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Towards an Integrative Computational Foundation for Applied Behavior Analysis in Early Autism Interventions

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Abstract. Applied Behavior Analysis-based early interventions are evidence based, efficacious therapies for autism. They are, however, labor intensive and often inaccessible at the recommended levels. In this paper we present ongoing doctoral research aimed at development of the formal, computational representation for Applied Behavior Analysis (ABA) that could serve as a reasoning foundation for intelligent-agent mediated ABA therapies. Our approach is to formulate the representation of ABA dynamics and concepts as a process ontology expressed in a controlled natural language (CNL). As an ontology language, CNL is not only a machine interpretable, logically sound reasoning foundation, but also understandable and editable by human users.

Keywords: Applied behavior analysis, knowledge representation, autism, ontology, intelligent agents.

1 Introduction

Autism Spectrum Disorder (ASD) is a complex developmental disability characterized by impairments in social interaction and communication and by restricted, repetitive and stereotyped patterns of behavior [1]. It is a prevalent and challenging condition affecting 1 in 88 children [2].

While there is no known cure for ASD there are a number of interventions aimed at remediation of the symptoms of the disorder. Behavioral and developmental interventions, based on demonstrated efficacy [3, 4], have become the predominant treatments for improving social, adaptive and behavioral functions in children. This dissertation research focuses on a group of behavioral treatment interventions based on the principles of Applied Behavior Analysis (ABA) [5].

According to Foxx [3], Applied Behavior Analysis incorporates all of the factors identified by the US National Research Council as characteristic of effective interventions in educational and treatment programs for children who have autism (p. 821). With the prevalence rates of autim stated earlier and with high hourly demands for this therapy to be effective, ABA-based approaches are still largely inaccessible to most families in need [6].

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Within the field of computer science, socially assistive robotics [7], intelligent tutoring systems [8] and general use of intelligent agents have been investigated for autism therapies and early interventions. This is a nascent field and approaches are limited to research settings. Even within current inititiatives it is recognized that this interdisciplinary research area, which brings together psychologists, special education teachers, computer scientists and electrical engineers, needs an integrated approach that will be accessible to all participants in the process.

2 Hypothesis

The main hypothesis of this doctoral research is that the deterministic nature of behavioral interventions [9, p. 5] and the scripted structure of ABA-based therapies are well suited for computational formalization. As an outcome of the research, we intend to represent the structure and governing principles of ABA as a process ontology that could serve as a theoretical foundation for different modalities for implementation of intelligent-agent-mediated behavioral therapies. Furthermore, we intend to use controlled natural language as a human user friendly medium of formal knowledge representation and as an ontology language.

3 Approach

Our research approach to developing an ABA ontology is to follow the formal ontology engineering process specified by OnTO [10]. We have chosen the OnTO approach to ontology specification and validation for its comprehensive, formal and modular approach to domain analysis and ontology engineering. OnTO was also devised with customizability and collaborative development in mind, hence we selected its domain analysis and validation components as the most relevant to the research process while omitting aspects that are suitable primarily for industrial and engineering applications. In developing an integrative, multidisciplinary, usable ABA ontology, we recognize that we need to establish a theoretical formalism for ABA and to specify and describe the key elements of the process in a manner that is both machine and human readable.

3.1 β-Calculus — A Logic Formalism for ABA Dynamics

The β-calculus is a concept we are introducing. It is a formal way to express the dynamics and inference rules that govern ABA. In part the β-calculus will formalize the key concepts behind ABA: three-term contingency, prompting, fading, forward and backward chaining, and intra-trial intervals [9, p. 32-328]. Further, its inferential processes will support the dynamics of ABA: initiation of antecedants, consequences and evaluation of the progress of trials.

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3.2 Controlled Natural Language as ABA Ontology Language

We use Attempto Controlled English (ACE) [11] to describe the ABA ontology. Attempto is a controlled natural language that supports writing of ontologies in a machine processable, logically sound but human understandable natural language. Writing well-formed Attempto expressions is supported by a set of tools developed for user friendly, collaborative and interactive authoring of ACE expressions by non-programming users. The advantage of ACE is not only its understandabilty but also its ability to process ACE expressions as logic statements and to translate them into other forms of knowledge or machine representation, such as RDF, OWL and OWL 2. Our choice of ACE as the ontology language is based on studies showing that controlled natural languages are effective, broadly understandable mediums for collaborative development and use of ontologies by a non-programming audience [12].

3.3 Validation

β-calculus is a logic formalism representing ABA dynamics, so the process of its derivation follows the validation rules and proof methods consistent with an axiomatic system. The ACE-encoded ABA ontology will be developed with the assistance of subject matter experts, and it will be validated against the ABA-related competency questions [13] that were developed by practicing behavioral therapists. Finally, to demonstrate translatability of the ACE-encoded ABA ontology, we intend to develop a small proof-of-concept translator from ACE expressions into executable Behavioral Markup Language (BML) scripts for intelligent agents.

4 Contribution and Expected Outcome

We expect this research to benefit Computer Science and other associated fields, including Psychology, Special Education and Artificial Intelligence. We specifically expect that:

1. The theoretical foundation and conceptual framework resulting from this research could serve as a foundation for development of interactive, flexible, intelligent-agent-mediated ABA-based therapies for children and adolescents with disabilities or special needs. We expect this framework to be applicable to the broad category of instructional applications ranging from traditional GUI-oriented to mixed reality and socially intelligent-agent-based therapies.
2. We will demonstrate how the cognitive gap between different, interrelated but mutually dependent fields can be effectively and formally bridged by the most universally undestood form of human expression: human language.

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References

[1] American Psychiatric Association: Pervasive developmental disorders. In: Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR), 4th edn., pp. 69–70. American Psychiatric Association, Washington, DC (2000)
[2] Baio, J.: Prevalence of autism spectrum disorders: Autism and developmental disabilities monitoring network, 14 sites, United States (2008); Morbidity and mortality weekly report. Surveillance Summaries 61(3). Centers for Disease Control and Prevention (2012)
[3] Foxx, R.: Applied behavior analysis treatment of autism: The state of the art. Child and adolescent psychiatric clinics of North America 17(4), 821–834 (2008)
[4] Voos, A.C., Pelphrey, K.A., Tirrell, J., Bolling, D.Z., Wyk, B.V., Kaiser, M.D., McPartland, J.C., Volkmar, F.R., Ventola, P.: Neural mechanisms of improvements in social motivation after pivotal response treatment: Two case studies. Journal of autism and developmental disorders, 1–10 (2012)
[5] National Research Council (US). Committee on Educational Interventions for Children with Autism: Educating children with autism. National Academies Press (2001)
[6] Wise, M., Little, A., Holliman, J., Wise, P., Wang, C.: Can state early intervention programs meet the increased demand of children suspected of having autism spectrum disorders? Journal of Developmental & Behavioral Pediatrics 31(6), 469–476 (2010)
[7] Feil-Seifer, D., Mataric, M.: Defining socially assistive robotics. In: IEEE 9th International Conference on Rehabilitation Robotics, ICORR 2005, pp. 465–468 (2005)
[8] Kay, J.: Ai and education: Grand challenges. IEEE Intelligent Systems 27(5), 66–69 (2012)
[9] Cooper, J., Heron, T., Heward, W.L.: Applied Behavior Analysis. Prentice Hall (2007)
[10] Suárez-Figueroa, M., Gómez-Pérez, A., Motta, E., Gangemi, A.: Introduction: Ontology engineering in a networked world. Ontology Engineering in a Networked World, 1–6 (2012)
[11] Kuhn, T.: Controlled English for Knowledge Representation. PhD thesis, Faculty of Economics, Business Administration and Information Technology of the University of Zurich (2010)
[12] Denaux, R., Dolbear, C., Hart, G., Dimitrova, V., Cohn, A.G.: Supporting domain experts to construct conceptual ontologies: A holistic approach. Web Semantics: Science, Services and Agents on the World Wide Web 9(2), 113–127 (2011)
[13] Gruninger, M., Fox, M.: The role of competency questions in enterprise engineering. In: Proceedings of the IFIP WG5, vol. 7, pp. 212–221 (1994)

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