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Arturo Cruz-Maya, Roxana Agrigoroaie, and Adriana Tapus

Autonomous Systems and Robotics Laboratory, U2IS
ENSTA ParisTech, Université Paris-Saclay
828 bd des Maréchaux, 91762 Palaiseau cedex France
arturo.cruz-maya@ensta-paristech.fr,
roxana.agrigoroaie@ensta-paristech.fr, adriana.tapus@ensta-paristech.fr

Abstract. The presence of a robot in our everyday life can generate both positive and negative effects on us. While performing a difficult task, the presence of a robot can generate a negative effect on the performance and it can also increase the stress and anxiety levels. In order to minimize these undesired effects, we propose the use of user's motivation, based on the Regulatory Focus Theory. We analyze the effects of using Regulatory oriented strategies in a robot speech, when giving a person the instructions of how to perform a Stroop Test. We found evidence that matching the Chronic Regulatory state of the participants with the Regulatory oriented strategy of the robot improves the user's performance, and a mismatch leads to an increase of cognitive load and stress in the participants.

1 INTRODUCTION

More and more research works in which robots are part of social human-centric environments are developed. The role of the robot in these environments can for example be a personal companion [4], health care assistant for children with autism [5] and for elderly people [12], or teacher for children [19].

The simple presence of a robot can induce both positive and negative effects on people. One example of negative effect is represented by the Social Facilitation effect[20]. According to this effect, the mere presence of a robot can have a negative impact on the performance of a user in a difficult task [7].

Studies have been done in the field of social robotics with the purpose of using the motivation of the user in order to improve its performance. It has been tested in activities related to physical exercises. The authors of [8] have done such a study for elderly people. In [18] the authors used the robot as a fitness companion. Other studies include the use of robot's gaze to increase user's motivation [2], and the use of anthropomorphic robot expressions using robot eyes and arms to maintain learning motivation in elderly people [16].

In this paper, we propose the use of motivation based on the Regulatory Focus theory [6] to match the Chronic Regulatory State of the participants with a Regulatory oriented strategy used by a robot. The Regulatory Focus theory states that people have one of the two different inclinations for decision making: promotion focus or prevention focus. According to the theory, promotion focus is related to risk situations, while prevention focus is related to security. Chronic Promotion Focus people are more inspired by positive models, which emphasize strategies for achieving success. Chronic Prevention Focus people are more inspired by negative models, which highlight strategies for avoiding failure [15]. Furthermore, it was demonstrated that these states can be induced, naming these states as Induced Promotion Focus and Induced Prevention Focus. Mismatch of the induced regulatory state with the Chronic Regulatory State can be counterproductive, resulting in a lower performance of a person in a task, and also an increase of that person's stress level.

To the best of our knowledge, regulatory focus has not been studied before in the field of social robotics. It has been studied in the field of virtual agents [9]. In this case different strategies were used by a virtual agent in a gaming scenario. Results show a regulatory fit effect on the likability of the game for prevention focus users.

In this work, we investigate the effect of regulatory focus induced by a robot to a group of participants, testing the match and mismatch of Chronic Regulatory State of the participants and the Regulatory oriented strategy used by a robot, when the participants performed a Stroop test.

This paper is organized as follows: Section 2 describes the experimental design setup; Section 3 shows the results obtained; and finally Section 4 concludes the paper.

2 EXPERIMENTAL DESIGN SETUP

2.1 Hypotheses

Based on the above statements, we elaborated the following hypotheses:

- H1. When the robot uses a Promotion oriented strategy to motivate the participants, the participants with a Chronic Promotion Focus, should perform better than participants with a Chronic Prevention Focus.
- H2. When the robot uses a Prevention oriented strategy to motivate the participants, the participants with a Chronic Prevention Focus, should perform better than participants with a Chronic Promotion Focus.
- H3. When the robot uses an oriented Strategy not Matching the Chronic Regulatory Focus of the participants, they will be more stressed than participants to which the robot uses a Matching oriented Strategy.

2.2 Scenario Description - Stroop Test

In this experiment, we used a non-verbal word color Stroop test [17]. We developed two types of items (congruent and incongruent) and presented them to the participants in a random order. The purpose of the task was to increase the cognitive load of the participants. The test was displayed on a computer monitor. Before starting the test, the participants were instructed on how to perform the task (using a computer mouse to press on the button, which corresponds to the color of the text). Furthermore, they had 60 trials to practice the test. For the experiment, the participants had to complete 50 trials. After finishing the practice test, the participants had to fill the Mood Questionnaire developed by Crowe and Higgins [6].

Participants were told to pay attention to the instructions given by the robot. They were instructed to start the task when the robot told them that they could start. In order to induce the Regulatory focus state in the participants, we developed 3 sets of instructions to be spoken by the robot. Therefore, we had 3 conditions, which are presented in the following section. After finishing the task, the participants were asked again to fill in the Mood Questionnaire and the Godspeed Questionnaire [3] (the sections for Likability, Perceived Intelligence, and Perceived Safety). When the experiment was finished, all the participants received some chocolate to show our appreciation for their help.

2.3 Conditions

30 participants agreed to take part in this experiment. We developed a between subjects design and we assigned participants of both Chronic regulatory states to each condition. The distribution of the participants in each of our 6 groups can be seen in Table 1 (C. Pro stands for Chronic Promotion State, while C. Pre stands for Chronic Prevention State).

We used 3 conditions to test our hypotheses: Control condition, Promotion Robot strategy, and Prevention Robot strategy.

The instructions given by the robot in each condition were different but all of them prompted the participants to answer as fast as possible without making any mistakes. The robot was located at a distance of 1.2 m. - 1.5 m.

The instructions given by the robot in each condition are:

Control: "Please complete the Stroop test on the computer. You have to answer as soon as possible, your score will be measured with respect to the

(a) Scenario

(b) Table with cards

Fig. 1: (a) Scenario used in the experiment; (b) Table with cards used as a negative motivation.

Table 1: Number of participants by condition and group. C.Pro = "Chronic Promotion State", C.Pre = "Chronic Prevention State".

Control		Induced Promotion		Induced Prevention	
Group A	Group B	Group C	Group D	Group E	Group F
C. Pro	C. Pre	C. Pro	C. Pre	C. Pro	C. Pre
7	4	7	4	7	4

number of correct answers, and the time spent for each test. I will say it again. You have to answer as soon as possible, your score will be measured with respect to the number of correct answers, and the time spent for each test. You can start now".

Promotion Robot: The same speech of the Control condition, adding the next phrase before saying "You can start now": "If your score is better than seventy percent of the participants you will get a special reward, otherwise you will have to arrange the cards on the black table behind you by descending order".

Prevention Robot: The same speech of the Control condition, adding the next phrase before saying "You can start now": "As long as you are not part of the seventy percent of the participants with lower score, you will not have to arrange the cards on the black table behind you by descending order, but you will get a special reward".

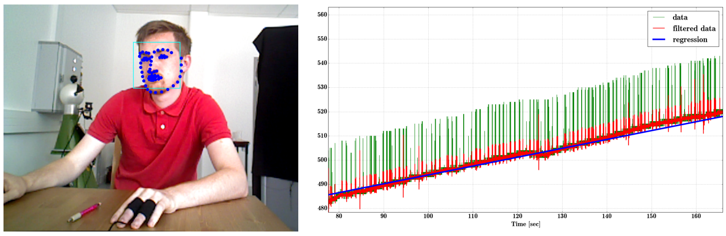
2.4 Regulatory Focus Questionnaire - Proverb Form

The Chronic regulatory state of the participants was obtained by applying the Regulatory Focus Questionnaire - Proverb Form (RFQ-PF 18 items), originally developed in French [10]. We translated the proverbs, by finding their English equivalents.

This questionnaire was chosen as it does not depend only on the personal history of the person, as is the Regulatory Focus Questionnaire [13]. Furthermore, it is not related to academic questions like the General Regulatory Focus Measure [15]. Instead, the usage of proverbs allows the evaluation of the strategy regulation preferences in a discrete and subtle way.

2.5 Measures

In order to validate our hypotheses, we used the Reaction Time expended for the participants to complete the Stroop Test, and the number of errors committed. We compared the participant groups in the different conditions using the total reaction time, the reaction time for congruent trials (corresponding word with color), and the reaction time for incongruent trials (not corresponding word with color). The same was done for the number of errors, total errors, errors for congruent trials, and errors for incongruent trials.



(a) Face detection (b) GSR signal, filtered data and regression

Fig. 2: (a) Face and face features extraction of the participants, (b) GSR signal filtered data and regression showing an increase of stress on the participant

We also measured the heart rate, the respiration rate, the blinking rate, and the skin conductance of the participants, with the purpose of detecting stress and anxiety.

The heart rate, respiration rate, and blinking were extracted using an Asus Xtion RGB camera. The faces and facial features were detected using the Dlib toolkit [14] (see Figure 2a). For blinking, we used the method presented in [1]. The skin conductance was measured using the Grove - GSR Sensor [1]. All the physiological measures were compared using a linear regression on the filtered data (with exception of blinking, which was measured using the total number of blinks detected), using the difference between the beginning and the end of the regression of the signal, an example of this (GSR signal with zoom) is presented in Figure 2b).

3 RESULTS AND DISCUSSION

We found statistical differences in the time and errors of the participants on the Stroop Test in the different conditions of the experiment, as well as correlations between the physiological measures and the Chronic and Induced Regulatory state of the participants. The mean and standard deviation of the Time and Errors of the participants on the Stroop Test, divided by groups (see Table 1), are presented in Tables 2, and 3, respectively.

We analyzed the Time and Errors, and we applied an one-way ANOVA using the different groups of the experiment as factors. We did not find any statistical difference among the groups. As this could be due to the small size of the groups, we proceeded to analyze each pair of groups with t-tests separately. No differences or correlations were found in relation with the mood of the participants and the different groups. The same result was obtained in the case of the Godspeed Questionnaire.

[1] `http://wiki.seeed.cc/Grove-GSR_Sensor/`

Table 2: Mean and Std Deviation of the time (secs) of the participants

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Group	Total Time	Congruent-color Time	Incongruent-color Time
	Mean - Std Dev	Mean - Std Dev	Mean - Std Dev
A	59.00 - 11.56	25.58 - 05.30	33.41 - 06.64
B	57.14 - 03.21	25.02 - 02.39	32.12 - 01.49
C	52.34 - 08.19	23.86 - 04.03	28.48 - 04.39
D	56.72 - 10.96	23.77 - 04.59	32.95 - 06.43
E	56.51 - 06.09	25.16 - 02.57	31.45 - 04.33
F	46.50 - 06.36	21.45 - 03.50	25.05 -02.91

Table 3: Mean and Std Deviation of the number of errors of the participants

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Group	Total Errors	Congruent-color Errors	Incongruent-color Errors
	Mean - Std Dev	Mean - Std Dev	Mean - Std Dev
A	0.42 - 0.78	0.14 - 0.37	0.28 - 0.48
B	0.25 - 0.50	0.25 - 0.50	0.00 - 0.00
C	0.16 - 0.40	0.00 - 0.00	0.16 - 0.40
D	0.25 - 0.50	0.00 - 0.00	0.25 - 0.50
E	0.71 - 0.48	0.14 - 0.37	0.57 - 0.53
F	0.00 - 0.00	0.00 - 0.00	0.00 - 0.00

3.1 Hypothesis 1

We did not find evidence that participants with Chronic Promotion State (Group C) performed better than participants with Chronic Prevention State (Group D), when the robot used a Promotion oriented strategy. Nevertheless, we found that participants with Chronic Promotion State performed better (having less errors in the Stroop Test) when the robot used a Promotion oriented strategy (Group C) than when it used a Prevention oriented strategy (Group E). This difference was found in the total errors in the Stroop Test. Also, we found a negative correlation between Time and Chronic Promotion State of the participants when the robot used a Promotion oriented strategy (Group C), meaning that a higher Promotion state was related with a lower time. The result of the t-test and the Pearson correlation test are presented in Table 4.

3.2 Hypothesis 2

We found that participants with Chronic Prevention State (Group F) performed better in time and number of errors than participants with Chronic Promotion State (Group E), when the robot used a Prevention oriented strategy. This difference was present in the overall time, in the incongruent-color trials time, and in the errors in the incongruent-color trials. Moreover, they performed better

Table 4: Tests to validate the hypothesis 1

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Total errors - T-Test				
Group B	Group F	P-value	t	df
57.14	46.50	0.0355	2.9835	4.4416
Promotion strategy and Chronic Promotion State - Pearson Test				
Group	Correlation	P-value	t	df
C	-0.8629	0.0269	-3.4152	4.0000

than participants in the control condition (Group B). The results of the t-tests are presented in Table 5.

Table 5: T-Tests to validate the Hypothesis 2

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Total time (secs)				
Group - Mean	Group - Mean	P-value	t	df
B 57.14	F 46.50	0.0355	2.9835	4.4416
E 56.51	F 46.50	0.0428	2.5480	6.1288
Incongruent-color trials time (secs)				
Group - Mean	Group - Mean	P-value	t	df
B 32.12	F 25.05	0.0096	4.3197	4.4828
E 31.45	F 25.05	0.0178	2.9226	8.5510
Incongruent-color trials errors				
Group E	Group F	P-value	t	df
0.57	0.00	0.0300	2.8284	6.0000

3.3 Hypothesis 3

We found evidence supporting the relation of Stress with a mismatch of the Strategy used by the robot and the Chronic Regulatory State of the participants. Analyzing the heart rate (HR) with an one-way ANOVA, we found differences in the groups. Moreover, by applying a pairwise t-test comparison, we found that participants with Chronic Prevention State had higher heart rates when the robot used a Promotion oriented strategy (Group D) than when the robot used a Prevention oriented strategy (Group F) or no strategy (Group D), giving us cues that participants in such conditions were more stressed.

We also found correlations between Time and respiration rate, and Time and blinking of the participants. When the robot used a Prevention oriented strategy, the Total Time spent in the Stroop test by the participants with Chronic Promotion State (Group E) presented a positive correlation with the respiration

Table 6: Tests to validate the hypothesis 3

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Heart rate and Groups - One-way Anova				
P	F-value	df		
0.0368	2.8328	5		
Heart Rate and Groups - Pairwise T-test comparison				
Group - Mean	Group - Mean	P-value		
B -0.41	D 6.01	0.0221		
D 6.01	F -3.21	0.0018		
Time and Respiration rate - Pearson Test				
Group	Correlation	P-value	t	df
E	0.9336	0.0020	5.8296	5
Time and Blinking rate - Pearson Test				
Group	Correlation	P-value	t	df
D	-0.9996	0.0165	-38.513	1
E	-0.9300	0.0023	-5.6607	5
GSR and Prevention Score - Pearson Test				
Group	Correlation	P-value	t	df
C	0.89013	0.0429	3.3832	3

rate. Blinking presented a negative correlation with the time when the robot used a not matching strategy in both Chronic Prevention (Group D) and Promotion (Group E) States. We can interpret this as a greater visual fatigue, when the participants tried to focus on the task, when the robot uses a mismatched strategy.

Analyzing the score of the Chronic regulatory state of the participants in relation with the respiration rate, we found correlations between them. A higher Chronic Promotion State was related with a higher respiration rate when the robot used a Prevention oriented strategy (Group D). In the same way a positive correlation was found between the respiration rate and the Chronic Prevention State when the robot used a Prevention oriented strategy or no strategy. This could imply that a Prevention strategy increases the cognitive load (cognitive load may lead to overbreathing [11]) for both kind of Chronic Regulatory states, or at least that this strategy does not help to decrease the cognitive load on the participants.

Regarding the data provided by the GSR Sensor, only a negative correlation has been found between the score of Prevention Regulatory State and the Skin Conductance in the participants with Chronic Promotion State when the robot used a strategy matching their chronic regulatory state (Group C). However, this can hardly found as evidence of stress, since the correlation is not with the Chronic Regulatory state of the participants.

The results of all the test to validate Hypothesis 3 are shown in Table 6.

4 CONCLUSION AND FUTURE WORK

We performed an experiment where a robot gave instructions to complete a Stroop Test to a group of participants. The participants were divided by their score on a test of Regulatory State. The robot had 3 conditions, in the first and control condition, the robot did not include any regulatory strategy. In the second condition the robot gave instructions that included a Promotion oriented strategy, while for the third condition it included a Prevention oriented strategy.

The results showed evidence that support most of our hypotheses. Only hypothesis H1 was not supported completely. Nevertheless, participants with Chronic Promotion State performed better in the condition of the robot with Promotion oriented strategy than in the condition with Prevention oriented strategy. Hypothesis H2 was supported as the participants with Chronic Prevention State performed better than participants with Chronic Promotion State when the robot had a Prevention oriented strategy. Hypothesis H3 was supported by correlations between different physiological signals and performance in Time of the participants, meaning that an increase in stress and cognitive load is correlated with a mismatch of the Regulatory Strategy of the robot and the Chronic Regulatory state of the participants.

In future work, we plan to make an adaptive Regulatory strategy for the robot in order to improve user's performance and decrease their cognitive load and stress.

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References

1. R. Agrigoroaie and A. Tapus, "Contactless physiological data analysis for users quality of life improving by using a humanoid social robot," in *Accepted in 19th Conference on Image Analysis and Processing*, 2017.
2. S. Andrist, B. Mutlu, and A. Tapus, "Look like me: Matching robot personality via gaze to increase motivation," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.* ACM, 2015, pp. 3603–3612.
3. C. Bartneck, D. Kulić, E. Croft, and S. Zoghbi, "Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots," *International journal of social robotics*, vol. 1, no. 1, pp. 71–81, 2009.
4. C. Breazeal, "Social robots: From research to commercialization," in *Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction.* ACM, 2017, pp. 1–1.

5. P. Chevalier, G. Raiola, J.-C. Martin, B. Isableu, C. Bazile, and A. Tapus, "Do sensory preferences of children with autism impact an imitation task with a robot?" in *Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction*, 2017, pp. 177–186.
6. E. Crowe and E. T. Higgins, "Regulatory focus and strategic inclinations: Promotion and prevention in decision-making," *Organizational behavior and human decision processes*, vol. 69, no. 2, pp. 117–132, 1997.
7. A. Cruz-Maya, F. Ferland, and A. Tapus, "Social facilitation in a game-like human-robot interaction using synthesized emotions and episodic memory," in *Proceedings of the International Conference on Social Robotics*, 2015, pp. 164–173.
8. J. Fasola and M. Mataric, "A socially assistive robot exercise coach for the elderly," *Journal of Human-Robot Interaction*, vol. 2, no. 2, pp. 3–32, 2013.
9. C. Faur, J.-C. Martin, and C. Clavel, "Matching artificial agents' and users' personalities: designing agents with regulatory-focus and testing the regulatory fit effect." in *CogSci*, 2015.
10. ——, "Measuring chronic regulatory focus with proverbs: The developmental and psychometric properties of a french scale," *Personality and Individual Differences*, vol. 107, pp. 137–145, 2017.
11. M. Grassmann, E. Vlemincx, A. von Leupoldt, J. M. Mittelstädt, and O. Van den Bergh, "Respiratory changes in response to cognitive load: A systematic review," *Neural plasticity*, 2016.
12. T. Hamada, Y. Kagawa, H. Onari, M. Naganuma, T. Hashimoto, and T. Yoneoka, "Study on transition of elderly people's reactions in robot therapy," in *The Eleventh ACM/IEEE International Conference on Human Robot Interaction*, 2016, pp. 431–432.
13. E. T. Higgins, R. S. Friedman, R. E. Harlow, L. C. Idson, O. N. Ayduk, and A. Taylor, "Achievement orientations from subjective histories of success: Promotion pride versus prevention pride," *European Journal of Social Psychology*, vol. 31, no. 1, pp. 3–23, 2001.
14. D. E. King, "Dlib-ml: A machine learning toolkit," *Journal of Machine Learning Research*, vol. 10, no. Jul, pp. 1755–1758, 2009.
15. P. Lockwood, C. H. Jordan, and Z. Kunda, "Motivation by positive or negative role models: regulatory focus determines who will best inspire us." *Journal of personality and social psychology*, vol. 83, no. 4, p. 854, 2002.
16. H. Osawa, J. Orszulak, K. M. Godfrey, and J. F. Coughlin, "Maintaining learning motivation of older people by combining household appliance with a communication robot," in *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on.* IEEE, 2010, pp. 5310–5316.
17. J. Stroop, "Studies of interference in serial verbal reactions," *Journal of Exploratory Psychology*, 1935.
18. L. Süssenbach, N. Riether, S. Schneider, I. Berger, F. Kummert, I. Lütkebohle, and K. Pitsch, "A robot as fitness companion: towards an interactive action-based motivation model," in *Robot and Human Interactive Communication, RO-MAN: The 23rd IEEE International Symposium on.* IEEE, 2014, pp. 286–293.
19. N. Tazhigaliyeva, Y. Diyas, D. Brakk, Y. Aimambetov, and A. Sandygulova, "Learning with or from the robot: Exploring robot roles in educational context with children," in *International Conference on Social Robotics.* Springer, 2016, pp. 650–659.
20. R. B. Zajonc *et al.*, *Social facilitation.* Research Center for Group Dynamics, Institute for Social Research, University of Michigan Ann Arbor, 1965.