2017 International Conference on Rehabilitation Robotics (ICORR)
QEII Centre, London, UK, July 17-20, 2017.

Modelling Engagement in Dementia through Behaviour. Contribution for Socially Interactive Robotics.*

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Abstract— **In this paper, we present a novel tool to measure engagement in people with dementia playing board games and interacting with a social robot, Pleo. We carried out two studies to reach a comprehensive inventory of behaviours accounting for engagement in dementia. The first one is an exploratory study aimed at modelling engagement in cognitive board games. The second one is a longitudinal study to investigate how people with dementia express engagement in cognitive games and in interactions with social robots. We adopted a technique coming from Ethology to mould behaviour, the ethogram. Ethogram is founded on low level behaviours, and allows hierarchical structuring. Herein, we present preliminary results consisting in the description of two ethograms and in their structuring obtained through thematic analysis. Such results show that an underlying structure of engagement exists across activities, and that different activities trigger different behavioural displays of engagement that adhere to such a structure.**

I. Introduction

Dementia is a neurodegenerative disorder that causes people to progressively lose their reasoning and planning abilities, producing cognitive (*e.g.* loss of memory, language, attention), and functional impairment (*e.g.* inability to dress, and care for themselves), but also affecting orientation in time and space, mood, and behaviour.

To date there is no effective cure for dementia, so the only strategy at our disposal is to enhance quality of life, involving people with dementia in meaningful and rewarding activities. To disclose whether an activity is meaningful for the person with dementia, the concept of engagement is crucial. Cohen-Mansfield et al. [1] define engagement in dementia as 'the act of being occupied or involved with an external stimulus'. In contrast, Nakamura & Csikszentmihalyi [2] define engagement as 'the experience of being positively immersed in engaging activities'. In the attempt to promote a definition of engagement for people with dementia that subsumes also its positive affective qualities, we define engagement as the psychological state of wellbeing, enjoyment and active involvement that is triggered by meaningful activities and causes people to be enraptured by the activity (thus more resistant to distraction), more energetic (thus prone to work more to achieve their objectives and less inclined to feel the effort), and in a more positive mood.

Most measurements of engagement rely on self-reports [3][4]. Howbeit, the technique is not usable with people with dementia, since retrieval and reporting of significant information is not straightforward for people with such a disease. In this context, assessment tools that measure the behavioural expression of engagement are more suited. They are either observational rating scales used to score the presence or intensity of certain target behaviours [1][5][6], or coding schemes aimed at quantifying the occurrence or duration of target behaviours via video annotation [7][8]. At present, these tools have several flaws. The former flatten the behavioural expression of engagement in an overall score, without taking into account its qualities. The latter are either scarcely interoperable, or they are composed by behaviours greatly differing in their granularity.

Modelling behaviour has a big potential for socially interactive robotics (SIR). Indeed, if we are able to unravel the complexity of engagement-related behaviours in dementia and return a hierarchy of behavioural items given a certain meaning in the economy of the engagement state, we can enable social robots to detect online the engagement state of the person with dementia and adjust the interaction accordingly. What is more, we could make social robots act similarly to a person with dementia, for instance embodying features of fallibility and vulnerability taken from the study of natural behaviour. This way social robot would become not only more human-friendly, but, specifically, more elderly-friendly. In this ambit, similar work has been done for autism by [9].

To get to a systematic modelling of engagement-related behaviours, we have developed two ethograms, which are catalogues of behaviours exhibited during activities. Ethogram-based analysis of behaviour has been previously adopted in the context of SIR by [10]. Subsequently, we have organised the behaviours in the ethograms in themes and sub-themes using thematic analysis. This was in order to identify an underlying structure of engagement-related behaviours. Our hypothesis was that, given the same activity context, the structure of engagement-related behaviours would not change between different activities.

Herein, we present two ethograms of engagement that stemmed from two studies: a formative exploratory study,

* Erasmus Mundus Joint Doctorate (EMJD) in Interactive and Cognitive Environments (ICE), funded by Erasmus Mundus under the FPA no. 2010-2012.

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and a summative longitudinal study. In addition, we describe how we obtained the structuring of the two ethograms via thematic analysis, and how this structuring could be used to compare engagement across different playful activities preserving the individuality of each context. The formative exploratory study was aimed at eliciting engagement playing cognitive board games (*i.e.* jigsaw puzzle, shape puzzle, domino, categorization game) and at developing an ethogram of engagement for cognitive games, the summative longitudinal study was targeted at producing an ethogram of engagement with social robots and at figuring out whether the structure of engagement in cognitive games *(i.e.* jigsaw puzzle, shape puzzle, and domino) differed from that of engagement with a social robot (the baby dinosaur robot Pleo).

II. RELATED WORK

Related work focuses primarily on studies made to assess engagement using measurement techniques based on observation of behaviour. We identified two main trends in the literature on dementia: observational rating scales, and coding scheme-based video analysis.

Observational rating scales are questionnaires filled out by a third person, usually an external observer, after a careful observation of certain target behaviours displayed by the participant. For instance, the Observational Measurement of Engagement (OME) [1] rates engagement across four dimensions: *duration of interaction* (in seconds), *attention towards the stimulus* (*e.g.* manipulating or holding the stimulus, 4-point Likert scale), *attitude towards the stimulus* (*e.g.* smiling/frowning; 7-point Likert scale), and *refusal* of the stimulus. The Observed Emotion Rating Scale (OERS) [5] rates the duration or intensity of five affective states (5-point Likert Scale): *pleasure* (*e.g.* laughing, smiling, kissing), *anger* (*e.g.* yelling, cursing, berating), *anxiety/fear* (*e.g.* shrieking, repetitive calling out), *sadness* (*e.g.* crying, frowning), and *alertness* (*e.g.* participating in a task, maintaining eye contact). The Menorah Park Engagement Scale [6] rates four types of engagement: *non-engagement* (*e.g.* blank stare), *self-engagement* (*e.g.* fiddling with clothes), *passive engagement* (*e.g.* listening), and *constructive engagement* (*e.g.* actively handling objects). These scales are all operationalised via behaviours, and the extent, intensity, or presence of each item is rated via a Likert scale. In the process of rating, we lose details about the type of behaviours used to express engagement. To outweigh the opacity of observational rating scales, coding scheme-based video-analysis is frequently adopted.

Video-analysis is the systematic quantification of a series of target behaviours, enlisted and operationalised in a coding scheme, which is obtained through the iterative visualisation and annotation of video footage. Jones et al. [7] designed the *Video Coding Protocol - Incorporating Observed Emotion* (VC-IOE) to gauge engagement in interactions between people with dementia and mobile telepresence (Giraff) and companion robots (PARO). The VC-IOE focuses on six dimensions of engagement: *emotional engagement* (facial emotional expressions of pleasure, anger, anxiety/fear, sadness, and neutrality), *verbal engagement* (conversation, either directed to the robot, or directed to others, but having the robot as subject), *visual engagement* (duration of visual alertness; e.g. eye contact), *behavioural engagement* (physical interaction with the robot; positive: petting, nuzzling, negative: hitting, shaking), *collective engagement* (use of the robot as a communication channel to interact and talk with others), and *signs of agitation* (presence and duration of agitated behaviours; e.g. restlessness). Cruz et al. (2013) [8] analysed the frequency and duration of engagement-related behaviours in the context of a multi-sensory and motor-based activity program. They used a coding scheme including the categories *engagement in the task* (movements of body or body part aimed at performing the task under observation), *interaction with objects* (movements of body or body part directed to reach an object), *verbal communication* (words or sentences with meaning aimed at communicating with another person), *smiling, laughing*, *nodding the head*, and *closed eyes*. In the VC-IOE, it is not clear how the quantification of behaviours is obtained in practice. In Cruz et al., the granularity of behavioural categories greatly differs, with some categories, such as *engagement in the task,* being rather wide, and others, like *smiling* and *laughing*, being extremely narrow. In general, however, the problem of coding schemes is that they are disposable assessment tools usable just for the context of activity they have been developed for.

In the following section, we present two studies that have been carried out to mould two ethograms of engagement in different playful activities: board cognitive games (*e.g.* jigsaw puzzles, shape puzzles, domino and categorisation game), and a free play with a social robot, the baby dinosaur Pleo.

III. EXPLORATORY STUDY

A. Aim

The exploratory study was undertaken to pursue two objectives: 1) collecting a first batch of videos to develop an ethogram of engagement in cognitive games; 2) determining a first approximation to a structure of engagement by grouping the behaviours of the ethogram in classes.

B. Participants

Participants with a score of 4 (mild) or 5 (moderate) at the Reisberg Global Deterioration Scale [11] and a score ranging from 10 to 23 at MEC (*Mini-Examen Cognoscitivo*, the Spanish version of MMSE, [12]) were included in the study. As a result, eight subjects (6 female and 2 male), aged between 69 and 92 years (mean age: 81 years), participated in the study. We considered exclusion criteria an accompanying bipolar or schizophrenic disorder, abnormality of the movement of face or hands, bedridden condition, and strong visual impairment.

The decision to include exclusively people with mild and moderate dementia in the study stemmed from the need to create a rich inventory of behaviours strictly connected with the engagement in the activity. In severe dementia, some behaviours could appear during sessions (*e.g.* sleeping) that are due to the progression of the disease, and not just to the engagement state of the person with dementia. Once a comprehensive inventory of behaviours is created for people with mild and moderate dementia, it could be scaled down to become apt to score engagement in severe dementia, but the opposite is not possible.

C. Activities

The study followed a repeated measurement design. Participants were randomly coupled, and took part in three sessions of cognitive games carried out in three consecutive weeks. During each session they were presented with three cognitive games (puzzles, a domino, and a categorisation game) in randomised order. Participants were coupled to try to replicate the normal course of activities in nursing homes, and study the role of social interaction in improving or being detrimental to engagement [13].

The activities carried out in each session were: 1) *Puzzles*. 1a) *Jigsaw puzzles:* participants were asked to collaboratively assembly a set of pieces in a complete picture, 1b) *shape puzzles*: participants were requested to wedge a set of shapes, usually in wood, in a board with a series of slots; 2) *Domino*. participants were requested to down a numbered tile from a set of seven that matched the tile on the table; 3) *Categorisation*. Participants were asked to couple two related pictures positioned in shuffled order in two parallel rows.

Each session lasted approximately 35-40 minutes and was considered over when all the cognitive games were completed. Traditional cognitive games were chosen as playful activities, since they could give good insights to mould the behaviour of social robots acting as gaming platforms, or assistants. Indeed, social robots such as iCat are always more used as collaborators during games involving cognitive exertion [14].

D. Measures

Videos. Videos from all 9 sessions were collected (around 6 hours of videos footage). For this purpose, a specific written consent was obtained from the families of the participants, and an oral video-recorded consent was obtained from participants.

E. Results

To develop an ethogram of engagement in cognitive games, we divided videos into short segments according to identifiable micro-behaviors. Each of these segments has been watched, and the identified behaviours were thoroughly described (operationalised). The notation of behaviours has been kept to a very fine granularity. In doing this, we were inspired by Dautenhahan and Werry [15], who discussed the importance of *micro-behaviours*, which are low-level well identifiable 'action-movement'-oriented behaviours, susceptible to be automatically recognised by computational vision systems. Since most participants of our study were on a wheelchair, and, in general, most elders in nursing homes are not able to properly ambulate, we focused on behaviours involving the upper body (head, torso, and arms/hands).

Once obtained the repertoire of behaviours, we pooled them using thematic analysis [16], a qualitative method used in psychology to identify, analyse, and report patterns within data. Thematic analysis was developed by sorting behaviours into potential themes, refining themes based on criteria of internal homogeneity and external heterogeneity, and dividing them in sub-themes when necessary.

We identified three main themes (or dimensions) of engagement: *attention*, *rapport*, and *affect* (Figure 2). *Attention* refers to behaviours expressing attentional allocation, interest, and participation in the activity, and can be divided into *passive attention*, and *active participation*. *Passive attention* refers to attentional allocation that does not involve a proactive participation in the activity ('I look at the activity'). *Active participation* refers to the active allocation of energies to the activity, involving, for instance, the manipulation of games ('I participate in the activity'). *Affect* refers to behaviours revealing the affective state of the person with respect to the activity ensemble (*i.e.* activity, partner, facilitator), and can be divided in *positive*, or *negative*. *Rapport* refers to behaviours accounting for the social interaction towards the partner, and the facilitator in the activity. Once behaviours were clustered this way, we further classified them in sub-themes according to the behavioural modality they belonged to. We identified three modalities participants used to express attention and rapport: *posture*, *gaze*, and *hands*, and two modalities they used to express affect: *face*, and *hands*. In a number of cases, behaviours already divided in themes, and subsequently in sub-themes, were additionally subdivided according to their function. For instance, in the category 'attention', hands behaviour was further divided into *manipulative* and *goal-directed*. The former refers to hand gestures related with the game, but not directly in relation with its aim (*e.g.* point, move, take, touch the game), the latter refers to gestures performed to pursue the goal of the activity (*e.g.* succeed, discard). Similarly, in 'rapport', hand behaviours are divided in *interpersonal* and *manipulative*. The former refers to touch that is explicitly and exclusively social (*e.g.* touch the partner), the latter refers to hand behaviour that is functional to the game, but has an associated social value (*e.g.* move the game towards the partner). In 'affect', face behaviours are divided into *facial expressions*, and *vocal behaviour*. The former refers to movements of the muscles of the face carried out to express emotions. The latter refers to affective vocal behaviour recognisable from features like prosody, and pitch. As a last distinction, in 'affect' hand behaviours were split into *non-directional* and *object-directed*. The former regards hand behaviour accounting for positive affect per se (*e.g.* applause), the second refers to hand behaviour expressing affect indirectly via manipulation of the game (*e.g. intensifier*; *intensifiers* are those behaviour that emphasise a just completed action, for instance tapping strongly with the fist on top of the just combined pieces of the puzzle).

IV. LONGITUDINAL STUDY

A. Aim

The longitudinal study was carried out with the following objectives: 1) collecting a rich database of videos, 2) creating an ethogram of a playful activity (interaction with a social robot) with differing characteristics from those of cognitive board games, and 3) figuring out if the same structure of engagement found in cognitive games was present in interactions with a social robot.

B. Participants

Participants were selected among the residents of two nursing homes. Selection was performed together with the psychologists of the two nursing homes. We chose 14 participants (12 women and 2 men) aged between 69 and 92 years (average age: 84 years) with mild to moderate dementia (as assessed through the Reisberg Global Deterioration Scale

[11], scores 4 and 5, and MEC [12], scores ranging from 10 to 23). Diagnosed bipolar or schizophrenic disorder, abnormality in the movement of face or hands (*e.g.* Parkinson's disease), strong hallucinatory or delusional states, and bedridden condition were considered exclusion criteria.

C. Activities

The study followed a repeated measurement design with two experimental conditions (figure 1): a game-based cognitive stimulation, and a robot-based free play (Pleo). Each condition was presented three times and the order of presentation was alternated. Cognitive games and robot play were presented every other week starting from cognitive games. The order of cognitive games was randomised using a Latin squares technique. Participants were coupled randomly and took part in the activities in pairs.

Figure 1. Participants involved in cognitive games and robot play

Overview of activities: 1) *Game-based cognitive stimulation*: jigsaw puzzles, shape puzzles, and domino (as described for the exploratory study); 2) *Robot-based free play*: a free interaction with the robot, Pleo.

Pleo is an animatronic pet robot commercialised by UGOBE, which has the appearance of a dinosaur. It is equipped with an array of sensors: touch sensors, microphones, ground foot sensors, force-feedback sensors, orientation tilt sensors, infrared mouth sensors, a camera-based vision system, and a beat detection system. Pleo is not only able to display a wide range of behaviours (*e.g.* sing, dance, walk, howl), but also to express its internal drives (*e.g.* hunger or sleep), and moods (*e.g.* happy, scared, curious). We selected this robot since it embodies the traits that Wu et al. [17] described as the most cherished by old people: it is small, it has a creative design, and it has a zoomorphic aspect (thus it is more socially acceptable). Moreover, Pleo, being designed for children, provides a very fast interaction, and this is crucial to interact with people with mild to moderate dementia, which are still able to sustain dynamic exchanges.

D. Measures

OME [1]: After each session, the facilitators filled out the OME. We used the items attention (4-points Likert scale) and attitude (7-point Likert scale), using the latter twice, to qualify the attitude of participants towards the activity, and towards the partner. What is more, the item cognitive difficulty was included (5 point Likert scale).

OERS. [5]: After each session, facilitators filled out the OERS. It measures on a 5 point Likert scale the behavioural correlates of affective states, such as pleasure, anger, anxiety/fear, sadness, and general alert.

Videos. Also, we collected video footage. In this case, the video database consisted of 42 videos of around 30 minutes (approximately 21 hours of videos). A specific consent was obtained from families of participants, and participants themselves to record videos.

E. Results

We performed a pairwise t-test using SPSS (version 22.0) on the items of OME and OERS obtained during the two playful activities to figure out whether the engagement elicited by the two different activities consistently diverged. Results revealed that cognitive games were perceived as significantly more difficult (M=2.07, SD=.730) with respect to interactions with Pleo (M=1.00, SD=.000, $t(13)$=5.491, p <.001). Moreover, they outlined that participants felt considerably more pleasure during social robot interactions (M=3.93, SD=1.141) compared to cognitive games (M=1.93, SD=1.141, $t(13)$=-5.508, p <.001), but were also less alert during interactions with Pleo (M=4.64, SD=.497) with respect to cognitive games (M=5.00, SD=.00, $t(13)$=2.687, p <.05). Results were not surprising, except for *general alertness*. Differences in alertness might be due to the fact that cognitive games gave participants very little room for distraction. Indeed, the board games had a very precise structure of goals and actions to perform, which was completely evident to participants. On the contrary, interactions with Pleo were unconstrained, and left more room for uncertainty in the actions to perform and the goals to attain.

The ethogram for robot play was developed following the same procedure used for cognitive games. Each video has been split into segments according to identifiable micro-behaviours and the behaviours found in each segment were enlisted and operationalised (*e.g.* table 1).

TABLE I. EXAMPLES OF OPERATIONALISED DESCRIPTIONS OF BEHAVIOURS IN THE ETHOGRAMS

Attention > Posture adjustment	
Leaning forward	The torso of the observed participant is folded onwards on the table and does not touch the back of the chair
Approach	The observed participant takes the robot and approaches it to the torso or head.
Attention > Gaze	
Gaze (partner)	The participant directs the head and the eyes or just the eyes toward the partner.
Gaze (game)	The observed participant directs the head and the eyes or just the eyes toward the game, being the game any component of the jigsaw puzzle (pieces), shape puzzle (pieces, wooden board), domino (tiles) and robot set (robot, leaves, stones, etc.).
Gaze (facilitator)	The participant directs the head and the eyes or just the eyes toward the facilitator.

We classified behaviours in the ethogram using thematic analysis [16] (figure 2). This led us to find the same three themes described for cognitive games in robot play: *attention*, *rapport*, and *affect*. As in cognitive games, attention was split into *passive attention*, and *active participation*, and affect in *positive*, and *negative*. What is more, at a further subdivision of themes into sub-themes, we found out that the same modalities used to express attention, rapport, and affect in cognitive games were used also in robot play: *gaze*, *posture*, and *hands* for attention and rapport, and *face*, and *hands* for affect. What really changed between activities were goal-directed behaviours. In cognitive games, the goal of the activity was to complete the game, whereas in robot play the goal was to interact, and take care of the robot. The former has produced behaviours like *attempt*, *succeed*, and *discard.* The latter has produced behaviours, such as *feed*, *cradle*, *stroke*, *hug*, and *wave* at the robot, but also *baby talk*, *nuzzle*, *kiss*, and *blow* on the robot.

As one can notice, albeit the t-test shows that the engagement elicited by the two activities is of a different type, the ethograms show that the two different engagement states share the same themes, and sub-themes, and differ on certain micro-behaviours. We consider that all playful activities sharing the same context of those described in this article (table leisure activities) have the same underlying structure, and that leveraging over this structure we can compare engagement using different ethograms. At a lower level, ethograms will enable us to measure engagement preserving the individuality of each playful activity (Figure 2, leaves of the diagrams). At a higher level (*e.g.* division in dimensions, and modalities of engagement), their structure will permit us to compare engagement in different activities (Figure 2, parent and child nodes of the diagrams). At present, the just described structure of engagement is still theoretical. Our intention is to score the behaviours in the ethograms as durations. Duration recordings enable us to measure for how long the observed participant carried out the behaviours in the ethogram. Future work entails scoring videos using the two ethograms, testing the reliability of the ethograms, and the validity of their structuring. The former will be obtained with inter-rater reliability testing (Cohen's K statistic), the latter via Structural Equation Modelling (SEM).

V. Conclusion

In this paper, we have presented the results of two studies carried out to mould the behaviour of people with dementia when involved in two types of playful activities: cognitive games, and interactions with social robots. First, we have disclosed significant differences in the engagement states elicited by the two types of activities as underlined by observational rating scales. Second, we have presented a novel methodology to measure engagement in people with dementia through structured ethograms. Observational rating scales disclosed a higher cognitive difficulty of cognitive games with respect to robot play, and highlighted that participants, while feeling more pleasure, were also less alert during interactions with the robot. Statistical analyses showed that the two activities differed in the engagement they elicited, being one more cognitive and the other more emotional. However, thematic analysis applied to the two ethograms unveiled that the two different types of engagement had the same underlying structure. Indeed, the behavioural expression of engagement could be pooled into the same three dimensions (attention, rapport, and affect) and behavioural modalities in both activities. We consider that the ethograms could be used to describe and measure the engagement specific to each activity, and that their common structure could be used to make sensible comparisons between different activities.

Acknowledgment

A special thanks for the support goes to the nursing homes Redós de sant Josep i sant Pere, and La Mallola. We would like to thank Anna Barea, Laia Aranda, Neus Sanchez, and Elisabeth Seguer for their precious support.

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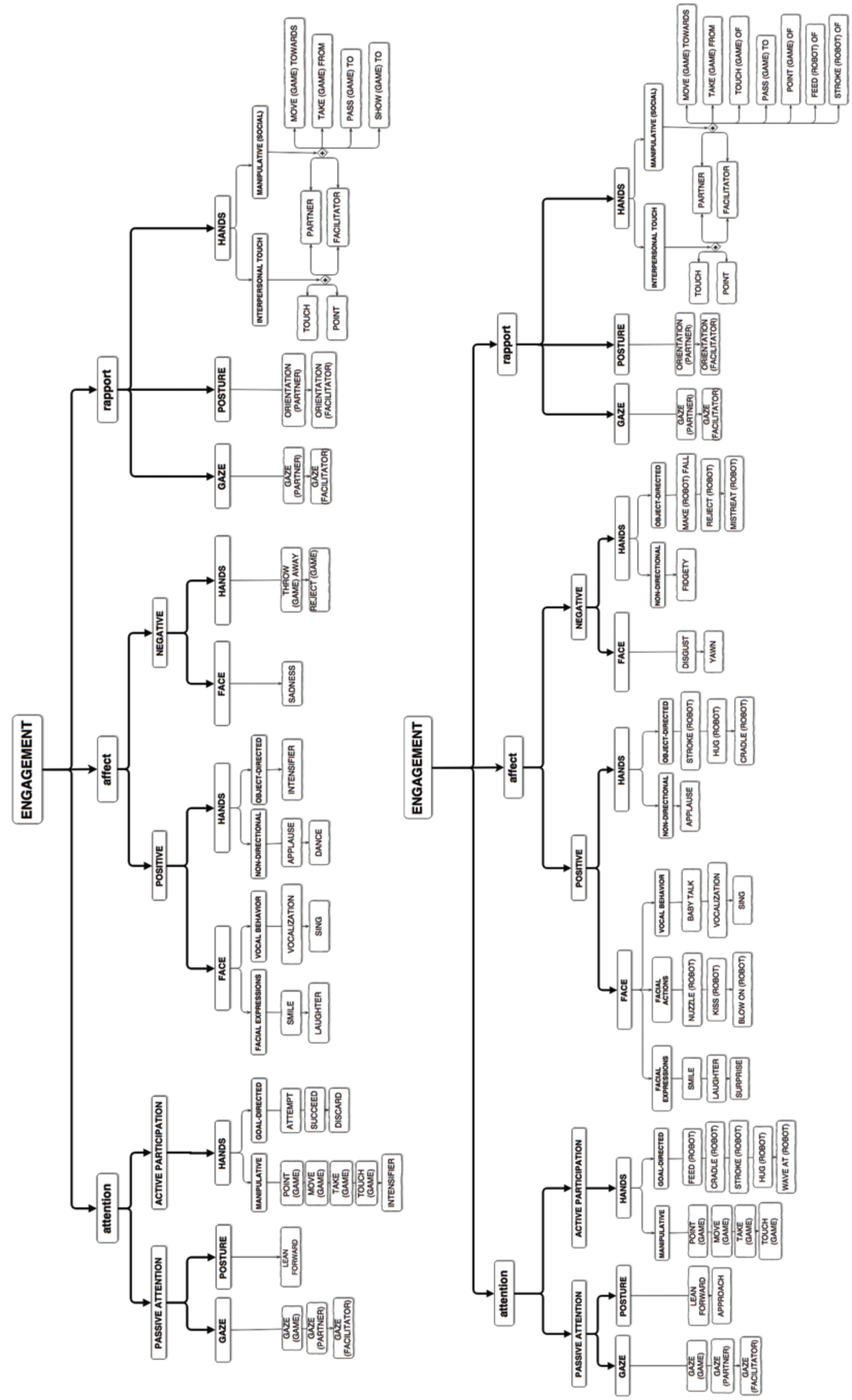

Figure 2. Structured ethograms (left: cognitive games; right: robot play)