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DREAM

Development of Robot-enhanced Therapy for Children with Autism Spectrum Disorders

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D1.3 Child Behaviour Specification

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PP	Restricted to other programme participants (including the Commission Service)	
RE	Restricted to a group specified by the consortium (including the Commission Service)	
CO	Confidential, only for members of the consortium (including the Commission Service)	

Contents

I Executive Summary

Deliverable D1.3 is concerned with the identification of the child's behaviour during robot-enhanced therapies. It forms a part of the Reference Manual of Clinical Requirements and describes the actions of the child that that need to be analysed in order to guide the robot behaviour and monitor child behaviour during diagnosis. D1.3 is based directly on Deliverable D1.1 Intervention Definition. Section 3 of D1.1 defines the child's actions during the interventions and diagnosis tasks and describes them in perceptual terms, from the perspective of the robot. The purpose of this deliverable is to abstract these robot perceptions of the child's behaviour, and the state of the therapy environment, and characterize them as perception primitives that can be used to determine the child's behaviour in relation to the therapy environment, e.g. identifyFaceExpression(x, y, z, expression_id) or getEyeGaze(x, y, z).

Deliverable D1.3 provides the requirements for the research in work package WP4 on sensing and interpretation (Task T4.4) and work package WP5 on child behaviour analysis (Task T5.1). In particular, it provides a detailed list of the visual appearance attributes and speech attributes that need to be sensed in WP4 and the associated behaviour states that will be modelled in WP5.

II Principal Contributors

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III Revision History

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Version 1.1 (DV 25-06-2014)
Added a parameter time_interval to all three track primitives and corrected some typos.

Version 2.0 (DV 01-07-2014)
Extended the introduction and added references.

IV Child Behaviour Definition

1 The Basis for Behaviour Definition

Imitation, joint attention, and turn taking are basic social-communicative abilities, which have a fundamental role in developing social skills, play skills, and language in typically developed children. Research has shown that these basic abilities are effected in children with autism spectrum disorders (ASD) (see Van der Paelt, Warreyn, & Roeyers, 2014; Lam, & Yeung, 2012; Vanvuchelen, Roeyers, & De Weerdt, 2011). Thus, these basic social-communicative abilities are the main focus of early social-emotional interventions for children (Rogers & Dawson, 2010).

Imitation. Imitation is a basic mechanism involved in social learning, by which a person observes and reproduces another person's behavior Regarding the imitation skills of typically developing children, they already have an imitative repertoire within their first year of life. These skills, allow children to learn social skills, language skills, and how to play with their peers (Brown, Brown, & Poulson, 2008). Imitation of facial expressions has been demonstrated in newborn infants; moreover, at 10-month old typically developing infants demonstrate novel imitative responses on behaviors that were never directly reinforced (Meltzoff, & Moore, 1994). These performances occur without any type of intervention and represent an important part in the development of age-appropriate social behaviors. Children with ASD have important imitation deficits in comparison to their typically developing peers (Rogers, Hepburn, Stackhouse, & Wehner, 2003). Imitation deficits were analyzed also by Receveur et al. (2005) using family videotapes of children with ASD. The videotapes were analyzed at four age periods: 10–12 months, 16–18 months, 24–26 months, and after 4 years, and their findings show that children who were later diagnosed with ASD showed clear delays in imitation skills at the 16–18-month assessment. While typically developing children demonstrate an increase in imitative responding associated with increasing chronological age (e.g., from 1 to 6 years), children with ASD did not show increases in imitative responding as a function of their chronological age, showing low levels of imitation regardless of their chronological age (Varni, Lovaas, Kogel, & Everett, 1979). Thereby, the typical developmental trend of increased imitation skills with increased chronological age is not present in individuals with ASD. They have impairments in facial expressions imitation skills, gestures imitation, imitation of actions with or without objects, and overall imitation skills.

Joint attention. Joint attention is a basic mechanism of social learning, which involves the child shifting gaze and making eye contact with the interactional partner, by using gestures and even vocalizing (Krstovska-Guerrero, & Jones, 2013). Joint attention is considered to be a key element of social cognition and a critical precursor of theory of mind (Dominey, & Dodane, 2004). Children need social cues, like eye gaze of a social partner, in order to develop appropriate social communication and interaction (Baldwin, 2000). Regarding the development of joint attention in typically developing children, initially, gaze following is constrained by perceptual factors (e.g., the ability to disengage attention from a central stimulus), afterwards, studies have reported successful triadic gaze following in 3-6 months infants, and by 12 months of age infants are capable of following cues to attend to objects located behind them (D'Entremont, 2000; Deak, Flom, & Pick, 2000; Swanson, & Siller, 2013; Brooks, & Meltzoff, 2005), providing more evidence for children's emerging perspective taking skills (Jao, Robledo, & Deak, 2010). Individuals with ASD are known to have impairments also in responding and initiating joint attention at different ages, abilities that mainly involve using eye contact, gaze shifting, pointing or verbal utterances to draw attention to an object (Bruinsma, Koegel, & Koegel, 2004; Jones, Carr, & Feeley, 2006; Meindl, & Cannella-Malone, 2011).

Turn taking. Simply said, turn taking refers to one basic aspect of the social learning (e.g., communicational process), in which people involved in a conversation decide who should speak next. Difficulties with reciprocal social interactions (e.g., turn taking) represent one of the greatest challenges that children with ASD face in their everyday lives and this type of impairements can lead to a range of negative outcomes, including also social isolation and dysfunctional emotions (Bellini, Peters, Bennet, & Hopf, 2007). During preschool, typically developing children's' abilities to understand social interactions, to initiate and maintain conversations, to make friends, to take good decisions regarding social problems, and engage in a range of prosocial behaviors, work together for a better social adaptation and transition to a successful school experience (Bodrova, & Leong, 2006; Denham, Brown, & Domitrovich, 2010). For children with ASD to be able to achieve these performances, they need to develop the following prerequisites: proximity to interaction partner, orient their body toward their interaction partner, initiate and sustain eye contact with conversational partner, wait for turn without skipping others or interrupting turn taking progression, demonstrate listening by sustaining eye contact while other person is speaking, join in the conversation without disrupting their partener, using an appropriate response or making a comment or ask a question related to conversation (see also Radley et al., 2014).

Deliverable D1.1 Intervention Definition identifies the set of baseline robot perceptions that are invoked during the interventions and diagnosis tasks. These perceptions represent the behaviour of the child and the state of the therapy environment, as perceived by the robot. They are summarized in Table 1 below.

Table 2 defines an abstract set of perception primitives, each of which encapsulates a subset of one or more of these baseline robot perceptions. Each perception primitive has a set of parameters that, suitably chosen, allows it to achieve one or more required baseline robot perceptions.

Table 3 maps the baseline robot perceptions to the corresponding abstract parameterized perception primitives.

Section 2 provides a more detailed explanation of each perception primitive and describes the parameters in each case.

Before continuing, we need to mention an important point: all perceptions (and all actions in Deliverable D1.2) are specified in a Cartesian world frame of reference. We have chosen to adopt this approach because sensory information is provided by several sensors that are distributed in the environment, specifically around the therapy workbench but also on the robot itself. All this information has to be integrated in a common frame of reference and for convenience we choose to use a world-centred frame of reference in Cartesian coordinates. As a consequence, a number of utility functions are required to calibrate the sensors with respect to this world frame of reference and to identify the position and orientation of the robot in this frame of reference. These allow objects sensed by the robot (specified in its own frame of reference) to be related the corresponding location in the environment (specified in the world frame of reference).

Active face tracking
Child body pose recognition
Compute child's eye gaze
Compute child's head gaze
Detect mutual gaze
Detection of high amplitude sounds
Determine intersection of gaze and table
Face detection
Face localization
Face recognition
Facial expression recognition
Grip point localization
Hand detection
Hand localization
Hand tracking
Hand-object (body) alignment detection
Hand-object (body) spatial relationship
Hand-object (eye) occlusion detection
Hand-object (head) spatial relationship
Hand-object (picture) occlusion detection
Hand-object (picture) spatial relationship
Hand-object spatial relationship
Head and hand tracking
Object (destination) detection
Object (destination) localization
Object (destination) recognition
Object (picture) detection
Object (picture) localization
Object (sand-tray) detection
Object (sand-tray) localization
Object tracking
Object-table spatial relationship
Search this area for a picture
Sound localization in horizontal plane
Speech recognition
Trajectory classification
Voice recognition

Table 1: The robot perceptions listed in Section 3 of Deliverable 1.1.

checkMutualGaze()
getArmAngle(left_azimuth, elevation, right_azimuth, elevation)
getBody(body_x, y, z)
getBodyPose(<joint_i>)
getEyeGaze(eye, x, y, z)
getEyes(eyeL_x, y, z, eyeR_x, y, z)
getFaces(<x, y, z>)
getGripLocation(object_x, y, z, grip_x, y, z)
getHands(<x, y, z>)
getHead(head_x, y, z)
getHeadGaze(<plane_x, y, z>, x, y, z)
getHeadGaze(x, y, z)
getObjects(<x, y, z>)
getObjects(centre_x, y, z, radius, <x, y, z>)
getObjectTableDistance(object_x, y, z, vertical_distance)
getSoundDirection(threshold, azimuth, elevation)
identifyFace(x, y, z, face_id)
identifyFaceExpression(x, y, z, expression_id)
identifyObject(x, y, z, object_id)
identifyTrajectory(<x, y, z, t>, trajectory_descriptor)
identifyVoice(voice_descriptor)
recognizeSpeech(text)
trackFace(seed_x, y, z, time_interval, projected_x, y, z)
trackHand(seed_x, y, z, time_interval, projected_x, y, z)
trackObject(objectDescriptor, seed_x, y, z, time_interval, projected_x, y, z)

Table 2: Perception primitives

Active face tracking	trackFace(seed_x, y, z, projected_x, y, z)
Child body pose recognition	getBodyPose(<joint_i>)
Compute child's eye gaze	getEyeGaze(eye, x, y, z)
Compute child's head gaze	getHeadGaze(x, y, z)
Detect mutual gaze	checkMutualGaze()
Detection of high amplitude sounds	getSoundDirection(threshold, azimuth, elevation)
Determine intersection of gaze and table	getHeadGaze(<plane_x, y, z>, x, y, z)
Face detection	getFaces(<x, y, z>)
Face localization	getFaces(<x, y, z>)
Face recognition	identifyFace(x, y, z, face_id)
Facial expression recognition	identifyFaceExpression(x, y, z, expression_id)
Grip point localization	getGripLocation(object_x, y, z, grip_x, y, z)
Hand detection	getHands(<x, y, z>)
Hand localization	getHands(<x, y, z>)
Hand tracking	trackHand(seed_x, y, z, projected_x, y, z)
Hand-object (body) alignment detection	getArmAngle(left_azimuth, elevation, right_azimuth, elevation)
Hand-object (body) spatial relationship	getHands(<x, y, z>) getBody(body_x, y, z)
Hand-object (eye) occlusion detection	getHands(<x, y, z>) getEyes(eyeL_x, y, z, eyeR_x, y, z)
Hand-object (head) spatial relationship	getHands(<x, y, z>) getHead(head_x, y, z)
Hand-object (picture) occlusion detection	getHands(<x, y, z>) getObjects(<x, y, z>)
Hand-object (picture) spatial relationship	getHands(<x, y, z>) getObjects(<x, y, z>)
Hand-object spatial relationship	getHands(<x, y, z>) getObjects(<x, y, z>)
Head and hand tracking	trackHand(seed_x, y, z, projected_x, y, z) trackFace(seed_x, y, z, projected_x, y, z)
Object (destination) detection	getObjects(<x, y, z>)
Object (destination) localization	getObjects(<x, y, z>)
Object (destination) recognition	identifyObject(x, y, z, object_id)
Object (picture) detection	getObjects(<x, y, z>)
Object (picture) localization	getObjects(<x, y, z>)
Object (sand-tray) detection	getObjects(<x, y, z>)
Object (sand-tray) localization	getObjects(<x, y, z>)
Object tracking	trackObject(objectDescriptor, seed_x, y, z, projected_x, y, z)
Object-table spatial relationship	getObjectTableDistance(object_x, y, z, vertical_distance)
Search this area for a picture	getObjects(centre_x, y, z, radius, <x, y, z>)
Sound localization in horizontal plane	getSoundDirection(threshold, azimuth, elevation)
Speech recognition	recognizeSpeech(text)
Trajectory classification	identifyTrajectory(<x, y, z, t>, trajectory_descriptor)
Voice recognition	identifyVoice(voice_descriptor)

Table 3: Correspondence between robot perceptions and perception primitives.

2 Perception Primitive Descriptions

In the following, the functionality of each perception primitive is defined. To make it easier to understand, parameters that pass values *to* the primitive are written in green whereas parameters that *return* values are written in red.

2.1 checkMutualGaze()

The checkMutualGaze() primitive returns a value of true or false depending on whether the child and the robot are looking at each other. Note, when detecting mutual gaze, the robot only has to determine whether or not the child looks at the robot's head, but not necessarily at the robot's eyes. The gaze has to be held for a minimum period, e.g. 3 seconds.

2.2 getArmAngle(left_azimuth, left_elevation, right_azimuth, right_elevation)

The getArmAngle() primitive returns the azimuth and elevation angles of the child's upper left and right arms, defined with respect to the robot's torso, i.e. in a child-centred frame of reference.

2.3 getBody(body_x, body_y, body_z)

The getBody() primitive returns the location of the centre of the child's body.

2.4 getBodyPose(<joint_i>)

The getBodyPose() primitive returns a vector (denoted by < >) of joint angles describing the child's current body pose. The joint angles correspond to a canonical representation of a body skeleton, yet to be defined.

2.5 getEyeGaze(eye, x, y, z)

The getEyeGaze() primitive returns the location in the world at which the child's eye gaze is directed. The gaze direction is given by the line connecting the child's eye and that location. Any point on that line could be the object of the child's attention. The eye to be used is passed in the eye parameter (left or right).

2.6 getEyes(eyeL_x, eyeL_y, eyeL_z, eyeR_x, eyeR_y, eyeR_z)

The getEyes() primitive the locations of the child's left and right eyes, specified in Cartesian coordinates in a world frame of reference.

2.7 getFaces(<x, y, z>)

The getFaces() primitive returns a vector (denoted by < >) of locations where faces are visible in the therapy environment (viewed from any of the therapy cameras). Each location is specified by a triple of Cartesian coordinates x, y, and z.

2.8 getGripLocation(object_x, object_y, object_z, grip_x, grip_y, grip_z)

The getGripLocation() primitive returns the location of a grip point of a play object in the therapy environment. The location of the object is passed to the primitive.

2.9 getHands(<x, y, z>)

The getHands() primitive returns a vector (denoted by < >) of locations where hands are visible in the therapy environment (viewed from any of the therapy cameras). Each location is specified by a triple of Cartesian coordinates x, y, and z.

2.10 getHead(head_x, head_y, head_z)

The getHead() primitive returns the locations of the child's head, specified in Cartesian coordinates in a world frame of reference.

2.11 getHeadGaze(x, y, z)

The getHeadGaze() primitive returns the location in the world at which the child's head is directed. The head direction is given by the line connecting the mid-point between the child's eyes and that location. Any point on that line could be the object of the child's attention.

2.12 getHeadGaze(<plane_x, plane_y, plane_z>, x, y, z)

This alternative version of the getHeadGaze() primitive returns the location on a flat surface (i.e. a plane defined by a vector of Cartesian coordinates) at which the child's head is directed. Typically, this plane corresponds to the table on which play objects are placed.

2.13 getObjects(<x, y, z>)

The getObjects() primitive returns a vector (denoted by < >) of locations where play objects are visible in the therapy environment (viewed from any of the therapy cameras). Each location is specified by a triple of Cartesian coordinates x, y, and z.

2.14 getObjects(centre_x, centre_y, centre_z, radius, <x, y, z>)

This alternative form of getObjects() primitive returns a vector (denoted by < >) of locations where play objects are visible in the therapy environment (viewed from any of the therapy cameras). Each location is specified by a triple of Cartesian coordinates x, y, and z. In this case, the search for the objects is restricted to a circular region given by the centre coordinates and radius parameters.

2.15 getObjectTableDistance(object_x, object_y, object_z, vertical_distance)

The getObjectTableDistance() primitive returns the vertical distance of an object given by the Cartesian coordinates to the table on which play objects are places.

2.16 getSoundDirection(threshold, azimuth, elevation)

The getSoundDirection() primitive returns the horizontal (azimuth) and vertical (elevation) angles defining the direction to the loudest sound in the environment (e.g. when someone is speaking). The angles are defined with respect to the robot's local frame of reference centred in its torso.

2.17 identifyFace(x, y, z, face_id)

The identifyFace() primitive classifies the face at the specified location. The possible classes are determined during the set up phase. Typically, they will include the therapist and the children involved in the therapy sessions. The class identifier is returned in the face_id parameter.

2.18 identifyFaceExpression(x, y, z, expression_id)

The identifyFaceExpression() primitive classifies the expression of the face at the specified location. The possible classes are determined during the set up phase. Typically, they will be happy, sad, angry, or fearful (i.e. the four classes of emotion used in the interventions defined in Deliverable D1.1). The emotion identifier is returned in the expression_id parameter.

2.19 identifyObject(x, y, z, object_id)

The identifyObject() primitive classifies the object at the specified location. The possible classes are determined during the set up phase. Typically, they will correspond to a designated set of play objects, pictures to be placed on the table, or pictures on the sand-tray. The object identifier is returned in the object_id parameter.

2.20 identifyTrajectory(<x, y, z, t>, trajectory_descriptor)

The identifyTrajectory() primitive classifies the trajectory defined by a vector of 4-tuples, each 4-tuple defining a 3-D location and a time-stamp. The possible classes are determined during the set up phase. Typically, they will correspond to a designated set of hand gestures to be made by the child (e.g. a wave). The trajectory identifier is returned in the trajectory_descriptor parameter.

2.21 identifyVoice(voice_descriptor)

The identifyVoice() primitive classifies the voice that is currently speaking. The possible classes are determined during the set up phase. Typically, they will include the therapist and the children involved in the therapy sessions. The voice identifier is returned in the voice_descriptor parameter.

2.22 recognizeSpeech(text)

The recognizeSpeech() primitive returns a textual representation of anything currently being spoken by the therapist or the child.

2.23 trackFace(seed_x, seed_y, seed_z, time_interval, projected_x, projected_y, projected_z)

The trackFace() primitive tracks the face that is currently located at the position given by the Cartesian seed coordinates and returns the projected location in the next time interval. The duration of the time interval is specified in milliseconds. By reassigning the projected location to the seed and repeatedly invoking trackFace() the locations of the face can be tracked and recorded.

2.24 trackHand(seed_x, seed_y, seed_z, time_interval, projected_x, projected_y, projected_z)

The trackHand() primitive tracks the hand that is currently located at the position given by the Cartesian seed coordinates and returns the projected location in the next time interval. The duration of the time interval is specified in milliseconds. By reassigning the projected location to the seed and repeatedly invoking trackHand() the locations of the hand can be tracked and recorded.

2.25 trackObject(objectDescriptor, seed_x, seed_y, seed_z, time_interval, projected_x, projected_y, projected_z)

The trackObject() primitive tracks the object given by the object descriptor and currently located at the position given by the Cartesian seed coordinates and returns the projected location in the next time interval. The duration of the time interval is specified in milliseconds. By reassigning the projected location to the seed and repeatedly invoking trackObject() the locations of the object can be tracked and recorded.

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