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Construct Validity in Child-Robot Interaction Research

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***Abstract*—The paper provides a review of existing approaches to understanding and defining validity in child-robot interaction research. Two main approaches are contrasted: construct validity in defining the phenomena, emerging in the process of interaction of the child with the robot, and system validity, defining the robot solely as a technological device. Examples are provided within a newly proposed approach, aiming at overcoming the existing theoretical debate in understanding construct validity in child-robot interaction research.**

***Keywords*—Child-robot interaction, construct, robot, validity.**

INTRODUCTION

The process of child–robot interaction is a focus of intensive research in the recent years. The motivation is twofold – on the one hand, the robotic technology is a radically new stimulus for the cognitive system of the child – it is attractive, capturing attention, novel, modifiable, "smart", "alien looking", etc. [1]. On the other hand, concerns are being raised stating that this novel technology may not be beneficiary to child's development [2]. Therefore, understanding the *construct* of the *communicative phenomenon*, underlying the interaction and defining the *validity* of child's responses to tasks performed with involvement of robots, is of paramount importance in research on pedagogical applications of robotic technology.

The paper describes our efforts to identify the pedagogically relevant *construct* of the *communicative phenomenon* underlying the child-robot interaction, which can be employed successfully in special education. Therefore, we are looking for relevant indicators of the validity of the proposed construct from the responses of the child in the investigated scenarios.

CONSTRUCT VS SYSTEM VALIDITY IN CHILD-ROBOT INTERACTION RESEARCH

A specific aim of the currently developed project CybSPEED (2017-2022) is providing a wider application of robotic technology than just improving the *problem solving* or *abstract thinking* abilities of children [3]. The research effort of the multidisciplinary team has been towards helping children better understand the complexity of the surrounding World, which is largely *socially-mediated*.

The complexity of the *human*-robot interaction case in general, and *child*-robot interaction in particular, falls out from the *dual nature* of the robot as technology. On the one hand, it is a complex technological device and is often tested within the *system validation* methodology [e.g. 4]. On the other hand, a large share of the attraction to the robots can be attributed to their *cognitive nature* [5]. Moreover, even if people focus on the *mechanical* nature of a humanoid robot, they acknowledge the robot's 'social presence' in the situation and expect manifestation of social behavior [6,7].

The *cognitive nature* of the robots – humanoid or abstract – provides the user/learner/child with a radically different and *novel* type of human-system interaction, transferring the theoretical approach to understanding it from *engineering*, in its essence, to *social-science based*, understanding of the observed interactive processes. The effect on the child's cognition cannot be described in *engineering* terms only, but have to be explained in *psychological* and *social science* terms. Therefore, a constellation of knowledge of probability theory, mathematical statistics and experimental psychology is necessary to be able to validate the main construct, defining the interaction of the child with the robot in pedagogical and special education scenarios.

A number of studies discuss the relations of different forms of validity tests in empirical and experimental research [8,9,10]. One particular study provides a classification, which is appropriate to illustrate some of our claims on *construct validity* testing in child-robot interaction. Figure 1 here presents an adaptation within the Creative Commons license of figure 2 from [11].

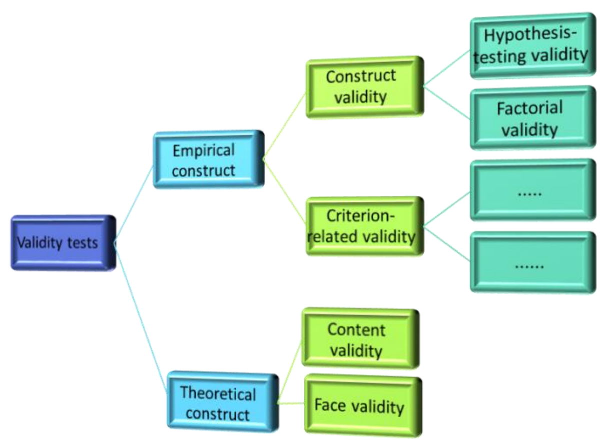

Fig. 1. Classification of validity tests in empirical research, adapted from [10] under the Creative Commons license.

DEFINITION OF CONSTRUCT

Construct is a concept, not easily formulated, especially when attempting to avoid circular definitions. For example, a definition of the dictionary of the American Psychological Association (APA) is stating the following: *construct* is "an explanatory model based on empirically verifiable and measurable events or processes—an empirical construct—or on processes inferred from data of this kind but not themselves directly observable—a hypothetical construct. Many of the models used in psychology are hypothetical constructs [12]." In the context of figure 1 here these refer to the Empirical construct and the Theoretical construct, respectively. The *construct* under study is therefore a natural phenomenon that we aim to investigate/manipulate by applying a scientific approach – a learning process, a cognitive ability, an internal state or the like. The *natural* character of the internal state of the learner should not be ignored since it requires a specific type of manipulation, which is not straightforward (as any parent can confirm). This is the reason why the strictly engineering approach to testing validity of robotic technologies in education is insufficient.

What we validate in our child-robot interaction scenarios is always the underlying cognitive 'construct' and not some objectified entity like a 'social robot', for example. This is the main difference of the proposed here approach from the commonly implemented engineering approaches, labelling the types of robots with behavioral descriptions without rigorously testing the validity of these descriptions as 'constructs' in psychological terms.

It is not easy to define the construct when we try to formulate an experimental task for research. The CybSPEED main construct, defining the learning process, which we aim to modify in special education, is being formulated as: "ability for social learning … or ability for learning in social contexts… or socially-grounded learning ability (SGLA)."

DEFINITION OF CONSTRUCT VALIDITY

"Construct validity is the degree to which an instrument measures the trait or theoretical construct that it is intended to measure… It does not have a criterion for comparison rather it utilizes a hypothetical construct for comparison... It is the most valuable and most difficult measure of validity [11, p. 197]."

Testing the validity of the construct is essential in order to link meaningfully the hypothetical assumption about the mental processing of the child and some measurable indicator as a proof of the assumption. This indicator is called an *operational definition* of the measurable process. For example, an IQ test is considered an indicator of the 'intelligence' construct. The operational definition for intelligence, as measured by the IQ test, is 'success in solving a set of abstract tasks', which is measurable and formalisable, although it is a limited descriptor of the variety of human 'intelligence' aspects.

Defining an indicator for testing the validity of a construct is also a difficult task and this is where the creativity of the experimenter is often revealed. In our case this has to be linked to the number/frequency of the child's attempts to 'do something' that we want to observe, register and analyze (quantitatively/qualitatively). In the context of figure 1, we have attempted to link the theoretical and empirical constructs by testing the Face validity aspect of the game with a toy-like robot BigFoot, designed at IR-BAS [13] and the Hypothesis-testing aspect of the validity testing of the formulated construct "socially-grounded learning ability", manipulated in a special education learning context, as presented in the next section.

CONSTRUCT VALIDITY IN CHILD-ROBOT INTERACTION WITH THE WALKING ROBOT BIGFOOT

An approach to iteratively design educational scenarios in special education is proposed and tested in [14]. An interface is designed to help the child control a toy-like walking robot called BigFoot (figure 2). The child controls the robot with the keyboard arrows in a certain direction, designated by a coloured tile. The control could be performed with a joystick, too.

Fig. 2. An interface to control the movement of a walking robot towards a coloured goal.

Content validity of the SGLA construct. In the study of [14] a child with autism (ASC), who avoided any contact with other people or children, became interested in the BigFoot robot with the help of the psychologist. This was interpreted in support of the construct "socially-grounded learning ability" (SGLA), which had improved in 3 sessions. The internal mechanism was the following: the child established interest in the game through the trusted social mediator - the psychologist.

An important distinction can be made between the definitions of *validity* and *reliability* of the empirical tests of theoretical constructs [5]. Whereas a sample of data is needed for defining the *reliability* of a test, it is not the case with *validity*. In our case the construct proved *valid* for the particular child. This is why both measures are necessary in order to prove that the construct is valid in general, but not just in individual cases.

It was also shown in [14] that children enjoy collaborative play with humanoid robots such as NAO.

In [15] we extended the game towards collaborative play with the walking robot BigFoot (figure 3). Also, the interface was extended to be used with the gaze [16] (figure 4). The Ethics Committee for Scientific Research (ECSR) of IR-BAS gave permission to conduct the study with Protocol 4/10.02.2022.

The game involves 2 children – one is setting the goal and the other is controlling the robot, then they change places. Children are encouraged to help each other and teachers/parents are encouraged to help them with the game.

Face validity of the SGLA construct. Face validity is typically employed with novel experimental paradigms, such as ours. For this, experts are being interviewed or asked to fill in questionnaires in order to prove the correctness of implementing the experiment in relation to the investigated construct.

Fig. 3. Children playing in turn to control a toy-like robot.

Fig. 4. "Heat map" of focusing the gaze on the robot.

In our case we implemented a set of Likert scales. Teachers/parents were asked to assess the extent to which the game is interesting or motivating to the child, whether it helps the cognitive development, etc. [15].

The question of interest is what the main indicator for validation of the proposed construct SGLA can be. An indicator was implemented, which was first proposed in [17] and applied to a robotic scenario in [18]. It is called “self-initiated social contact” (SISC). This is the type of contact a child would direct to the other child if they ask about their intentions, feelings, etc., not just asking about daily routines or facts.

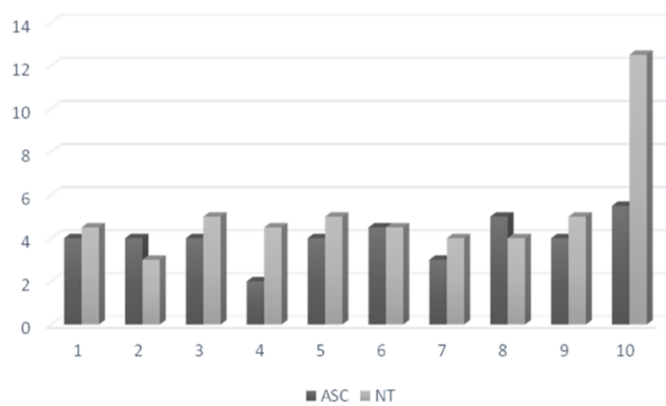

Fig. 5. Mean scores on different criteria in both groups of children. 10 – No of self-initiated social contacts; 5 – role in development of social abilities; 3 - role in development of cognitive abilities. Reproduced from [15] under the Creative Commons license.

The final question to the teachers/parents was about the number of SISC type of interactions, initiated by the individual child. The results of the comparison between 2 pairs of children – with and without symptoms of autism - are presented in [15]. Here figure 5 reproduces the chart of the results from [15] under the Creative Commons license. The clearly expressed difference in the number of SISC indicators between children of typical development (NT) and children with high-functioning autism (ASC) is evident from the figure – indicator 10 of the chart.

Another interesting observation was that children with ASC turned to the authority – parent or teacher - much more often than NT children, who preferred the company of peers. Correcting this tendency can be set as a further pedagogical goal in special education, supported by robotic devices.

CONCLUSION

The paper discusses the need to define the investigated *construct* when addressing the topic of child-robot interaction first of all, and implement a set of measures to validate it. This substantiates and confirms the plausibility of the currently designed novel educational scenarios with the walking robot BigFoot from a cyber-physical system perspective to pedagogical rehabilitation in special education.

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