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Design based on fuzzy signal detection theory for a semi-autonomous assisting robot in children autism therapy

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ABSTRACT

There are different kinds of robots that are used to assist autistic children during therapy; however, there is not a previous evaluation in place to decide if the robot can detect and send social interaction clues to the child in correct manner. Since the signal detection and fuzzy signal detection theories are well known techniques in human psychology for detecting signal and noise relationships, this work proposes those techniques as a main tool to identify how effectively stimuli are detected by social robots. Unlike traditional psychophysical approaches, which treat observers as sensors, signal detection theory recognizes that observers are both sensors and decision makers, and that these are distinct processes that can be measured using separate indices, sensitivity and response criterion. Hence, the robot can be defined as an observer using the signal detection theory. This proposal allows to evaluate social robots with human psychology tools in order to improve the human–robot interaction. Thus, the robots accomplish specific social responses that can be a better approach during the autism therapy. Furthermore, the fuzzy signal detection theory (FSDT) applied to social skills can be an enhanced procedure for designing social robots. A semi-autonomous social robot was designed to validate the proposal.

1. Introduction

Since assistive robots have been included in autism therapies, the number of technology tools has increased. However, there are few evaluations that are used to evaluate social skills in robots. Thus, Fuzzy Signal Detection Theory (FSDT) can be incorporated into the validation process for assistive robots (Robins, Dautenhahn, & Boekhorst, 2005). The Fuzzy signal detection theory could be integrated into the validation process for assistive robots as it was used in psychological human evaluations. Children with Autism Spectrum Disorder (ASD) (Riviére, 2002; Rogers, 2000), exhibit significant difficulties while interacting with their parents as well as socially (DSM 5 (Diagnostic and Statistical Manual of Mental Disorders, May 27, 2013)). They avoid eye contact, seem indifferent or even resistant to hugs or physical contact, and they seem withdrawn, isolated, and not able to adapt to their environment. This does not mean to say that children with ASD cannot feel or are not attached to their parents, caregivers, teachers, or later, their peers (Werry, Dautenhahn, Ogden, & Harwin, 2001). Children with ASD have difficulty identifying emotions (Cohen et al., March 2014), both in themselves, and in others, therefore in expressing this attachment in a way that is recognizable or interpretable. They also have difficulty interpreting what others may be thinking or feeling. They cannot interpret the social meaning of a smile (Xu & Tanaka, 2014), facial expressions or body language. When some social abilities are not developed, children exhibit confusion and anxiety in social relationships. Children with ASD are slower at learning than their typically developing peers; however, this does not mean to say that they cannot advance in acquiring the necessary skills in order to adapt to their environment. Technology, taking into consideration the needs of children with ASD, offers exciting possibilities for intervention innovation aiming towards the acquisition of social skills. The clinical use of robots to aid children with ASD seems to be promising and much of it is concentrated on eliciting a specific behaviour from the child (Giullian et al., 2010; Ricks & Colton, 2010). The hypothesis being that individuals with ASD are drawn to technology because of its predictability and so robots may be useful for eliciting target behaviours, particularly pro-social (Diehl, Schmitt, Villano, & Crowell, 2012) since the main deficit is in social interaction. Robots have been used to provide interesting visual displays and respond to a child's behaviour during an intervention aiming at eliciting joint attention or shared

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enjoyment in interaction (McConnell, October 2002), behaviours that are difficult for children with ASD. In several papers, the robot has served as the object of joint attention. However, Dautenhahn (2003), thinks that it could be used as a catalyst that could eventually aid the child in interacting with another individual (Feil-Seifer & Mataric, 2009). Hence, the designed robot in this paper serves as an interactive object with the child. Probably one of the most renowned autism-related robots is Keepon (Kozima, Michalowski, & Nakagawa, 2008) Developed by teams at NIICT in Japan and Carnegie Mellon University, Keepon is described as having a yellow, snowman-like body and is only 120 mm tall. Its eyes are colour cameras with a wide-angle lens.

Keepon has also been used to direct the joint attention to an object outside the dyad robot-child (Hideki & Marek, January 2009). Robins et al. (2005), Robins, Dautenhahn, et al. (2004), Robins, Dickerson, et al. (2004) and Ruffman, Garnham, & Rideout (2001) measured eye gaze, touch, imitation and proximity of four children to the robot. In addition, De Silva, Tadano, Saito, Lambacher, & Higashi (2009) studied five children with encouraging results as far as joint attention was concerned and demonstrated the robot's capability to track the object that the child was looking at as a defined moment. Costa (2014), Costa, Lehmann, Robins, Dautenhahn, & Soares (2013) had a robot that taught children how to play a game with a ball and then reported that the children continued playing with each other without the participation of the robot. Robins, Dautenhahn, & Dubowski (2006), Robins & Dautenhahn (2006), Robins, Dautenhahn, et al. (2004), Robins, Dickerson, et al. (2004) also found that children included a third participant in a conversation with a robot. Feil-Seifer & Mataric (2009) had two children, one with ASD and one without, play a game similar to Bubble Play from the Autism Diagnostic Observation Schedule (The Autism Diagnostic Observation Schedule (ADOS) By & Lord) and reported that the social behaviours towards the robot and the adult increased when the robot blew bubbles contingently rather than randomly. Wainer, Ferrari, Dautenhahn, & Robins (2010) used Lego robot kits with children with higher functioning ASD and found that enjoyment in class and collaboration increased, and they were able to continue interacting with each other after the class was over. As a result, therapy could be improved when technology is used (de Urturi, Zorrilla, & Zapirain, 2012). Several advances have been made in the use of robots in autism therapy (Cabibihan et al., November 2013; Scasselati, 2007), and the development of detailed requirements has the potential to help improve upon the effectiveness of using clinical robots in the treatment of children with autism (Blow, Dautenhahn, Appleby, Nehaniv, & Lee, 2006; Dautenhahn, 2003; Diehl et al., 2012). As mentioned above, a large number of robots have been created with great variations in shape, size, and style. The evaluation of their effectiveness is primarily based on the judgment and experience of expert clinicians and engineers (Giullian et al., 2010). Furthermore, it has been suggested that a robot must be robust, easily reprogrammable, affordable (Robins et al., 2006; Robins & Dautenhahn, 2006), and appealing to children with autism in order to be useful in therapy (Bandura, 1987; Benedet, 2002; Grofer-Klinger & Renner, 2000). Other requirements that have been proposed for the creation of a robot include having aspects familiar to the child, providing choices, having a modular design that can easily be customized, and being simple to use. Hence, the robot proposed in this paper is an excellent alternative because it can deal with these requirements. Signal Detection Theory (SDT) is used to analyse data coming from psychological experiments where the task is to categorize ambiguous stimuli which can be generated either by a known process (signal) or be obtained by chance (noise). For example, a radar operator must decide if what he sees on the radar screen indicates the presence of a plane (the signal) or the presence of parasites (the noise). This type of application was the original framework of SDT. Signal detection theory (SDT) assumes a division of objective truths or "states of the world" into the non-overlapping categories of signal and noise. The definition of a signal in many real settings varies with context and over time. In the terminology of fuzzy logic, a signal has a value that falls within a range between unequivocal presence and unequivocal absence. The definition of a response can also be non-binary. Accordingly, the methods of fuzzy logic can be combined with SDT, yielding fuzzy SDT. A social skill survey can be used to evaluate the social skills in the robot using fuzzy SDT. Fuzzy SDT can considerably extend the range and utility of SDT by handling the contextual and temporal variability of most signals. This paper gives an insight into the possibility of using an evaluation tool that was mainly developed for human psychology in assistive robots. Although the robot is not able to answer the survey by itself, the survey is answered by the responses provided by the robot when it is used in autism therapy for children.

2. Signal detection theory

Since signal detection theory was developed by (Green & Swets, 1966), it has been used in different areas in order to evaluate the response to different input-signal conditions. SDT is a theoretical form of detection between signal (stimulus) plus noise and noise (distractors) only in which the response is classified in binary categories (Paredes-Olay, Moreno-Fernández, Rosas, & Ramos-Álvarez, 2005). This concept is based on normal distributions in both signals as it is shown in Fig. 1 (e. g., raw score = −0.989, Z-score = −0.989,

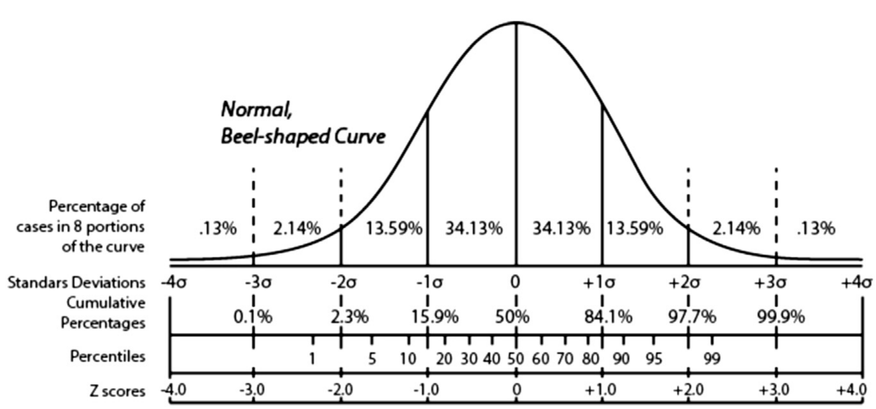

Fig. 1. Normal distribution used for noise and signal.