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Keep on Moving!

Exploring Anthropomorphic Effects of Motion during Idle Moments

Thibault Asselborn[1], Wafa Johal[2] and Pierre Dillenbourg[3]

Abstract— **In this paper, we explored the effect of a robot's subconscious gestures made during moments when idle (also called adaptor gestures) on anthropomorphic perceptions of five year old children. We developed and sorted a set of adaptor motions based on their intensity. We designed an experiment involving 20 children, in which they played a memory game with two robots. During moments of idleness, the first robot showed adaptor movements, while the second robot moved its head following basic face tracking. Results showed that the children perceived the robot displaying adaptor movements to be more human and friendly. Moreover, these traits were found to be proportional to the intensity of the adaptor movements. For the range of intensities tested, it was also found that adaptor movements were not disruptive towards the task. These findings corroborate the fact that adaptor movements improve the affective aspect of child-robot interactions (CRI) and do not interfere with the child's performances in the task, making them suitable for CRI in educational contexts.**

I. INTRODUCTION

Over the years, research has used humanoid robots in various contexts pertaining to child-robot interactions, such as autism therapy [1], [2] or educational scenarios [3], [4]. The research community has agreed that assistive robots should be socially intelligent in order to be accepted in daily usage [5]. In order to improve human-robot communication, research aims to improve robots with human-like abilities in their social expression and intelligence. Noticeable progress has been made for functional tasks, such as holding conversations [6], catching objects [7] or expressing emotions [8], [9]. However, very little research has been taking the robot's motion into account when it does not have any particular task, which we call *idle moments*.

Non-verbal movements were categorized [10] into five classes: (1) *emblems*, (2) *illustrators*, (3) *affect displays*, (4) *regulators* and (5) *adaptors*. The first four are communicative movements, used with a semantic goal such as the "OK" sign (1), pointing towards an object (2), nodding to show comprehension (3), or smiling (4) for example. The last category: adaptor movements are postural or other non-verbal movements that are often performed during idle moments (we are still constantly moving even when we are not engaged in a particular task). Adaptors often occur at a low level awareness. They include self touching behaviors (such as twisting of the hair, scratching or swinging of the legs) and object-adaptor (such as tapping of a pen or pushing one's glasses up one's nose) [11]. The frequency of these adaptor movements may vary depending on the context & the individuals, and are considered to be social signals of communication. In robotics, it is commonly admitted that these micro-movements can help in making the interaction more natural and the robot more credible [12], [13]. Indeed, the absence of movements during idle moments may make them look like statues - frozen while waiting. However, their impact on anthropomorphism and on task performances hasn't been studied yet.

In this paper, we explore children's perception of robots (with or without adaptor movements) in terms of anthropomorphism and performance. We hypothesize that the robot displaying adaptor movements will be perceived to be more human and friendly than the one displaying a static posture during idle periods. Conversely, we also make the hypothesis that a high intensity of idle motion can be disruptive and thus reduce children's performances in an attention demanding task such as a memory game.

We designed a within subject experiment in which children were playing a memory game against two Nao humanoid robots. The two robots performed functional motions in the exact same way, but only one of them displayed adaptor movements. We compared attentional behaviour of the children by recording their gaze, and evaluated their subjective perception with a questionnaire.

II. RELATED WORK

Anthropomorphism plays an important role in the attribution of social skills to robots and gestures are a part of the anthropomorphic cues making robots more social [14]. In [15], authors compared two robots during an interaction with a human: one using gestures when speaking, while the other stayed immobile. The robot using gestures "was more anthropomorphized, participants perceived it as more likable, reported greater shared reality with it and showed increased future contact intentions" compared to the immobile robot. The impact of the non-verbal expressions of emotions and their anthropomorphic incidence was also investigated as in [16], where authors showed that "the robot's socially intelligent behaviour (i.e., the expression of emotional states) affected subsequent user evaluations" of robot's anthropomorphism and "clearly influence both perceptions of the interaction partner as well as the interaction itself" during HRI.

While there exist studies exploring the effect of movements during interactions, the effect of gestures during idle moments (i.e. moments when the robot doesn't perform a

[1]Thibault Asselborn, CHILI lab, EPFL, Switzerland, thibault.asselborn@epfl.ch
[2]Wafa Johal, CHILI/LSRO labs, EPFL, Switzerland, wafa.johal@epfl.ch
[3]Pierre Dillenbourg, CHILI lab, EPFL, Switzerland, pierre.dillenbourg@epfl.ch

task) has not been largely studied, especially in robotics. Some research in this domain concerns avatars. In [17], the authors propose to "generate subtle head and face movements while a virtual character is in idle mode" and show that this leads the character to be perceived to be more friendly. [18] reports an implementation of adaptor movements for the whole body of virtual agents. The authors designed a module that allowed generation of subtle movements i.e. "changing balance because of fatigue, variations in body posture caused by small muscle contractions or eye blinking" to avoid "the lack of animation between different animation clips responsible of the unnatural-looking frozen posture between motions". This research shows that avatars performing adaptor movements were perceived as more human by users [19]. A few instances of recent research present implementations of adaptor movements for humanoid robots. In [6], the authors implemented one hundred interactive behaviours on a Robovie humanoid robot where twenty of them were "idle behaviors such as scratching the head or folding the arms". However, the goal of this research was totally different than that of ours as the behaviours were implemented to increase the number of interactions between children and the robot. In [20], the authors showed the importance of bodily motion in speechless situations by exploring five distinguished roles of motion used during moments where one does not speak: *mood-setting*, *observing*, *listening*, *expecting* and *idling* (corresponding to our adaptor movements). The study does not explore the anthropomorphical incidence of one particular category taken separately as the aim of the research was to provide a guideline to "help create preferable motion designs of a humanoid robot" in speechless situations. Due to the small number of studies exploring the effect of adaptor movements on affect in robotics, we believe that this research can be valuable to the field of CRI.

III. Design of adaptor modes

In order to evaluate the degree of motion the robot should adopt during idle moments, we designed three different levels of adaptor mode. We created a database containing a set of 60 animations that mimic adaptor movements. These animations were tagged with a mode according to their intensity (namely: low, medium and high). Several factors may influence the intensity of an animation; for instance : the angle swept by joints during motions, the duration of animations, the velocity of joints, or the joints concerned (a movement of hand will have a lower impact compared to a movement of the shoulder for example). Thus, as this intensity can be computed in several ways making it quite subjective, it was decided to sort them according to the perceived intensity. However, a treatment check was applied in section Treatment check proving the consistency of this manual sorting.

In addition, the frequency of animation triggering depended on the level of intensity of adaptor movements. Animations were triggered every 25 seconds on the first level of intensity (low), every 18 seconds for the second level (medium) and finally every 12 seconds for the third one (high). For the sake of clarity, we will call this scale the *adaptor scale* from now on.

IV. Experimental evaluation of adaptor modes

A. The memory game

The memory game features a set of matching card pairs that are randomly disposed face-hidden. Players alternatively flip two cards (now face-showing) in an attempt to find and collect matching pairs. The player that wins is one who collected the maximum number of pairs. Since we targeted children younger than 6, we decided to limit the number of cards to 16 (disposed in a 4 by 4 grid). The choice of designing the memory game was done due to the simplicity of its rules, the short duration of the game and the fact that it is a competitive game (which pushes task engagement). It requires children to pay attention and to memorize previously returned cards in order to defeat the robot players. A very simple artificial intelligence was implemented for the robots' strategy. The robots were forgetting the cards flipped during a given round R_i according to a certain probability depending on the difference between the current round R and R_i. The probability to forget a card on R_i is given by the formula: $P(i) = 1 - 1/(R_i - R)$ (with i being the index of the round). The game was implemented on a tablet running Android.

B. The Experimental Setup

The experiment took place in a school where 20 five years old children (12 boys, 8 girls) participated and took around 20 minutes per child. Two Nao robots [1] were placed in front of the child (see figure 1, A and B) and were playing against her. Both were performing functional movements in the same manner: they were performing a flipping gestures, launching animations when they were winning or losing, speaking the same way and were also having the same face-tracking module implemented. The head movements implemented on the robots (coming from the face-tracking module) were kept in both cases as lots of studies showed the important influence of head movement in human perception [17], [21], [22], [23].

In order to avoid some preference bias, the two robots had the same color and the same gender (both female, named respectively "Myrtille" and "Clementine"). The difference between them was lying on the adaptor movements implemented in only one of them (randomly assigned). This means that during idle moments, this robot was displaying adaptor movements such as breathing, changing posture, scratching itself or stretching for example, which, we believe, was supposed to make it look more human from the child's perspective.

During the experiment, each child played three games, each time at a different level of adaptor mode (in a random order).

[1] Softbank Aldebaran, https://www.ald.softbankrobotics.com

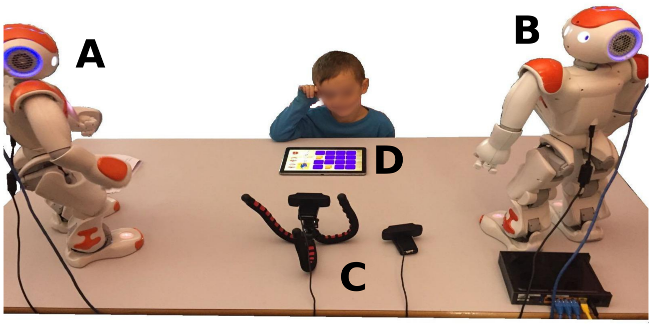


Fig. 1: A and B: The two Nao robots playing memory. One of them stays static whereas the other performs adaptor movements during idle moments. C: Two cameras are facing child. One is used to record a video of the experiment, the other is used to detect if the child is either looking at the left robot, right robot or the tablet computer. D: The tablet implementing the memory game.

C. Measures

1) Task Performance: The number of matching pairs collected during rounds of the memory game by the child has been used as a measure of performance.

2) Child's Visual Attention: Two cameras facing the children were used (see figure 1, C). The first one was simply used to record the experiment (audio and video). The second one was used for head pose estimation and gaze tracking. This information was used to extract the localisation in space the child was looking at and especially if she was looking at the tablet, the robot on the left or the one on the right. Based on previous work from [24] on with-me-ness, the FeatureFace library [2] has been implemented for this purpose. FeatureFace widely uses the OpenFace library proposed by [25] and enables head pose and gaze pose estimation with ROS compatibility.

3) Perceived Anthropomorphism and Proficiency: We adapted some items from the GodSpeed questionnaire [26] to measure the anthropomorphical difference between the two robots [3]. Children evaluated the robots on four different metrics namely *humanity*, *friendliness*, *attention* and *proficiency* using a Likert scale. At the end of each game (so 3 times in one experiment, each time for a different level of adaptor mode), the child was asked to answer four questions (each one related to one different anthropomorphical metric) to rate the robots on a five levels scale.

D. Hypothesis

H1: The robot with adaptor movements will be perceived more human and friendly by the children compared to the other one. We think that this impact will depend on the level of the adaptor mode. We also don't expect to see any correlation of the adaptor movements with the attention and task performance metrics.

[2]https://github.com/asselbor/features_face
[3]https://github.com/asselbor/Questionnaire

Ankle	Elbow	Hand	Head	Hip	Knee	Wrist
6	2	1	3	4	5	1

TABLE I: Weighting factor assigned to the different joints of Nao to compute the Quantity of motion of the different animations.

H2: The best robot (the one that collects the highest number of pairs during a game) will be perceived as more proficient and attentive by children independently from the idle mode.

H3: The child will be more prone to look at the robot displaying adaptor movements. Once again, we expect to see an increase of this tendency with the level of adaptor mode.

E. Treatment check

As explained in Section Design of adaptor modes, the animations were manually sorted in three modes depending on their intensity. In this section, we evaluated the intensity of the animations composing the three groups to verify the manual annotation objectively. To do so, we used the product of three variables previously cited: angle swept, angular speed and duration of animation, for each joint. As commonly done to compute the quantity of motion [27], we used a weighting factor for each joint according to their impact on the motion. The joints having less impact on the motion (hand, fingers) had a smaller coefficient than joints which had a bigger impact on the motion (shoulder, knees). The following equation shows how to compute the intensity score S for a given animation:

$$S = t_{motion} * \sum_{i=1}^{n} c_i * \alpha_i * v_i \quad (1)$$

with:

- c = weighting factor depending on the type of joint concerned (see table I)
- α = Angle swept during motion
- v = Mean joint velocity while moving
- t_{motion} = Total duration of motion
- i = The joint id starting from the first one to the last one n

Figure 2 shows the intensity of motion for each of the three levels sorted manually (calculated with equation 1). Even-though we observe high variability, a t-test between the means of the groups of animation showed statistically significant differences between each of them. We decided to keep the groups as sorted manually in order to have smoother transitions between groups, hence not making the difference obvious to the player.

V. Results and Discussion

A. H1: Perceived Anthropomorphism

Figure 3 shows an increase in terms of perceived humanity and friendliness with the level of adaptor mode. As the data were not found to follow a normal distribution, a one-sided

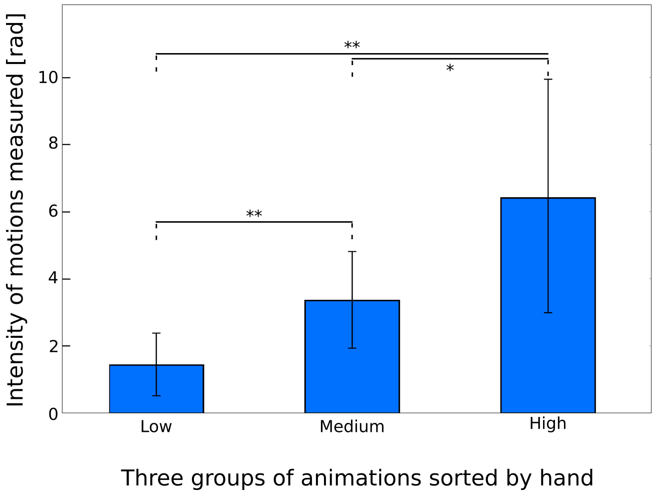


Fig. 2: The measured intensity for the different groups of animations. Asterisks denote statistically significant differences between the mean of different groups found with a t-test. $*p < 0.05$ and $**p < 0.01$.

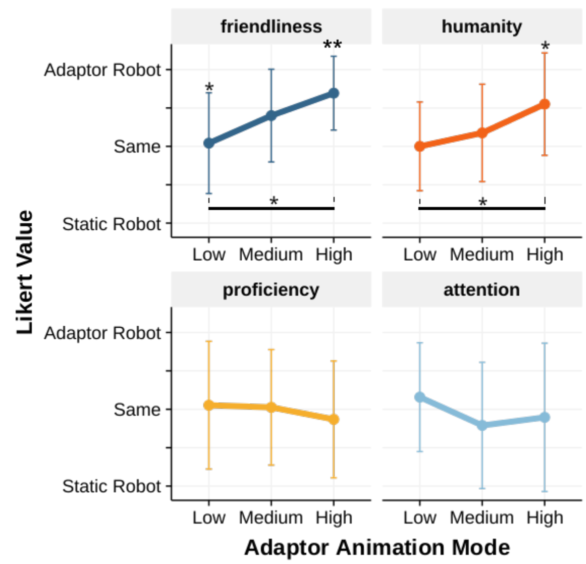


Fig. 3: Anthropomophical differences between the robot with adaptor movements (called "Adaptor Robot") and the other one (called "Static Robot") as a function of adaptor mode in terms of friendliness, humanity, proficiency and attention ($*p < 0.05$ and $**p < 0.01$).

Wilcoxon test was used and showed that the robot with adaptor movements was perceived more friendly ($M = 1.38$, $SD = 0.92$, $t(19) = 2.5$, $p < 0.01$) and human-like ($M = 1.1$, $SD = 1.3$, $t(19) = 9.0$, $p < 0.05$) compared to the static one for adaptor mode on level 3. It was also found to be more friendly at adaptor mode on level 2 ($M = 0.8$, $SD = 1.16$, $t(19) = 13.0$, $p < 0.05$). For adaptor mode on level 1, no statistical significance was found. As expected, we didn't find any difference concerning the perceived attentiveness of the robots. The robot with adaptor movements was not perceived less attentive than the static robot. No significant difference was found for the proficiency metric for any adaptor mode level, meaning that the static and adaptor robots both looked equally competent.

It was also extracted that the robot with adaptor movements was found to be more human-like and friendly at level 3 than at level 1 ($p < 0.05$ for both).

B. H2: Proficiency

As expected, it was found that the best robot (the one that collected the highest number of pairs at the end of a game) was perceived more proficient than the other one (Wilcoxon test: $t(49) = 125.0$, $p < 0.01$). No influence of the static or adaptor mode was found on the proficiency metric. These results are not surprising but tend to prove the proper functioning of the questionnaire.

C. H3: Visual Attention

In Figure 5a, we can see that the children tend to look more at the robot with adaptor movements compared to the static one. As expected, this tendency depends on the mode of the adaptor movements. The proportion of gaze on the static robot seems to be relatively constant (around 20%) across the three adaptor mode conditions. The gaze proportion to the tablet seems to decrease as the intensity of the adaptor movements increase. We expected the mode of

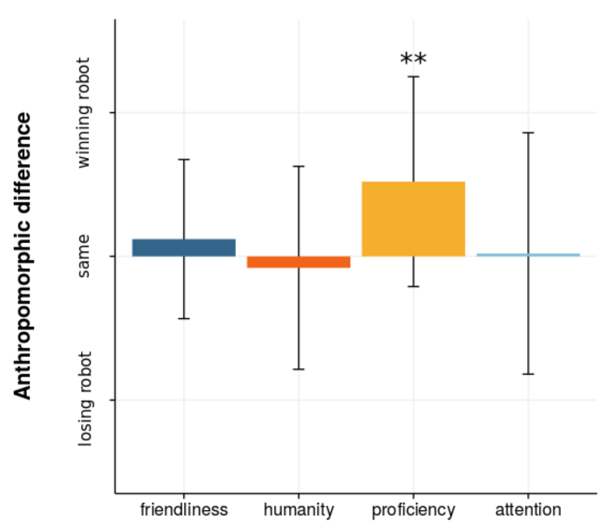
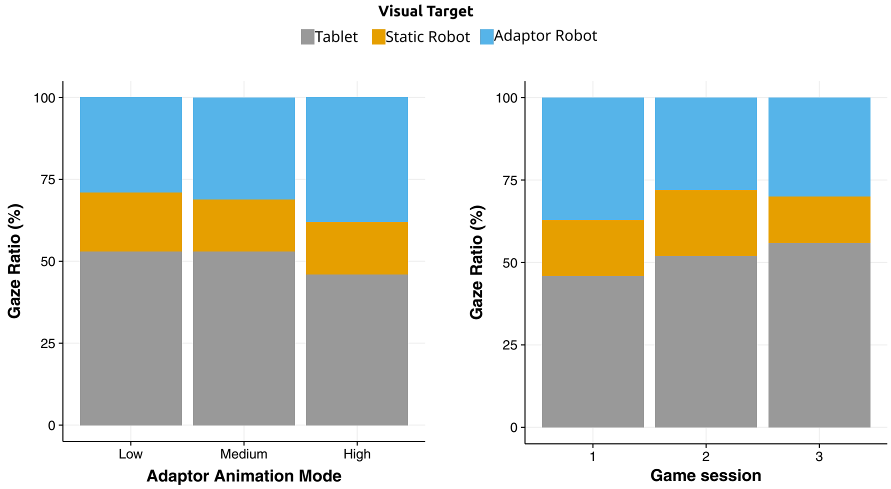


Fig. 4: Anthropomorphic difference between the robot winning the game and the other one. Asterisks denote statistically significant differences between the mean of different groups found with a Wilcoxon test. $**p < 0.01$.



(a) Adaptor Mode

(b) Game Session

Fig. 5: Gazing proportion for the robots and the tablet according to (a): the mode of adaptor movements, (b): the game session.

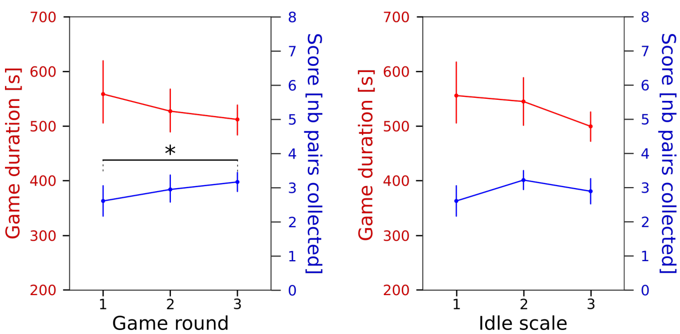


Fig. 6: Number of matching pairs found by children (blue) and game duration (red) as a function of left: the game id, and right: the scale level of idle movements. Asterisks denote statistically significant differences between the mean of different groups found with a one-sided Wilcoxon test (*$p < 0.05$).

adaptor movements to be correlated with the average number of pairs collected by the children during a game; as she/he will be more distracted by the robot as well as the duration of the game that would increase. We failed to extract a clear tendency (no statistical difference found for both metrics) as can be seen in Figure 6, right. These results show that adaptor movements are, in addition to making the robot look more natural, not disruptive for performances in the tasks where they are implemented (in this case, the memory game). Of course, this result is only valid for this task and for the mode of adaptor movements implemented during this experiment. It may change for a new mode where these movements would be more intense. This will be discussed in Section Conclusion and Future Work.

Figure 5b showed a significant increase in the proportion of gaze match on the tablet according to the game session (children were playing three games in a row during the experiment). We believe that the children's habituation of the robots is responsible of this tendency. As time goes by, children become less distracted by the robots and then more focused on the tablet and therefore on the memory game itself. We would therefore expect an increase in the children's performance measured by a higher number of matching pairs collected and therefore by a diminution of the game session duration as the game is more likely to be finished quicker. The increase in the number of matching pairs collected as a function of the game session could be extracted as can be seen on Figure 6, left. A one-sided Wilcoxon test showed a statistical increasing number of matching pairs between game round 1 and 3 ($p < 0.05$). Concerning the game duration, even if we can see a decreasing tendency in function of the game session, we failed to observe any statistical significance between data of each sessions.

VI. Conclusion and Future Work

We presented a within subject experiment with twenty children, where they had to play a simple memory game against two physically identical Nao robots. The robots had the exact same functional movements implemented but only one of them was performing adaptor movements during idle moments. Each child played three games, each time with a different mode of adaptor movements (assigned in a random order). We extracted children's visual attention data thanks to a camera facing them and allowing to compute the gaze position in space where children were looking at. A questionnaire based on some GodSpeed items was also created to extract the anthropomorphical perception of the robots by children.

A clear correlation was found between the adaptor movements and the humanity and friendliness perception. These correlations are dependent on the intensiveness of the adaptor movements during idle moments. It was also found that the adaptor movements was attracting children's gaze also depending on the intensiveness of them. Moreover, the adaptor movements for the range of intensity tested were not disruptive for the task as the number of pairs collected by children stayed relatively constant across the three levels of adaptor mode.

Even if this research have formally proved our assumptions, a clear limitation comes from the fact that experiments were conducted only on five years old children. It would be very interesting to check if our assumptions would also stand for other age range such as adults or for different cultures. It would be very premature to say that the anthropomorphic relations showed indefinitely increase with the intensiveness of adaptor movements. We believe that there exists a threshold (in term of intensiveness of adaptor movements) where the movements are no more beneficial for anthropomorphical perceptions. Our research unfortunately does not take that into account, as in this experiment, the intensiveness is too low to be disruptive for children. It would be interesting to measure the anthropomorphical implications of even more intensive adaptor movements concerning the child-robot interaction. It could allow to determine at which point, the intensiveness of adaptor movements becomes more disruptive than useful for the interaction.

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