Effects of Non Verbal Cues and Walking Speed

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***Abstract*—The non-verbal behavior used to indicate much about a person's personality, by its body postures, head movements, gestures and even speed of its motions. In this project, I tried to manipulate the head movements if NAO robot. When it walks, whatever object is near by it, it will look over that object by moving its head. The certain body postures indicates certain emotions. And along with these non-verbal cues, walking speed is also manipulated of NAO robot to find the peoples preference of walking speed of NAO. The fast-walking speed or slow walking speed are the parameters which are manipulated during the experiment. The main question is will people like the fast walking robot showing no head movements and emotions over the slow walking robot showing head movements and emotions as non-verbal cues. By showing certain emotions like happiness, sadness, thinking when confused, will it change or affect the mood of the person playing with the robot or not. The head movements will lead to perceived intelligence or more competency of NAO robot or not.**

***Index Terms*—Human robot interaction, emotions, non verbal cues, human behaviour, NAO robot**

I. Introduction

Sometimes, when any robot cannot speak verbally, humans try to understand its non-verbal behaviors. Its plays an important role to understand people. Sometimes, even if person is speaking something, other people understands that person is scared or telling lie just by its body language and non-verbal cues. People understand the non-verbal cues very easily and unconsciously. So even if human is communicating with the robot, people will find the non-verbal cues in robot also even if it is only machine, but it looks like human so they will treat it as other social being. If the person is talking with you and you are not looking at that person, then it will be rude behavior, or they another person is intentionally ignoring as they are uninterested.

In this project, focus is on head movements, and posture of NAO robot. The robot will look left side if there is any object on left side and look at right side if there is any object on right side. Robot will also show happiness by raising and moving its hands side by side to indicate happiness emotions by posture. It indicates sadness emotion by turning its head down. It also shows thinking behaviour by confusingly looking both the sides, right side and left side and then raises its hand towards its head, indicating posture that it is thinking.

Another interesting factor is walking speed of nao robot. If someone walks fast, humans think that person is in hurry, and when person is in hurry, it tends that person might hit some obstacle in a way or some other person while walking, or running, and other person might get annoyed for few seconds. Will the people think the same about the robot when it is walking fast, or will people find it funny, because the height of the robot is too short, and it is trying to walk fast. Do the people will treat this anthropomorphic robot, as another human or will find it annoying?

A. Why NAO robot?

In this project, head movements is needed to produce non-verbal cues, body postures are used to produce certain emotions like happiness, confusion where it thinks which way to move, sadness when get hurt. The appearance of Nao robot is like a kid and people may find it cute. So will they get bored while playing with slow speed robot or not. The selection of NAO robot is based on how many joints and actuators it have and its anthropomorphic appearance. It does not have gender. So, the people's feedback will not be biased based on robot's gender.

B. Why head movement and leg speed?

The head movements are important part for expressing body language of humans. According to [1]–[3], nodding of head lead to agreement in the conversations, whereas shaking head horizontally will lead to disagreeing with statement in the interaction. By titling the head, people express that they are watching something unusual or specific thing. When people goes to new place, they explore it, by head movements and gaze movements. In case of Nao robot, it cannot move its eyes, so instead head movement is used. According to [acm8], for tracking the object in the area, head movement is used and even sometimes to attract attention of multiple people head movements are used. This head movements might lead the people to think that robot is more intelligent and competent, as it can identify the obstacles and avoid it intentionally. Additionally, leg speed is important to determine people preference of fast speed or slow speed robot in physical world.

II. Literature Review

The importance of non-verbal behaviors is shown in many previous works. There are different cues like gaze movements, head movements, mimicry, imitation, posture, and many other components. In this project, my focus is on speed of the robot, head movements and few body postures which indicates certain emotions.

According to [4], Nao robot size is same as couple of years old kid, so the speed of walking is kept 0.6 kilometer per hour which would be of human kid's walking speed of 2 years. But people are patient towards the kid, and will people show this patience towards robot when it is walking. But I am curious to know about whether the people will get bored of this slow walking nao robot, and gets frustrated if it walks too slow, and would prefer fast speed of walking of nao.

In [5], low power walk is suggested, which means power provided to the motors of the legs is regulated. The stiffness of joints of legs while walking is changed which causes 60 percent more fast speed than normal speed. Due to this, power consumption is low. They have also increased speed without changing stiffness, but power consumption of it is approximately same as normal walk. In this [6], use of grounded learning of simulation is used where each time the data is the joint movements and behavior of robot is simulated and optimized. Then they compared the simulation results with the real NAO robot results. The task was to minimize the difference, for doing so machine learning algorithms are used to predict the values of joints for smoother transition of walking. They have resulted increase in 25 percent of NAO's walking speed after optimization.

In [7], micromovements made by robots is very important to determine the impression of robot in people's mind. Only generation of motions are not important, but the way the motion is generated is important too. If the robot creates the motion in the same way as humans do then it will be more socially acceptable in society and considered more lifelike especially for humanoid robots. In [1], it pretends to listen to person giving guidance to robot by performing non-verbal cues like nodding using head movements and gaze movements. The importance of this non-verbal behaviors are shown in [3] also. In [8], they proved that anthropomorphic motions perceives the internal state of robot. In this nao robot performs various postures and the speed of the motion to create a posture also determines that how excited the robot is. And people understand this cues very easily.

In this project, I will focus on non-verbal cue like head movements of Nao robot. The head movement will also result into gaze movement in case of Nao robot as it cannot rotate its eyeballs. In this [2], Nao robot shows non-verbal gestures and body movement while explaining something to participants. The head movements are used to express the agreement and disagreement. The head movements such as nodding if they agree in the conversation or listening to the conversation. The head is shaken vertically if robot disagree with something in conversation. If the person shows its palm to NAO robot, then it stops the speech, it detects the palm of person and stops speaking. If the user touches the head of the NAO, then NAO will move further to the next topic's explanation. So, people prefer robots who understand the non-verbal cues in communication because humans understand them easily.

In this [9], NAO robot is using head movements to indicate various cues in communication like, when nao looks up means (at person), then it indicates the turn taking mechanism. It gives chance to that person to speak. For expressing surprise emotions, nao robot will look up, and also to indicate that there is new information available, and nao wants to share it, it looks at people by head movement. In this nao uses hand gestures, head movements, and gaze following along with speech to express robot more human like. The nao appeared to be cheerful and expressive if non-verbal behaviors are used. In this [10], NAO robot can detect the head movement of the user and mimics the same, they resulted that likeability of NAO robot increases because of this kind of non-verbal behaviour. In this [11], humans will rate the robot based on head movements, tracking objects with head movements, smoothly or unsmooth, with object avoidance behavior. They resulted that, people prefer object avoidance behavior with unsmooth head movements over the smooth head movements without avoiding obstacle.

According to [3], robot can be more expressive using posture of the body when it cannot express using facial expressions. The paper [12], [13], demonstrated that people understand the robot better through body postures. People can interpret that emotions based on affective postures of body. The paper [12], shows that emotions can be expressed through body movements and not only facial expressions. They demonstrated frightening and sad emotions of NAO robot through body postures. In [13], they have shown that mood of the people gets affected based on postures the Nao robot make.

In this project, I am trying to create certain body postures, to demonstrate some emotions like happiness, sadness, thinking. In this [14], body movement, eye color and sound is used to let participant determine the emotion of the robot. Their results says that based on solely body movements user can determine the emotion, and LED colors in NAO robot cannot determine the emotion of the robot, whereas sound can at some level, determine the emotion but not only sound can determine the exact emotion whereas, body movement can.

There are various applications in which non-verbal behaviors will be much helpful, like in [15], [16], experiment is performed with children with autism, firstly they familiarize the child with robot and then later talk to each other and then perform some physical activities with each other. After all this, children with autism give its feedback to robots. The children's IQ improves after communicating with NAO robot with verbal and non-verbal cues. Due to non-verbal cues like postures of playing air instruments also entertain children. In this [17], NAO robot is used to make children distract from their pain during their vaccination. NAO robot tells jokes, mimics to play instruments in air, performs such non-verbal cues when it detects the pain from facial expressions or from speech. It also checks whether a child is responding to jokes by laughing if not then it will try again. So, in this NAO robot adapts its behavior based on a child's expression. The behavior of NAO robot will affect the child's mood and distract it from pain for atleast few seconds.

In [18], NAO robot performs certain actions to be perceived as funny, after making mistakes. In this, NAO robot is working as the receptionist and when user comes in order to check the attendance it spills the glass of water, robots say jokes to provide verbal cues, starts laughing or salute to user at the end in order to provide the non-verbal cues. The results are calculated based on questionnaires. In their results, people thought that robots showing non-verbal motions as more intelligent than other ones. Apparently, likability was below average, and people don't find it that funny or humorous.

In this paper [19], NAO robots' personality is determined based on non-verbal cues it performs. The user personality affects the preference of robot, like extroverted person would more like the robot showing more non-verbal cues than introverted one. Additionally, overall people liked the robot performing non-verbal actions along with speaking than robot that just speaks. In this [20], based on different postures of Nao can be judged such as whether it is authoritative and dominating or obedient and permissive.

III. Research Questions

In this project, I am performing confirmatory research approach, where I want to testify the hypothesis and get answers of the research questions mentioned below.

Q 1: What is effect of walking speed of the nao robot on people's perspective towards it?

- Which robot will people like, the one who shows non-verbal behaviour but has slow speed or the one who does not show non-verbal behaviour but has fast speed?
- Will people like the robot showing non-verbal cues and emotions or find it unnecessary, especially when they are in hurry. The hypothesis is people may get annoyed with robot when it shows emotions or walks slowly when they are in hurry or need something fast.

Q 2: What is effect of emotions on people's mood?

- The hypothesis here is humans may find it humorous, when robot stands and thinks. The path selection is pretty easy for people. When it finds robot standing couple of seconds and thinking about it, it may seem funny to people. But when people are in hurry, then people might get annoyed with it.
- When two-year-old kid collides with obstacle, adults take care of them, will people show this anthropomorphic behaviour towards robot also, or instead get annoyed with it.

Q 3: Do head movements will lead the people to think that robot is more intelligent, or have more human like behavior and feel more familiar with it?

- Will people find the robot showing head movements and emotions as more expressive robot or more confident robot?
- The hypothesis here is that people may find robot showing head movements as more expressive, and have perceived intelligent, because it can see the objects and behave little bit like humans.

IV. Robotics Implementation

I have used NAO robot and implemented its behaviour using Webots software. The C language is used for programming of NAO. The non-verbal behaviour like head movements while walking, then showing emotions if particular situation appears, is programmed.

For head movements, two sonar distance sensors are used to detect the objects in the environment, and if the object is detected on left side then head will rotate to left side while walking, and if object detected is on right side then head will be rotated to right side. The head movements are manipulated by changing HeadYaw Rotational Motor per timestep.

For speed of the NAO robot, the motion files are manipulated. For walking purpose, multiple rotational motors are used at the same time. The positions of all the rotational motors at a time is specified in motion files. For increasing the speed of walking, the time period in fast speed motion file is decreased, apparently, for slow speed it is increased. For walking continuously, motion is set to the loop.

NAO generates different emotions on different situations like, when robot reached the destination happy emotion is created. When robot has two possible path to reach the destinations, it will stand and think and performs confused behaviour. When robot hits the obstacle, it becomes sad. For implementing happy and confused emotions separate motion files are generated, in which positions of different rotational motors are described. For sad emotion, only HeadPitch rotational motor is required, and to detect when it hit the obstacle, four bumper sensors in nao foot is used. This bumper sensors are touch sensors. So, whenever, the bumper sensors detects the collision, then the head of Nao robot is lowered which will indicate the sad emotion. The led lights are used alongside body posture to indicate the emotion, when happy all leds will be of green color, when sad all leds will be od blue color, when thinking in confusion all leds will be turned red and normally while walking all leds will be off. I want to determine that does LED can perceive the robot as more expressive in human's eyes.

V. Experiment

A. Overall design

The venue is of L shape, the task is to understand people's perception towards NAO robot. Nao has to reach from one end of room to another end of the room while walking. The nao will show non-verbal behaviour by head movements. If it detects the object near by in the path, then it will look at the objects by head movement while walking. If nao is walking in fast speed, then it gets hit by the obstacle and shows sad expression as shown in Fig. 2. If nao is walking at slow speed, it does not hit the obstacles on the way, but instead think when it is confused. If the two path appears to reach the destination the Nao robot will stand for couple of seconds and thinks where to go when it is in confusion, this behavior is shown in Fig. 3. If nao reaches it destination then it will express happiness as shown in Fig. 1.

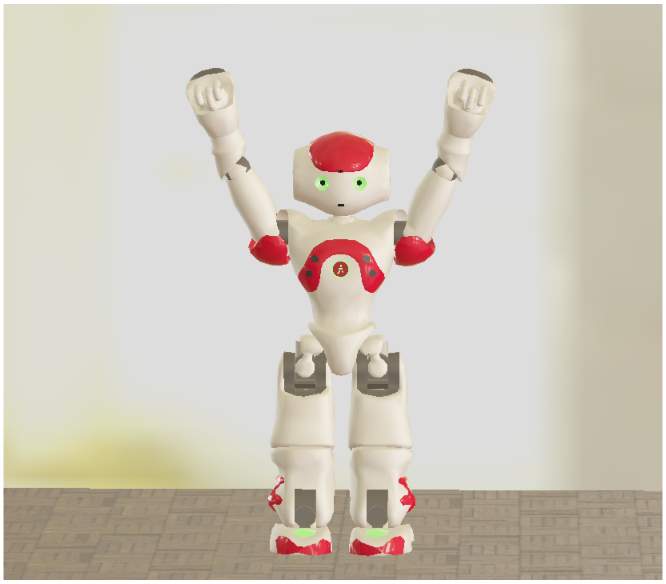

Fig. 1. Happy Emotion

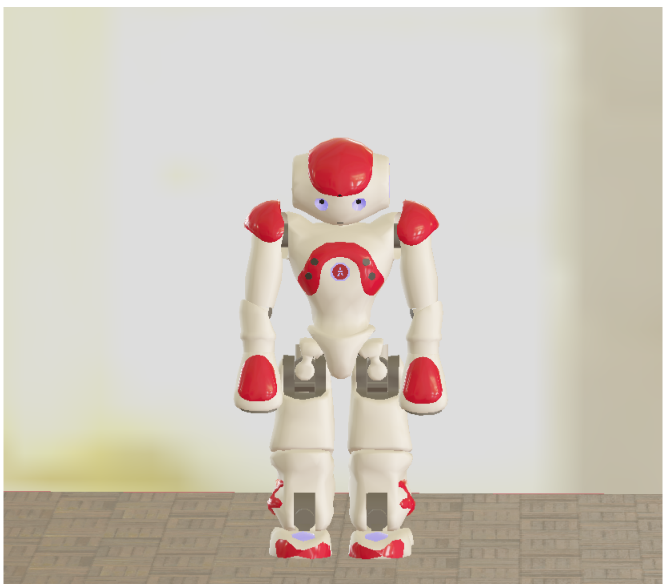

Fig. 2. Sad Emotion

- Happy: Nao raises its both the hand up in the air and moves side by side, to express happiness. It is shown in fig 1.
- Sad: Nao lowers its head for couple of seconds when got hit by obstacle. This sad expression is shown in Fig. 2.
- Thinking: Nao is confused whether to go from left side or right side of the object to reach the destination. In this, Nao looks at left side by moving its head, then looks at right side by moving its head, then raises its hand towards its head, showing that it is thinking. This thinking posture is revealed in Fig. 3.

The robot may or may not show different emotions like if the nao is walking in fast speed, it may often hit the obstacles, then it expresses sad emotion, and when it reached the destination, it performs happy emotion. If nao is walking at slow speed then, it will not get hit by obstacle, and when two path appear to reach the destination, it may express thinking or confused expression. The emotions expressed are in this manner:

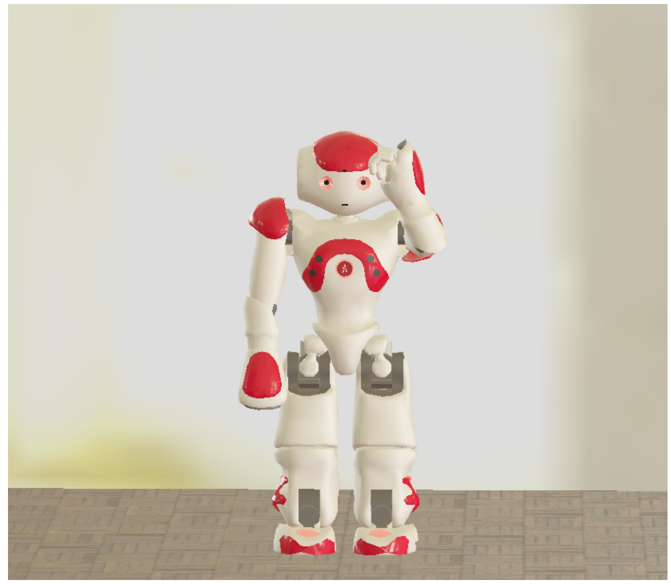

Fig. 3. Confused Emotion

1) Fast speed: Happiness, Sadness
2) Slow speed: Happiness, thinking when confused

There are 4 conditions of human robot interaction:

1) Walking with fast speed and showing head movement and expresses happiness and sadness emotions.
2) Walking with slow speed and showing head movements, and expresses happiness, and thinks if confused in any situation.
3) Walking with fast speed and showing no head movements and no emotions.
4) Walking with slow speed and showing no head movements and no emotions.

There are two independent variables which are walking speed, and non-verbal cues like head movements and emotions. This experiment is of 2*2 design, where robot can be either walk with fast speed or slow speed, and robot may either shows non-verbal behavior and emotions or does not express.

The walking speed variable is within participants and the non-verbal cues and emotions variable is between participants. So, one group of participants will be shown robot demonstrating non-verbal cues and emotions with both fast walking speed robot and slow walking robot. Apparently, another set of participants, will be shown robot showing no head movements and emotions, with both waking in fast speed and slow speed.

The simulation will be based on videos. There will be four videos showing the above four simulation conditions. Each participant will be walking two simulation videos because speed variable is within participant.

B. Participants

For conducting this experiment, minimum 50 participants are required. The 25 participants will robot showing non verbal cues and emotions with both fast speed and slow speed. Where as, another 25 participants will see the robot not showing any non verbal cues and emotions with both fast speed and slow speed. The expected participants need to be approximately half female and half of the male in each group of participants, so that results are not influenced based on gender. If variety of age in participants is present, then it would be better, because I can get to know perceptions of all generations towards robot.

TABLE I
INTERACTION SCENARIO WITH PARTICIPANTS

Group 1		Group 2	
Show head movements and emotions		Not showing non-verbal cues	
Fast Walking Speed	Slow Walking Speed	Fast Walking Speed	Slow Walking Speed

C. Artifacts

The nao robot is implemented using hybrid control of autonomy. The non-verbal behaviour which is head movements when the object is detect is automatic. The two sonar distance sensors of nao robot is used to detect the object. The sonar sensors, only senses the object that falls into 45 degrees of area from the sensor. If left sonar sensor detects the object then, nao will look left side. If right sonar detects the object, then nao will look at right by moving its head. Otherwise, it will look straight.

The sad emotion is automatic when it hits the object. It is triggered when either of the four bumper sensor from its foot results that, the collision is occurred. These bumper sensors returns the Boolean values. Normally, the value is false, but if it touches any object then, it returns true as value. Whenever, it is true, nao will express the sad emotion. The happy emotion is triggered by the keyboard when robot reaches at the end of the path. The thinking emotion is triggered by keyboard when it finds the obstacle placed right in front of it, and it can go from left side also and right side also, so when robot is walking in slow speed, this thinking expression is triggered.

The direction given to robot is by keyboard, as my main purpose is to understand that how people will react to robot performing non-verbal cues, and whether they like fast walking robot or slow walking robot.

D. Procedures, Measures and Data Collection

The dependent variables are to measure the likability of robot by participants after the change in independent variables. The perceived intelligence is measured according to participant. The manipulation checks is whether participant detects the changes in speed of robot. Whether participant notices the head movements and emotions of the robot.

The participants will watch the two simulation video one with fast speed and other with slow speed. Each participant will watch either robot with non-verbal behavior in both the simulation videos or not showing any emotions or head movements in either of videos. After watching the simulation of robot, each participant will fill the God Speed Questionnaire [21], and IOS questionnaire [22]

The quantitative data will be collected by the subjective measures, after the experiment. After participant, watches the simulation videos, few questionnaires is filled by them. The Godspeed Questionnaire can be used to measure perceived intelligence, perceived security, anthropomorphism, animacy and likeability towards the robot [21]. This questionnaire will mainly determine that whether the participant find the robot competent, expressive, knowledgeable, and have human like behavior or not. I would like to add few other Likert scale questions with the scale from 1 to 5, along with the God Speed Questionnaire such as :

- **Expressive or unexpressive**: To determine that participant noticed the motions expressed by robot, or not and did they find it expressive or not.
- **Emotional or not Emotional**: To measure that does sad emotion expressed by robot, is perceived as emotional behavior by participant or not.
- **Humorous or not funny**: When robot is thinking or showing happiness, does people find it funny as nao robot is small in size also.
- **Interesting or boring**: To determine that the speed of the robot, have affected peoples perception towards robot. It determines that do people find it boring if robot walks slowly.
- **Busy or free**: If robot is in fast speed then people might think that it is in hurry, and if robot walks in slow speed then robot might have much free time and is relaxed and walking slowly.
- **Confident – not confident**

Then psychological closeness is measured using questionnaire in [23]. The psychological closeness is measured to see that whether there is any impact of non-verbal behaviour of robot onto participant. It measures that do human finds robot's behaviour similar to its own or not. The IOS questionnaire [22] is filled to determine how close the participant finds itself with the robot, or how close is the behaviour of robot with the participant.

VI. Results

People will find robot with non-verbal behavior as more natural with anthropomorphic actions. The manipulation checks which are walking speed of robot, and emotion expressed will be identified by all participants. The participants will like fast speed robot over slow speed robot. The people will find the robot showing head movements and emotions as more interactive and responsive and less mechanical and more humanlike. People will find it more expressive and lively the one showing different body postures. The likability will be more for robot with head movements, emotions, and fast speed. When people have leisure time, and want to play with nao robot then they might like slow speed robot, but when they are in hurry, they would prefer fast walking speed of robot. So the speed will be depended on people's time. The robot showing emotions may be perceived as more friendly robot, and more people might approach it, by contemplating its personality as extroverted because it shows certain emotions. The emotions can also lead to people thinking that robot is emotional or interesting rather that boring.

The head movements may lead to perceived intelligent, more confident robot because people might think that robot knows which object it is as it looks towards the object. The competence of the robot showing head movements will be more as people might think that robot can identify obstacle and is avoiding it intentionally. People might find the robot funny when it is standing and thinking for couple of seconds, particularly, the body posture for confusion is exaggerated, so people will clearly know that robot is thinking and may find that body posture funny.

The expected results of IOS questionnaire is people might feel closer with robot, which shows head movements and expresses emotions. Apparently, people might feel distinct with robot, which does not show any non-verbal cues and simply walks by looking in straight direction.

VII. Discussion

In order to find the answers of the research questions, I need to perform the experiment. So here I am discussing the expected results of the experiment, if conducted.

The effect of walking speed will be based time of the people. If person is free to play with robot or want to get entertained by NAO then they might like the slow speed of NAO, but if the are bored while playing with NAO over a long time, then they might like robot which has fast walking speed. And when people are busy or need something urgently, asks nao to go over other place by walking and at that time if NAO walks at slow speed, person might get annoyed with NAO.

Sometimes, when person is having bad mood then NAO can change the mood of human by performing certain body postures. Like when robot performs the overexaggerated thinking posture, confusion emotion, at that time, person watching it might find it funny. So, by performing certain body postures, robot expresses its emotions and people can easily identify those emotions, and which lead to change in their own mood. The people may feel sorry or may sympathize with robot when it shows sad emotions, when it hot the obstacle in fast speed. People may also determine the robot's personality as more expressive, emotional and extroverted as it shows certain emotions in public. The head movements will lead the people to think that robot understands the environment around it and even distinguish between obstacles and human beings. So, they might think that robot showing head movement is more intelligent, competent, and aware of environment. People may think that robot does not want to get hurt by colliding with obstacles, so it intentionally avoids the obstacles and walks aways from it.

The limitations is that NAO have sonar sensors as distance sensors. It only cover the 45 degrees in front if it. So sometimes when object is very near by slightly to the left or right then it will not be detected using the distance sensors. Instead of sonar, we can use other kind of distance sensor whose coverage area is more. However, if number of sonar sensor increases then more area can be covered and can identify the obstacles in environment around it. Apparently, fast speed of nao robot may sometimes lead to imbalance and unknown behavior.

In future, work on NAO robot with fast walking speed should be expanded along with expressing non-verbal behavior for various applications where it might be more helpful to people.

VIII. Conclusions

From this project, I learnt about importance of non-verbal behavior in robots. Humans don't even notice these cues and unconsciously perform it, but if robot don't not perform these non-verbal cues, then it might be perceived as socially inappropriate or rude behavior. Another thing is head movement, when robot does not have facial features like typical mouth, nose, or eyes, still it can direct the human's attention by head movement. When children are bored and want to play with something, they can play with NAO robot, as by appearance it is cute, and small in size and light in weight, security wise it is not dangerous. The walking speed of the robot is important factor, if robot is bigger in size then people will prefer slow walking speed of robot as it may be dangerous if the accident occurs by robot. But in case of NAO robot, it is small in height and light in weight, so fast walking speed of NAO robot will be preferable by people. When people are in bad mood or upset, then robot can cheer them up, by showing certain emotions using body postures. So, the mood of people gets changed or affected by behavior of robot, as people does not consider the robot as a simple machine, but as a social being.

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APPENDIX

A. Controller Code

```
#include <assert.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <webots/distance_sensor.h>
#include <webots/keyboard.h>
#include <webots/led.h>
#include <webots/motor.h>
#include <webots/robot.h>
#include <webots/touch_sensor.h>
#include <webots/utils/motion.h>

#ifdef _MSC_VER
#define snprintf sprintf_s
#endif

#define MAX_SPEED 4.0

static int time_step = -1;

bool left, right, straight;

static WbDeviceTag us[2];
static WbDeviceTag leds[7];
static WbDeviceTag LShoulderPitch,
    RShoulderPitch;
static WbDeviceTag HeadYaw, HeadPitch;
static WbDeviceTag LHipYawPitch,
    RHipYawPitch;
static WbDeviceTag LHipRoll,LHipPitch,
    RHipRoll,RHipPitch;
static WbDeviceTag LAnklePitch, LAnkleRoll,
    RAnklePitch, RAnkleRoll;
static WbDeviceTag LKneePitch,RKneePitch;
static WbDeviceTag lfoot_lbumper,
    lfoot_rbumper;
static WbDeviceTag rfoot_lbumper,
    rfoot_rbumper;

static WbMotionRef hand_wave, stable, ready,
    move_fast, go_slow;
static WbMotionRef move_back;
static WbMotionRef sturn_left, sturn_right,
    bturn_left, bturn_right;
static WbMotionRef head_left, head_right;
static WbMotionRef happy, sad, confused;
static WbMotionRef currently_playing = NULL;

static void find_and_enable_devices() {
  us[0] = wb_robot_get_device("Sonar/Left");
  us[1] = wb_robot_get_device("Sonar/Right");
  int i;
  for (i = 0; i < 2; i++)
```

```c
    wb_distance_sensor_enable(us[i],
        time_step);

  lfoot_lbumper = wb_robot_get_device
    ("LFoot/Bumper/Left");
  lfoot_rbumper = wb_robot_get_device
    ("LFoot/Bumper/Right");
  rfoot_lbumper = wb_robot_get_device
    ("RFoot/Bumper/Left");
  rfoot_rbumper = wb_robot_get_device
    ("RFoot/Bumper/Right");
  wb_touch_sensor_enable(lfoot_lbumper,
    time_step);
  wb_touch_sensor_enable(lfoot_rbumper,
    time_step);
  wb_touch_sensor_enable(rfoot_lbumper,
    time_step);
  wb_touch_sensor_enable(rfoot_rbumper,
    time_step);

  leds[0] = wb_robot_get_device
    ("ChestBoard/Led");
  leds[1] = wb_robot_get_device
    ("RFoot/Led");
  leds[2] = wb_robot_get_device
    ("LFoot/Led");
  leds[3] = wb_robot_get_device
    ("Face/Led/Right");
  leds[4] = wb_robot_get_device
    ("Face/Led/Left");
  leds[5] = wb_robot_get_device
    ("Ears/Led/Right");
  leds[6] = wb_robot_get_device
    ("Ears/Led/Left");


  // shoulder pitch motors
  RShoulderPitch = wb_robot_get_device
    ("RShoulderPitch");
  LShoulderPitch = wb_robot_get_device
    ("LShoulderPitch");

  HeadYaw = wb_robot_get_device
    ("HeadYaw");
  HeadPitch = wb_robot_get_device
    ("HeadPitch");

  LHipYawPitch = wb_robot_get_device
    ("LHipYawPitch");
  RHipYawPitch = wb_robot_get_device
    ("RHipYawPitch");

  LHipRoll = wb_robot_get_device
    ("LHipRoll");
  LHipPitch = wb_robot_get_device
    ("LHipPitch");
  RHipRoll = wb_robot_get_device
    ("RHipRoll");
  RHipPitch = wb_robot_get_device
    ("RHipPitch");

  LAnklePitch = wb_robot_get_device
    ("LAnklePitch");
  LAnkleRoll = wb_robot_get_device
    ("LAnkleRoll");
  RAnklePitch = wb_robot_get_device
    ("RAnklePitch");
  RAnkleRoll = wb_robot_get_device
    ("RAnkleRoll");

  LKneePitch = wb_robot_get_device
    ("LKneePitch");
  RKneePitch = wb_robot_get_device
    ("RKneePitch");


  // keyboard
  wb_keyboard_enable(10 * time_step);
}

// load motion files
static void load_motion_files() {
  hand_wave = wbu_motion_new
  ("../../motions/HandWave.motion");
  ready = wbu_motion_new
  ("../../motions/ready.motion");
  stable = wbu_motion_new
  ("../../motions/stable.motion");
  move_fast = wbu_motion_new
  ("../../motions/move_fast.motion");
  go_slow = wbu_motion_new
  ("../../motions/go_slow.motion");
  move_back = wbu_motion_new
  ("../../motions/move_back.motion");
  sturn_left = wbu_motion_new
  ("../../motions/TurnLeft40.motion");
  sturn_right = wbu_motion_new
  ("../../motions/TurnRight40.motion");
  bturn_left = wbu_motion_new
  ("../../motions/TurnLeft60.motion");
  bturn_right = wbu_motion_new
  ("../../motions/TurnRight60.motion");
  head_left = wbu_motion_new
  ("../../motions/head_left.motion");
  head_right = wbu_motion_new
  ("../../motions/head_right.motion");
  happy = wbu_motion_new
  ("../../motions/Happy.motion");
  sad = wbu_motion_new
  ("../../motions/Sad.motion");
  confused = wbu_motion_new
  ("../../motions/think.motion");
```

```
}

static void start_motion(WbMotionRef motion) {
  // interrupt current motion
  if (currently_playing)
    wbu_motion_stop(currently_playing);

  // start new motion
  wbu_motion_play(motion);
  currently_playing = motion;
}

static void loop_motion
    (WbMotionRef motion,bool a) {
  wbu_motion_set_loop(motion,a);
  if (a) {
    start_motion(ready);
  }
  else if (! a) {
    wbu_motion_play(stable);
    wbu_motion_stop(motion);
  }
}

static void hit_sad() {
  int ll = (int)
  wb_touch_sensor_get_value(lfoot_lbumper);
  int lr = (int)
  wb_touch_sensor_get_value(lfoot_rbumper);
  int rl = (int)
  wb_touch_sensor_get_value(rfoot_lbumper);
  int rr = (int)
  wb_touch_sensor_get_value(rfoot_rbumper);

  if ((ll==1) || (lr==1)
    || (rl==1) || (rr==1))
  {
    printf("|%d\t%d| |%d\t%d|\n",
        ll, lr, rl, rr);
    loop_motion(move_fast,false);
    loop_motion(go_slow,false);
    wbu_motion_play(sad);
  }
}

static void detect_object() {
  double dist[2];
  int i;
  for (i = 0; i < 2; i++)
    dist[i] =
    wb_distance_sensor_get_value(us[i]);

  straight = (dist[0] <= 2)
    & (dist[1] <= 2);
  left = (dist[0] <= 0.8)
    & (dist[1] > 0.8);
  right = (dist[1] <= 0.8)
    & (dist[0] > 0.8);

  if (straight){
    printf("Obstacle Ahead.
        Please stop\n");
    wb_motor_set_position
        (HeadYaw, 0);
    wb_motor_set_velocity
        (HeadYaw, MAX_SPEED);
  }
  else if (left){
    printf("Left\n");
    wb_motor_set_position
        (HeadYaw, 1);
    wb_motor_set_velocity
        (HeadYaw, (0.5*MAX_SPEED));
  }
  else if (right){
    printf("Right\n");
    wb_motor_set_position
        (HeadYaw, -1);
    wb_motor_set_velocity
        (HeadYaw, (0.5*MAX_SPEED));
  }
  else{
    wb_motor_set_position
        (HeadYaw, 0);
    wb_motor_set_velocity
        (HeadYaw, (0.5*MAX_SPEED));
  }
}

static void set_all_leds_color
    (int rgb)
{
  int i;
  for (i = 0; i < 5; i++)
    wb_led_set(leds[i], rgb);
  wb_led_set(leds[5], rgb & 0xff);
  wb_led_set(leds[6], rgb & 0xff);
}

static void print_help() {
  printf("----------nao----------\n");
  printf("The 3D window should be focused");
  printf("[Up]: move forward Slow speed\n");
  printf("[Ctrl]+[Up]: move forward
    Fast speed\n");
  printf("[Down]: move backwards\n");
  printf("[<-][->]: slightly turn left/right
    (40 degree)\n");
  printf("[Shift]+[<-][->]: turn left/right
    (60 degree)\n");
  printf("[Alt]+[<-][->]: head movement
    left/right\n");
```

```
  printf("[1]: for happy expression\n");
  printf("[2]: for sad expression\n");
  printf("[3]: for confused and thinking
    expression\n");
  printf("[L]: look at left side\n");
  printf("[R]: look at right side\n");
  printf("[END]: to stop all motions
    and stand still\n");
  printf("[H]: print this help message\n");
}


static void terminate() {
  wb_robot_cleanup();
}

static void simulation_step() {
  if (wb_robot_step(time_step) == -1)
    terminate();
  else
  {
    detect_object();
    hit_sad();
  }
}

static void run_command(int key) {

  switch (key) {
    case WB_KEYBOARD_UP:
      loop_motion(go_slow,true);
      wb_motor_set_position(LHipYawPitch, 0);
      wb_motor_set_position(RHipYawPitch, 0);
      wb_motor_set_velocity(LHipYawPitch,
        MAX_SPEED);
      wb_motor_set_velocity(RHipYawPitch,
        MAX_SPEED);
      start_motion(go_slow);
      break;
    case WB_KEYBOARD_DOWN:
      start_motion(move_back);
      break;
    case WB_KEYBOARD_CONTROL | WB_KEYBOARD_UP:
      loop_motion(move_fast,true);
      wb_motor_set_position(LHipYawPitch, 0);
      wb_motor_set_position(RHipYawPitch, 0);
      wb_motor_set_velocity(LHipYawPitch,
        MAX_SPEED);
      wb_motor_set_velocity(RHipYawPitch,
        MAX_SPEED);
      start_motion(move_fast);
      break;
    case WB_KEYBOARD_LEFT:
      start_motion(sturn_left);
      break;
    case WB_KEYBOARD_RIGHT:
      start_motion(sturn_right);
      break;
    case WB_KEYBOARD_SHIFT | WB_KEYBOARD_LEFT:
      start_motion(bturn_left);
      break;
    case WB_KEYBOARD_SHIFT | WB_KEYBOARD_RIGHT:
      start_motion(bturn_right);
      break;
    case WB_KEYBOARD_ALT | WB_KEYBOARD_LEFT:
      start_motion(head_left);
      break;
    case WB_KEYBOARD_ALT | WB_KEYBOARD_RIGHT:
      start_motion(head_right);
      break;
    case WB_KEYBOARD_END:
      set_all_leds_color(0x000000);

      /*wb_motor_set_position(LAnklePitch, 0);
      wb_motor_set_position(RAnklePitch, 0);
      wb_motor_set_position(LAnkleRoll, 0);
      wb_motor_set_position(RAnkleRoll, 0);
      wb_motor_set_position(LHipRoll, 0);
      wb_motor_set_position(RHipRoll, 0);
      wb_motor_set_position(LHipPitch, 0);
      wb_motor_set_position(RHipPitch, 0);
      wb_motor_set_position(LKneePitch, 0);
      wb_motor_set_position(RKneePitch, 0); */
      wb_motor_set_position(LHipYawPitch, 0);
      wb_motor_set_position(RHipYawPitch, 0);

      /*wb_motor_set_velocity(LAnklePitch, 1);
      wb_motor_set_velocity(RAnklePitch, 1);
      wb_motor_set_velocity(LAnkleRoll, 1);
      wb_motor_set_velocity(RAnkleRoll, 1);
      wb_motor_set_velocity(LHipRoll, 1);
      wb_motor_set_velocity(RHipRoll, 1);
      wb_motor_set_velocity(LHipPitch, 1);
      wb_motor_set_velocity(RHipPitch, 1);
      wb_motor_set_velocity(LKneePitch, 1);
      wb_motor_set_velocity(RKneePitch, 1); */
      wb_motor_set_velocity(LHipYawPitch,
        4.16);
      wb_motor_set_velocity(RHipYawPitch,
        4.16);
      start_motion(stable);
      loop_motion(move_fast,false);
      loop_motion(go_slow,false);
      loop_motion(move_back,false);
      break;
    case '1':
      set_all_leds_color(0x00ff00);
      start_motion(happy);
      break;
    case '2':
      set_all_leds_color(0x0000ff);
      start_motion(sad);
```

```
      break;
    case '3':
      set_all_leds_color(0xff0000);
      start_motion(confused);
      break;
    case 'H':
      print_help();
      break;
  }
}

int main() {
  wb_robot_init();
  time_step =
    wb_robot_get_basic_time_step();
  find_and_enable_devices();
  load_motion_files();
  print_help();

  // walk forwards
  wbu_motion_set_loop(hand_wave, true);
  wbu_motion_play(hand_wave);

  // until a key is pressed
  int key = -1;
  do {
    simulation_step();
    key = wb_keyboard_get_key();
  } while (key >= 0);

  wbu_motion_set_loop(hand_wave, false);

  while (1) {
    if (key >= 0)
      run_command(key);
    simulation_step();
    key = wb_keyboard_get_key();
  }
  return 0;
}
```

B. *Happy Emotion (.motion file)*

```
#WEBOTS_MOTION,V1.0,RShoulderPitch,
RShoulderRoll,RElbowRoll,LShoulderPitch,
LShoulderRoll,LElbowRoll
00:00:000,Pose1,0,0,1.396,0,0,-1.396
00:00:240,Pose2,-1.3,0.1,0,-1.3,-0.1,0
00:00:280,Pose3,-1.3,0.2,*,-1.3,-0.2,*
00:00:320,Pose4,-1.3,0.3,*,-1.3,-0.3,*
00:00:360,Pose5,-1.3,0.2,*,-1.3,-0.2,*
00:00:400,Pose6,-1.3,0.1,*,-1.3,-0.1,*
00:00:440,Pose7,-1.3,0,*,-1.3,0,*
00:00:480,Pose8,-1.3,-0.1,*,-1.3,0.1,*
00:00:520,Pose9,-1.3,-0.2,*,-1.3,0.2,*
00:00:560,Pose10,-1.3,-0.3,*,-1.3,0.3,*
00:00:600,Pose11,-1.3,-0.4,*,-1.3,0.4,*
00:00:640,Pose12,-1.3,-0.5,*,-1.3,0.5,*
00:00:680,Pose13,-1.3,-0.5,*,-1.3,0.5,*
00:00:720,Pose14,-1.3,-0.4,*,-1.3,0.4,*
00:00:760,Pose15,-1.3,-0.3,*,-1.3,0.3,*
00:00:800,Pose16,-1.3,-0.2,*,-1.3,0.2,*
00:00:840,Pose17,-1.3,-0.1,*,-1.3,0.1,*
00:00:880,Pose18,-1.3,0,*,-1.3,0,*
00:00:920,Pose19,-1.3,0.1,*,-1.3,-0.1,*
00:00:960,Pose20,-1.3,0.2,*,-1.3,-0.2,*
00:01:000,Pose21,-1.3,0.2,*,-1.3,-0.2,*
00:01:040,Pose22,-1.3,0.1,*,-1.3,-0.1,*
00:01:080,Pose23,-1.3,0,*,-1.3,0,*
00:01:120,Pose24,-1.3,-0.1,*,-1.3,0.1,*
00:01:160,Pose25,-1.3,-0.2,*,-1.3,0.2,*
00:01:200,pose26,-1.3,-0.3,*,-1.3,0.3,*
00:01:240,Pose27,-1.3,-0.4,*,-1.3,0.4,*
00:01:280,Pose28,-1.3,-0.5,*,-1.3,0.5,*
00:01:320,Pose29,-1.3,-0.4,*,-1.3,0.4,*
00:01:360,Pose30,-1.3,-0.3,*,-1.3,0.3,*
00:01:400,Pose31,-1.3,-0.2,*,-1.3,0.2,*
00:01:440,Pose32,-1.3,-0.1,*,-1.3,0.1,*
00:01:480,Pose33,-1.3,0,*,-1.3,0,*
00:01:520,Pose34,-1.3,0,*,-1.3,0,*
00:01:560,Pose35,-1.3,0,*,-1.3,0,*
00:02:000,Pose36,1.4,0,*,1.4,0,*
00:05:000,Pose37,1.4,0,*,1.4,0,*
```

C. *Sad Emotion (.motion file)*

```
#WEBOTS_MOTION,V1.0,HeadPitch
00:00:000,Pose1,0
00:00:040,Pose2,0.1
00:00:080,Pose3,0.2
00:00:120,Pose4,0.25
00:00:160,Pose5,0.3
00:00:200,Pose6,0.35
00:00:240,Pose7,0.4
00:01:000,Pose8,0.4
00:02:000,Pose9,0
```

D. *Confused Emotion (.motion file)*

```
#WEBOTS_MOTION,V1.0,HeadPitch,
HeadYaw,LShoulderPitch,LElbowYaw,
LElbowRoll
00:00:000,Pose1,0,0,1.5,0,0
00:00:100,Pose2,0.2,0,1.5,0,0
00:00:400,Pose3,0.2,0,1.5,0,0
00:01:200,Pose4,0.2,1,1.5,0,0
00:01:300,Pose5,0.2,1,1.5,0,0
00:01:500,Pose6,0.2,1,1.5,0,0
00:01:800,Pose7,0.2,0,1.5,0,0
00:01:900,Pose8,0.2,0,1.5,0,0
00:02:200,Pose9,0.2,-1,1.5,0,0
00:02:300,Pose10,0.2,-1,1.5,0,0
00:02:500,Pose10,0.2,-1,1.5,0,0
00:02:800,Pose11,0,0,1.5,0,0
00:03:200,Pose12,0,0,1.5,-1,-1.54
```

```
00:03:300,Pose13,0,0,0,-1,-1.54
00:03:500,Pose14,0,0,0,-1,-1.54
00:03:800,Pose15,0,0,0,-1,-1.54
00:04:500,Pose16,0,0,0,-1.2,-1.54
00:04:800,Pose17,0,0,0,-1.2,-1.54
00:05:200,Pose18,0,0,0,-1.2,-1.54
00:05:500,Pose19,0,0,0.7,0,0
00:05:900,Pose20,0,0,1.5,0,0
```

E. Stable Mode (.motion file)

```
#WEBOTS_MOTION,V1.0,LHipRoll,LHipPitch,
LKneePitch,LAnklePitch,LAnkleRoll,
RHipRoll,RHipPitch,RKneePitch,RAnklePitch,
RAnkleRoll
00:03:000,Pose1,0,0,0,0,0,0,0,0,0,0
```

F. Other Information

I have changed motion files duration for fast and slow walking speed, and its poses. For fast speed, duration is reduced and for slow speed duration is increased. Those files are present in zip folder submitted. For walking infinitely, this motion files are manipulated and kept in loop in the controller code.