Design Rationale (sDR) and the method to get this. As test case, the European ALIZ-e project is used to instantiate this design rationale and to evaluate the usage. This case study showed that sDR provides concrete guidance (1) to derive robot functions and behaviors from the theory and (2) to designate the corresponding effects with evaluation instruments. Furthermore, it helps to establish an effective, incremental and iterative, design and evaluation process, by relating positive and negative evaluation outcomes to robot behaviors at the task and communication level. The proposed solution for explicating the design rationale makes it possible for others to understand the decisions made and thereby supports replicating experiments or reusing parts of the design rationale.

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1. Introduction

There is a need for social robot design methods, which provide theoretically and empirically founded implementations that can be systematically reused, compared and built upon progressively (cf., Fong, Nourbakhsh, & Dautenhahn, 2003). Current design methods do not (yet) meet these needs, holdings back the coming of age of the research field.

This paper focuses on the development of robots for behavior change. Although there is a substantial amount of research in social robots and behavior change techniques, it is hard to compare the results of studies due to a lack of agreement on (1) the (definitions of) relevant theoretical concepts, (2) the design specifications, (3) the methods for validation (or evaluation), and (4) the approach to relate these concepts, specifications and methods. Literature from the social robot domain on classification of robots (e.g. Dautenhahn, Ogden, & Quick, 2002) and evaluation (e.g. Weiss, Bernhaupt, Lankes, & Tscheligi, 2009) provides valuable information for design specifications and their evaluation. However, it is unclear how they relate and can be linked to behavior change theories. On the other hand, for behavior change techniques there is a taxonomy in development (Susan Michie, Marie Johnston,
Charles Abraham, Jill Francis, & Eccles, 2013) which supports disambiguation of results, and therefore validation of effective techniques, but it does not relate these to design specifications (such as use contexts). Use contexts are taken into account in the research of Behavior Change Support Systems (BCSS), for instance in the persuasive systems design (PSD) model (Oinas-Kukkonen & Harjumaa, 2009). This model emphasizes the translation between method and design patterns for functionalities related to the context. Although method, requirement, design and implementation are related in PSD, it does not model the correlations and interrelations between different implementations.

An open question remains: “How can we conduct experiments in such a manner that it will be really possible to pinpoint a change to have been caused by a BCSS, or even more precisely, by a specific software feature in it?” (Oinas-Kukkonen, 2010). Our social robot is in essence a BCSS and the question we want to answer is quite similar:

- How can we design and evaluate in such a manner that (a) robot behaviors are derived from theory and (b) evaluation effects can be designated to specific robot behaviors?

The situated Cognitive Engineering (sCE) methodology (Neerincx, 2011) can partially answer this question. sCE has been used in different domains, amongst which to systematically design and evaluate robot systems (Kruijff et al., 2014). Although sCE supports iterative and incremental design and evaluation, it does not provide precise and concise translations and relations between the theory, functionalities of the system, hypotheses and instruments to evaluate (i.e. the concepts).

The situated Design Rationale (sDR) was developed as a refinement of the sCE methodology. This formal template supports the design of functionalities, the planning and performance of evaluations, and makes it possible to reason about the evaluation effects and decisions afterwards. To come to this formal template, we distinguish three sub-questions all in the context of the development of a social robot for supporting behavior change:

1. Which minimal set of concepts is needed to describe the what, when and why of design decisions?
2. How do these concepts relate to each other?
3. What is an adequate, concise and coherent, representation for describing the concepts and its relations for the design and evaluation process?

The research took place in the context of the development of a social robot that provides self-management support for children with diabetes (i.e., the European ALIZ-e project1). The structure of this paper is as follows: First in Section 2, we provide background on diabetes, social robotics, behavior change and situated Cognitive Engineering. Second in Section 3, we describe the sDR template, that describes the concepts and it relations, followed by the instantiation of sDR in Section 4. In Section 5 the use of the sDR is further exemplified with an experiment performed within the ALIZ-e project. And we finish with the conclusions and discussions on future work in Section 6.

2. Background

Type 1 diabetes has an enormous impact on the daily life of children with this illness as we will discuss in Section 2.1. There is a need for support of self-management and behavior change. A social robot might provide this support for this user group (age 7–12) (Section 2.2). The behavior of the robot should be based on knowledge from behavior change theories and systems (Section 2.3), and the design of the robot should be based on a state-of-the-art design methodology (Section 2.4). Based on this background we can conclude what is lacking to come to a concise and precise situated Design Rationale.

2.1. Type 1 Diabetes Mellitus

To understand why we want to develop a social robot to support children with diabetes to increase their self-management it is necessary to understand what diabetes is and what this means for the life of the children, and their environment. There are two types of diabetes, Type 1 and Type 2 (IDF, 2012). Type 1 typically presents itself at a young age, while Type 2 often occurs at a later age. Where Type 1 Diabetes Mellitus (T1DM) is a result from destruction of the insulin-producing cells in the pancreas by the autoimmune system, Type 2 is a metabolic disorder where the body does not make and absorb enough insulin. We will further focus on T1DM, because that is the type that is most prevalent in children and the incidence is rising (Patterson et al., 2009). For these children it is very important to keep their blood glucose levels as steady as possible. To reach this objective, children and their social environment (parents, teachers, siblings, friends etc.) need to have knowledge and skills to manage the disease. Examples of these are: Regularly measuring of blood glucose, counting of carbohydrates, calculating needed insulin and injecting (when pen is used) or bolusing (when pump is used) accordingly, and discounting the (interactive) effects of food intake, physical exercise, mental stress and hormones. Furthermore, a child and his or her environment need to be able to recognize symptoms of high and low blood glucose to act accordingly. Even when managed properly, a child will have periods of high imbalance due to for instance hormones or growth spurts. The effects of T1DM, even with our modern treatment, are quite severe. More than 50% of the children develop complications with regard to major organs like the heart and blood vessels 12 years after

1 http://www.aliz-e.org.
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