Growing Emotions

Using Affect to Help Children Understand a Plant's Needs

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***Abstract*—This study proposes a homeostasis-based affective system with emotion and mood as a way to communicate a plant´s health state and environmental needs to preschool and primary school children. A system is proposed that expresses mood and emotion to express the plant's health state and its affective reaction to user-induced environmental changes respectively. A long-term goal is to enhance empathic reasoning in children and respect for plants and life in general, using affect as a communicative interface (even though the underlying system is not emotive per se). A fundamental issue addressed in this work is to what extend it is useful to add affective communication to a system that is otherwise non-affective (plants in our case) in order to better understand that system's state. A computer simulation of the affective plant was tested (n=7). Our results suggest that children can identify the simulated plant's needs and state based on graphically expressed affect, and can act to enhance the homeostasis of the plant.**

Keywords—machine affect expression; interactive system; education; plant; environment

I. INTRODUCTION

Pressure on the environment caused by humans increases. As a result governments are increasing the spreading of information and developing policies to bring a halt to this. Schools are given more responsibility to educate children on caring for the environment. Ways to educate the next generation are not keeping up with the needs for education plans [17]. An educational tool is proposed that makes environmental education a positive experience for both teachers and students. The proposed tool is a hands-on activity in which preschool children are actively involved, which are requirements to make children acquire new knowledge, skills, and attitudes. Being actively involved helps students to apply knowledge provided by the teacher and giving direct feedback helps to make plants and their environment fun and easy to understand [13].

Preschool children are often given plants to take care of in a classroom setting. Aside from the inherent science lesson given by observing a living entity, another reason for this activity could be the promotion of empathy [3]. Teachers hope that by making a child responsible for another living being, it will teach the child how to care about others.

Empathy is one of the most challenging skills for preschool children, understanding another person's perspective and keeping this in mind whilst taking actions is hard for self centered minds [5]. Empathy is needed for people to consider the needs of others; Cavner [5] describes that the ability to feel empathy is directly related to the ability to create relationships. Relationships let children move beyond their own needs and care for others.

This research focuses on a branch of affective computing; machine affect expression [8]. Machine affect expression aims to allow inanimate (emotionless) objects to exhibit a set of emotions that could impact people's affect towards these objects. In this research we use synthetic emotion generation based on biological needs of a plant to add simulated emotions to that plant. Our aim in this work is to improve the ability of children to take care of a living object that normally is not associated with affect or affective communication by using emotions as a means to give insight into the consequences of the child's actions on the objects' internal state. During normal interaction with a real plant, the plant will show its needs and health state only after a long time of waiting (hanging flowers, dropping leaves). Hence, the more immediate timescale and the fact that consequences of actions are communicated affectively are a crucial factor of our system. This hopefully enhances the learning experience of taking care of another living being, because consequences of actions are seen more quickly. A secondary aim may be the improvement of the empathic skill of the care-takers, this is however not the focus of this study. Our work also informs us about the more fundamental issue of acceptability and usefulness of affect as an "add on" to an otherwise non-affective system, in order to better understand that system's internal state.

In this paper we report on a pilot experiment to test if children can identify a plant's needs through graphically expressed affect based on an affective model of the plant's basic needs. To answer this question, two sub questions need to be answered; How to simulate emotion for a plant and how to express this emotion to children.

Based on prior research it is expected that children are able to rate a mood on one dimension (valence) based on the expression of that mood through a progressive smiley scale [10]. It is also expected that children are able to identify four basic emotions using the expression of these emotions through

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four categorical emoticons [16]. We hypothesize that children are able to identify *that* the plant has needs, and can accordingly *identify the right* need and *act* upon it.

II. Related Work

One of the earliest examples of a relational artifact came on the market in 1996 with the introduction of Bandai's Tamagotchi, a small virtual pet in the form of an egg with a screen [15]. The screen displays the internal state of the pet and its current needs. If the child was successful in determining the creatures need the pet would be "happy".

Moving away from animals, Flona is a system that implements lifelike traits to a plant, the plant's branches are moved by stepper motors trying to induce an affective state in users [14]. However, it is not defined what kind of affect, positive or negative, Flona tries to induce to its users, since Flona does not express defined emotions. Therefore, it does not explicitly encourage users to take care of the plant by means of affective reactions.

Plantio is a pot that augments the plant's reaction to changes in the environment [11]. When users interact with the plant, the actuators in the plant register environmental changes and the pot expresses direct feedback in the form of LEDs, vibrations and sound. Actions on which the plant reacts include touch, talking, watering, proximity and moving the plant. The state of the plant is not mapped to any emotion. The output is directly linked to environmental changes.

The Pet Plant tries to develop an inanimate emotional interactive tool for the elderly [12]. It is an ordinary house plant with a pot augmented with LEDs that react to touching the pot, speech and touching the leaves. In their research they showed that people attribute more emotion to the pet plant, in comparison with a similar plant that does not respond to human presence or action.

III. Approach

In order for children to understand the emotional state of the plant we need a suitable expression mechanism. Research in graphic emotion recognition showed that four-year-olds have the ability to recognize graphic representations of the emotions happy, sad, afraid, and angry [16]. The research also showed that certain graphic representations are easier to recognize than others. Visser describes that the lower part of the face plays an important part in the emotions happy and sad, whereas the upper part of the face is more important for the emotions afraid and angry.

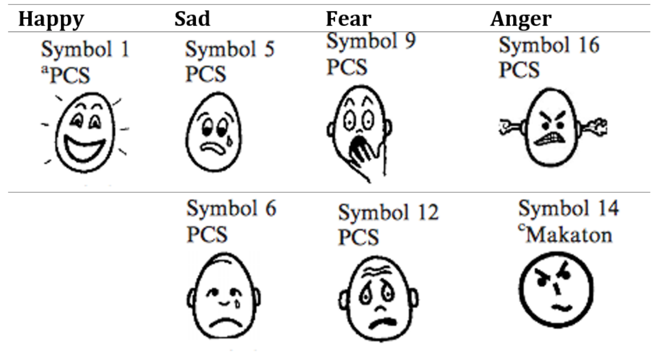

Fig 1. The four best recognizable emotions and their best scoring graphical representation (Visser, Alant, & Harty, 2008).

In order for children to understand the mood of the plant, we opted for a simple positive-negative scale. In research on children with minimal verbal and reading skills, the Kunin smiley scale is often used [10]. This scale is used for children to convey their attitude towards a product or their overall well-being. The scale is used to express pleasure (valence).

Fig. 2 ISO-9241, the Kunin smiley scale (Kunin, 1998)

Unlike animals, plants cannot move or manipulate their environment to provide for their needs themselves (at least not at a timescale we are accustomed to perceive the world around us); they are dependent on external factors such as water, sunlight, carbon dioxide and nutrients [2]. Plants need all of these ingredients to generate energy, a process also known as photosynthesis, and to complete a life cycle [4]. The exact needs differ greatly per plant, but for the purpose of this research a simplified model of the plant's needs will be used, in which only water, light and correct temperature are taken into account.

As mentioned, a plant cannot initiate any actions to meet its needs, a caretaker needs to take actions for the plant (at least if it is a house plant in a pot). To trigger caring behavior, an affective system is designed that expresses the plant's state as it relates to its needs. Needs are met by manipulating the environmental factors water, light and moisture. The affective system is therefore based on homeostatic principles derived from how well the plant is surviving.

A plant has three environmental factors; moisture, temperature and light. These factors are combined to represent the internal state of the plant. Mood is derived from this internal state. Each environmental factor is represented by a variable, ranging from -10 to 10. Each variable has an optimal zone defining the range in which this factor is comfortable for the plant. The distance from the current environmental state to the optimal zone is stored as a variable, the *need-state*, T_{state}, M_{state} and L_{state} for temperature, moisture and light. The need-state is mapped to a range from 0 to 10, where 10 represents

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the biggest distance to the optimal zone and 0 represents that the variable is within the optimal zone. The need-states are combined to reflect the current mood of the plant. This is represented on a one-dimensional pleasure scale, ranging from -10 (not pleasurable) to 10 (very pleasurable). Because not every need is equally important for the plant [1], each need-state is assigned a certain weight in the calculation of the mood. Mood is calculated according to the following formula:

$$mood = \left(\frac{(T_{state} \times T_{weight}) + (L_{state} \times L_{weight}) + (M_{state} \times M_{weight})}{10} \right) \times -20 + 10 \quad (1)$$

Note that the accumulated weight can exceed 1.0, which can lead to a calculated mood below -10 or above 10. In the system this is limited to [-10, 10].

A user action (e.g. watering the plant) leads to a sudden and steep change in the need state. Such a change will thus lead to a change in the mood of the plant. But to provide direct feedback to the user (the child executing the action) an emotion is generated and expressed. Emotion is used to express if a user action will aid or oppose the plant in reaching its required state (having each environmental variable within the required threshold), again in accordance with homeostatic principles.

Four-year-old children are at least capable of recognizing four of Ekman's basic emotions [7]; happy, sad, fear and anger [16]. However, because we wanted to be able to express two levels of positive and negative, we needed our affective system to have two positive and two negative emotions. We chose joy (low intensity positive), happiness (high intensity positive), fear (low intensity negative) and anger (high intensity negative). Although it is debatable whether anger is of higher intensity then fear (anger being an emotion that is typically attributed to someone doing wrong on purpose), we reasoned that fear would be modeling something bad happening without intentional harm (a kid manipulating the environment in the wrong direction), while anger would be the plant's affective reaction when a kid would continue to do so (effectively attributing the wrongdoing to the kid because the change in the environment is assumed to be intentional at this point not due to the kid not knowing what it is supposed to do). Emotion is based on changes in *one environmental variable at a time*, using the current environmental state and the direction of change. To do so, each environmental scale is split up into five zones, as seen in figure 3.

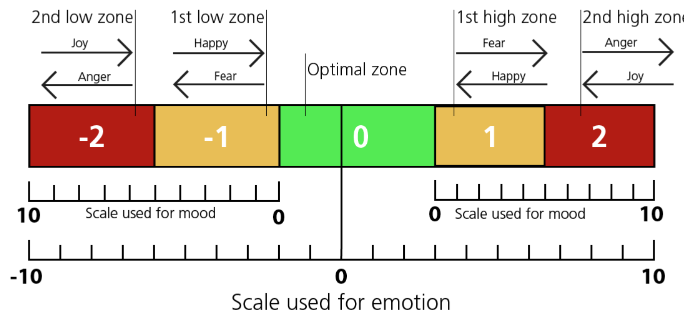

Fig. 3. Graphical representation of how an environmental variable is mapped to mood and emotion. The mood scale is used to calculate how much mood is influenced by a deviation from the optimal zone (i.e., the *need-state*, see formula 1). The emotion scale is simply the environmental variables raw value, and is, together with the zones, the basis of the calculation of the emotion. For example, when temperature goes up from -10 to -4, this generates happiness with intensity 6, and when it goes up from 7 to 9 it generates anger with intensity 2 (note that intensities are not expressed in the current setup).

When a change in environmental variable occurs, the direction of the change will bring a variable closer to (aiding) or further away (opposing) from the optimal zone. Aiding the plant will lead to either joy or happiness, opposing leads to anger or fear. The exact emotion is dependent of the current value of the changed variable, as can be seen in Figure 3. Note that no emotion is shown when a change happens within the optimal zone; the change is not significant for the plant and thus invokes no emotion.

Graphical representations of faces (emoticons) are used to express the affective state. The expression for the mood is based on the Kunin smiley scale ISO-9241 as discussed earlier, but extended to be a progressive scale as shown in Figure 4. Mood is used to generate the curve of the mouth, with a slight offset at pleasure 0, as children do not identify a straight mouth with neutral pleasure [6].

Figure 4. Progressive scale of the mood.

Emotions are expressed categorically (Figure 5), and directly mapped from the zones as defined in Figure 3. To highlight the distinction between the expression of mood and emotion, the latter has a different configuration for the eyes, has eyebrows (except for "joy") and always an open mouth. These emoticons are based on research by Visser [16].

Figure 5. The emoticons for the emotions; 1. Joy 2. Happy 3. Fear 4. Anger

Mood is constantly shown when there are no sudden environmental changes, the emotion is shown when there are, and emotions mask the expression of mood. The timing of this masking is based on the duration of the environmental event. The emotion onset is immediate, the emotion is sustained during the event and decay is immediate when the event ends (so there is no expression of emotion intensity).

IV. METHOD

A user test was conducted to validate the use of mood to communicate a plant's state to children and the use of emotion to communicate feedback on actions.

Participants

Participants (n=7) were recruited in the age of six to nine years old at a daycare center in Delft (with prior permission). A total of seven children participated in the study, three males and four females.

Simulation system

During the test the participant would interact with a simulation of the system. This simulation would run on a laptop computer. A script was available for the researcher as well as an observation sheet, filled in by a second researcher.

The simulation consists of a software model of the affective system with a graphical user interface. A static image of a plant is present, with a dynamic emoticon on the plant's pot showing either the mood or the emotion. The mood is based on virtual environmental variables (moisture, light and temperature). Through graphical icons the user can add water, change temperature and light. A button-click translates to an increment or decrement of 1 on the -10 to 10 scale of each environmental variable. The duration of an emotion expression is set to a fixed 1 second to simulate the duration of an environmental change in a set-up with physical sensors. The parameters used for each environmental variable in the affective system of the test can be found in Table 1. Participants did not see the actual environmental state of the plant.

The Test Setting

The test consisted of three training stages, one for each environmental variable. In these three stages the participants were asked to only change the variable that was trained in that stage. In the first stage the water need of the plant was explained. The participant was shown a predefined state with the plant expressing a low pleasure mood with only a button available to water the plant. The participant was asked to water the plant with the button to show it's affective reaction. This first stage was done twice to make the participants familiar with the system's graphical user interface. The second and third stage included respectively light and temperature, so new buttons were added accompanied by a verbal explanation. A standardized script was used for this training stage.

After the training stages, five stages with predefined environmental values were shown to each participant resulting in 7x8=56 play sessions. The values of each stage can be found in Table 2.

Table 1. Environmental parameters used in test

Environmental variable	Low threshold	High threshold	Weight
Moisture	-1	1	0.8
Light	-4	10	0.8
Temperature	-3	3	0.8

Table 2. Preset environmental values and resulting mood for each stage.

	Pleasure value	Water	Light	Temperature
Stage 1	-6	-10	0	0
Stage 2	-6	0	-10	0
Stage 3	-6	0	0	10
Stage 4	-7	-8	6	5
Stage 5	-10	0	-10	-6
Stage 6	10	0	0	0
Stage 7	-10	-10	-10	-10
Stage 8	6	2	-3	-4

Experimental setup

The researcher and participant sat down and the researcher explained the process. The parents of the participant in the meantime were asked to fill out an informed consent, when both parents and child agreed to participate the test would start. The participant was shown the first scene while a researcher gave an explanation and asked questions as stated in the script, responses were noted in the observation sheet. The participant used a mouse to interact with the system, clicking buttons to perform actions until the participant expressed that he or she was done, after which the next stage was shown. After each stage the participant was asked questions regarding the stage. Furthermore, notes on (verbal) expressions by the participants were made on the observation sheet. All button clicks by the participants were logged and exported to a CSV file after each test, accompanied by a randomly generated ID for each participant. When all stages were covered the researcher thanked the participant and the parent.

V. RESULTS

Focusing on the last five experimental (non-training) stages, the results of this small number of tests are promising. All tests had an average mood value over time above 0, meaning the participants saw some form of smile on the progressive scale and were able to keep the plant happy overall. All participants continued the simulation in case the mood showed a negative mood. Apart from stage 5, each individual participant ended up with a mood above 1. Stage 6 had a perfect starting situation, and resulted in hardly any action by the participants. One user lowered the mood value by adding too much water, two others corrected their actions and ended at a perfect mood. All other participants did nothing at this stage, and stated the plant did not need anything, which is exactly as intended. In the following analysis stage 6 is left out, as there is hardly any data available.

The participants used an average of 19 clicks per stage, while the most optimal course of action for each stage would result in an average of 10 clicks per stage. The average duration of a stage was 40 seconds, in which the participants raised the mood value by an average of 10.14 points. This shows that the participants were able to interpret the plant's state from the mood expression and that they were able to define whether the plant still had needs. It however did not always lead to a perfect mood (a pleasure of 10), which could be due to over-watering, an irreversible action (water has to evaporate over time in the simulation). It also shows that the participants were able to interpret the emotion expression, as this is necessary for successfully improving the mood because the emotional expression gives feedback about whether the action is in the right direction or not. This is further shown by children's reactions on emotion expression. Participants that clicked a button during a negative emotion expression (fear or anger) switched to a different action 60% of the time. This indicates that the participants interpreted the emotion as undesirable and understood that a different action should be taken.

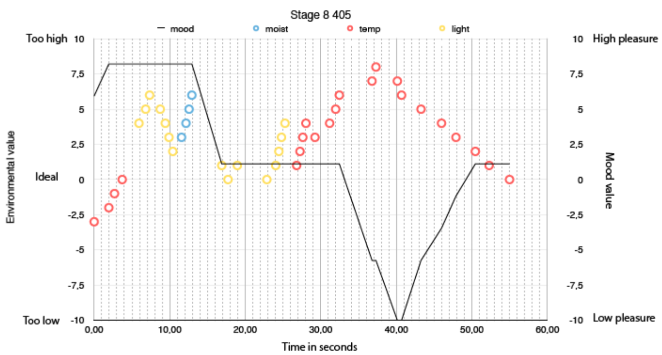

Fig. 6. An example of the progression through stage 8 by a participant. Showing actions, their resulting environmental values (colored circles) and the resulting mood (line) over time.

Stage 8 proved to be the most challenging for all the users, as it started with a rather high mood value and a slightly too high moist level. In figure 6 an example of the progression through this stage by one of the participants can be seen. This participant first raised the temperature, which was the only possible desirable action for this scenario. However, as the mood value was not the highest possible, this participant tried to find out what else could change. Over watering the plant led to a steep decrease in mood. Changing the light value did not cause any change, which led the participant to change to temperature even more. It is shown clearly in this graph that the participant reverses its actions based on the mood shown, ending up with the same mood as before. This is a good example of the plant's affective communication working as intended, and being interpretable by this child.

Observations made during the tests, provided some additional qualitative findings. Most children awaited the emotion to pass, and based their next action on a combination of the shown emotion and the new mood. Most participants followed the arrangement of the buttons on the screen to find out what action resulted in a positive emotion. If a button resulted in a negative emotion, the action was usually reversed by the participant if this was possible. If clicking a button did not result in anything, the participants usually went on to the next button. The test appeared to be fun for many of the children as there were a lot of giggles. Nearly all participants also stated afterwards that they enjoyed playing this 'game'. Participants reacted strongly on the shown emotions, for example, one participant raised a hand to the mouth, shocked that the plant was scared.

VI. DISCUSSION

The results mentioned above are from a fairly small test group (n=7), from different age groups. This makes it challenging to answer the research question based on these results. Further, to show effectiveness of affective communication, ideally one needs to contrast taking care of the system using affective communication with taking care of the system using other means of communication (e.g., icons of the needs). What can be concluded from the test is that the participants managed to understand the principle of the mood and emotion, without confusing the two. The participants interpreted emotion as a reaction to a taken action, and the mood as the overall state of the plant. The children found out what the plant needed, without the plant specifically stating its need, comparable to the discussed related works, such as the Tamagotchi. This research shows that using a combination of emotions and a continuous mood, can steer users in the right direction in taking care of an entity to help it achieve its goals. It should be emphasized that the current simulation and the conducted experiment are far from taking care of a real plant, as this involves much longer timescales and different dynamics, as well as expectations (e.g., kids noted that they like playing this "game", while taking care of a real plant probably is not seen as a game and this might also influence the acceptability of a plant having artificial emotions). To answer these questions we recommend that the system is implemented on top of a real plant, using sensors to measure the environmental variables, followed by a test consisting of preschool children, over a longer period of time.

A challenge encountered was the tendency of children to ask for approval whilst going through the test. Following a tight script with the children proved to be difficult. Great care should be taken to avoid children doing what is intended by the researcher based on subtle cues from the researcher, and it is preferred to test usage without researcher or parent present.

VII. CONCLUSION AND FUTHER WORK

Based on earlier research into the needs of plants and the ability of preschool children to recognize emotions, an affective system was designed that maps a plant's needs and health state to affect in the form of emotion and mood. These emotions and mood were graphically expressed using emoticons that were validated by prior research. A simulated version of the system was tested on a small user group. Our data and observations suggest that that children can identify the simulated plant's needs and state based on graphically expressed affect. The children participating in the test all understood that the display of positive affect was desired, while display of negative affect was to be avoided.

Our research suggests that the addition of affective communication, when done in a meaningful way, even to systems that otherwise are not perceived to be affective (plants), is accepted by children and can be used to understand the internal state of the system, even if that state consists of multiple variables. This conclusion comes with one remark: this should be confirmed with a study taking care of a real plant.

The next step should be a physical prototype of the system; a pot with sensors and a display that shows the plant's affect. A next test should be done with this prototype in a primary school classroom. This test should be done with three conditions: one control group (normal plant), one group using a prototype of the affective plant, and one group using another form of graphical representation of the plant's needs. Such an extensive test should determine whether the affective system actually works on a real plant and whether it supports children in taking care of the plant. This would be the next step towards a longer-term study in which it is investigated if the addition of affective communication helps children to develop more empathy towards living things.

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