A Motivating Social Robot to Help Achieve Cognitive Consonance During STEM Learning

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Abstract

In this paper, we show that cognitive consonance could be measured using the perceived cognitive consonance questionnaire that we present in this paper or using three different constructs which are the prospect an learner helplessness, use different motivating agents and whether the student's motivation would increase too. In the second study, we measure the cognitive consonance using the related questionnaire and the three constructs that we proofed that they help on measuring the cognitive consonance using the robot. This ethos is called the triangulation because it helps to answer the research questions. Results show that using a robot is the best solution that helps the student to achieve better motivation.

1 INTRODUCTION

The field of social robots has grown into an extensive body of literature over the past years, with a wide variety of approaches for extracting human patterns and modeling robots' skills. Robots operate as partners, peers, or assistants in a range of tasks such as with autistic children (Boccanfuso and O'Kane, 2011) or at home (Bilge and Forlizzi, 2008), in hospitals (Roomba, iRobot: http://www.irobot.com), or for having fun; e.g. the robotic toys from Wowwee (Limited, WowWee Group. http://www.wowwee.com/). Another role that a robot can play is the role of a motivating agent to do difficult tasks; e.g. solving a difficult exercise. Motivating a student may increase the student's strive for cognitive closure while doing difficult exercises.

Many studies from HRI tackled the fact of how to afford the robot with the ability to motivate people in many application fields such as at school (Szafir and Mutlu, 2012), as story-tellers (Ham et al., 2015), or as inciters to conserve energy (Ham and Midden, 2014), etc. Different points were investigated in other HRI studies such as the design strategies to improve patient motivation during robot-aided rehabilitation (Colo bo et al., 2007) the effect of robot appearance types on motivating donation (Kim et al., 2014), and the role of the socially assistive robot in motivating older adults to engage in physical exercise (Fasola and Mataric, 2013) etc.

However, to the best of our knowledge no concern was paid to the serious conflicts that students encounter at schools while learning science, technology, engineering, and mathematics (STEM) and the social robot key motivating role that can be played. The conflicts emerging from solving difficult STEM exercises may lead to an increased anxiety and learned helplessness (Fincham et al., 1989). Anxiety refers to the extent to which an exercise causes fear and reluctance from the student's behalf. Learned helplessness refers to a disruption in motivation, effect, and learning when the student feels they do not have any control of the outcome.

Consequently, it is important to give a serious attention to the issue of the dangerous consequences of cognitive conflict while doing a STEM exercise. Cognitive conflict is a discomfort that one in general experiences when a student holds beliefs, attitudes, or values in conflict with the task requirements (Mataric, 2013). This can lead to a decrease in motivation and a decrease in performance.
titudes or behaviors that are at odds with one another (the ratio between dissonant and consonant preconceptions about a STEM notion. As a result, we need to grant the social robot with the ability to follow closely the student's engagement in any use of otivating strategies that may increase the cognitive consonance of the student. This approach allows us to get feedback while solving STEM exercises.

In the current research, we investigate how cognitive consonance-related characteristics (e.g., motivational aspects) relate to implicit and explicit attitudes. More specifically, we test whether the effect of otivation on perceptions of cognitive consonance is mediated by appraisals of the cognitive consonance-related characteristics. In the first study, we explored the role of the social robot as a mediator in the relation between cognitive consonance and the student's engagement.

3 FIRST STUDY

3.1 Method

Different groups of participants in open-ended trials were asked to answer a set of 100 mathematical questions. In this study, we employed a within-subjects design in which participants were given the opportunity to do different tasks. The current study comprised 100 mathematical questions, with 31 participants (15 males and 16 females, mean age = 16.03, SD(age) = 2.45, with age range [13.5-19.5]).

3.2 Materials and Measures

The current study comprised 100 mathematical questions. Different groups of participants were asked to answer questions on cognitive consonance-related characteristics (i.e., prospect, anxiety, and learned helplessness) or on perceived cognitive consonance. We expected that appraisals of prospect would be positively associated with perceived cognitive consonance and that appraisals of learned helplessness would be negatively associated with perceived cognitive consonance. The students evaluated a set of 100 small mathematical questions included in a quiz and then evaluated exercises either on cognitive consonance-related characteristics or on perceived cognitive consonance, and that appraisals of learned helplessness and anxiety would be negatively associated with perceived cognitive consonance.

The current study comprised 100 mathematical questions, with 31 participants (15 males and 16 females, mean age = 16.03, SD(age) = 2.45, with age range [13.5-19.5]). The participants were students in Ibnou Sina College for Women.

2 BACKGROUND

In our current society, education plays a vital role. Motivating the student's while acquiring new knowledge is one of the most often used strategies. A motivating robot or a tablet can better increase the student's motivation. If the student's motivation is increased, his or her performance during study would increase too. He or she would have better implicit and explicit attitudes because they would be more likely to oint if cult exercises without using the easy one. When the student experiences difficulties, the social robot can help by providing counter-attitudinal actions. We want that students get all of their basic attitudes so that they can store on a long-term basis on the student's cognitive consonance.

4. Procept is tpicall e ne as the e tent o which the e - exercise s easiness allows the stu ent to continue resolving the e erercise.
5. The stu ent thin s that he has to change his attitu e of

6. After all science learning is not that important. Many teachers and students may get through while solving STEM exercises.
7. The stu ent thin s that the answer afforded by the book is incorrect.
8. The student thinks that he has to change his attitude of the important cognitive consonance or a perception change b getting a new information to support one's previous conclusion.
3.3 Results and Discussion

All of the reporte anal sis are perfor e on the aggregate eaur scores for each athe atical uesn across all participants. Descriptives for the eaur scores of our epen ent variables are presente in Table 1. e rst e a ine correlations between cognitive consonance an the eaur of the consonance-relate characteristics prospect an iet learne helplessness Table 2. As epec e perce cognitive consonance was positivel corre- late with prospect p ≤ .001 an nega- tivel corre- late with an iet r = .65 p ≤ .001 an learne helplessness r = .85 p ≤ .001. These results show that appraisals of prospect an iet an learne helplessness are high associate with the perception of cognitive consonance even when the ratings of perceive cognitive consonance an the cognitive consonance-relate situation characteristics are obtain in epen ent fro each other e t we e a ine the correlations a ong the eaur of the cognitive consonance-relate characteristics Table 2. prospect was negativel corre- late with an i-

<table>
<thead>
<tr>
<th>Cognitive Consonance</th>
<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>prospect</td>
<td>3.16</td>
<td>0.70</td>
<td>1.25</td>
<td>4.31</td>
</tr>
<tr>
<td>An iet</td>
<td>3.12</td>
<td>0.55</td>
<td>1.98</td>
<td>4.56</td>
</tr>
</tbody>
</table>

Table 1 Descriptives for the measures of cognitive consonance

et r = -.83 p ≤ .001 an learne helplessness r = -.72 p ≤ .001 an iet was positivel correlate with learne helplessness r = .73 p ≤ .001.

e t we use ultriple regression anal sis to test whether appraisals of the cognitive consonance-relate situation characteristics prospect an iet learne helplessness pre icte appraisals of perceive cognitive consonance e found that the three pre icctors accoun e for appro iat 75 of the variance of perceive cognitive consonance with F 3 96 9477 p ≤ .001 R² 75 an R²adj 74. As epecc appraisals of both an iet an prospect signi cant pre icte perceive cognitive consonance Table 3. An iet was not found to pre- icte perceive cognitive consonance to a signi cant e nent Table 3.

One proble with ultriple regression anal sis is that the fail to appropriatel partition the vari- ance when the pre ictors in the elo are high correl. Thus an assess ent of the relative contrib- ution of the three pre ictors to cognitive consonance evaluation characteristics was i pe e b the high uiltineari- bit between these pre ictor variables in our ata Table 2. Hence we e plo e the reg2 pac age available for Stata that utili es Shaple value eco position to eco pose the over- all o el goo ness-of- t in e in our case R² into in epen ent contributions of the pre ictor variables hile appraisals of an iet were not found to signi cant pre icte cognitive consonance in our ultriple regression anal sis the results fro the R² eco position reveale that an iet contribut e n slighl less to the overall variance as co pare to prospect Table 3. In line with the ultriple regression anal sis the results of the R² eco position in icate that of the three pre ictors in our elo el appraisals of learne helplessness contribute ost strongl to the overall variance e teste the robust- ness of our regressio elo el b perfor ing 100 split

*Cognitive consonance characteristics evaluation is ac- count for b prospect perceive stu ent s esire to con- tinue with solving the athe atical eric s an iet perceive stu ent s an iet after solving a athe atical e eric s an learne helplessness a situation in which a stu ent believes that his efforts are going for waste an that he got a proble atic cognitive proble that prevent hi fro un ersta ning atic atics
Table 2 Correlations between measures of cognitive consonance, prospect, an iet an learne hellessness ote $p \leq .001$

<table>
<thead>
<tr>
<th>Cognitive Consonance</th>
<th>respect</th>
<th>An iet</th>
<th>Learne Hellessness</th>
</tr>
</thead>
<tbody>
<tr>
<td>respect</td>
<td>71</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>An iet</td>
<td>-65</td>
<td>83</td>
<td>-</td>
</tr>
<tr>
<td>Learne Hellessness</td>
<td>-85</td>
<td>73</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3 OLS multiple regression results with the eco position of $R^2$ in of total $R^2$ Lower level LLCI an upper level LCI conence intervals base on bootstrapping with 5000 resamples

<table>
<thead>
<tr>
<th>Multiple Regression</th>
<th>Deco position of $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>eta</td>
<td>t</td>
</tr>
<tr>
<td>------</td>
<td>---</td>
</tr>
<tr>
<td>respect</td>
<td>0.26</td>
</tr>
<tr>
<td>An iet</td>
<td>0.12</td>
</tr>
<tr>
<td>Learne Hellessness</td>
<td>-0.75</td>
</tr>
<tr>
<td>Observations</td>
<td>100</td>
</tr>
<tr>
<td>Full o a $R^2$</td>
<td></td>
</tr>
</tbody>
</table>

In each instance the original 100 stimuli were ran o l assigne to two groups of e ual si e. The regression weights of prospect an iet an learne hellessness obtaine fro a multiple regression anal sis on the rst group were then use to calculate pre icte scores for perceive cognitive consonance of the secon group. In the last step the correlation between the observe scores an the pre icte scores for the secon group was calculated. The results show a high robustness of our regression o el across the 100 split sa ple valiations $M_r = .86 \ SD_r = .033 \ M_{R^2} = .74$.

Across our large sa ple of representative envirom ents our regression o el pre icting perceive cognitive consonance fro appraisals of prospect an iet an learne hellessness accounte for appro i atel 75 of the variance in cognitive consonance u g ents The o el was foun to be robust across 100 split sa ple valiations As e pect both prospect an an iet were i ent e as significant pre ic tors of perceive cognitive consonance Moreover our n ings are in line with previous n ings in icating that appraisals of learne hellessness are ost strong! associate with perceive cognitive consonance In contrast to previous n ings an iet was not foun to a e a signi cant contribution to perceive cognitive consonance in our o el.

4 SECOND STUDY

e e ten e our investigation to the role of a o tivating agent s presence in the cognitive consonance appraisal process b inclu ing participants appraisals of the agent in our regression o el. Our goal is to enhance the stu ent s ac e i c s ill e assu e that the presence of a o tivating agent that a con-vince the stu ent to continue resolving the if cult STEM e xer ise even when he she faces a cognitive issonance situation a enhance the stu ent s ap-preciation of the STEM science technolog engi-neering an ath etics subects The agent is sup-pose to encourage the stu ent to achieve the tas of answering the ath etical set of quest ions In ge-neral when a stu ent faces a if cult STEM e xer ise an he she n at out that his her answer is incorrect he she will up to the ne t e xer ise b a opting a belief change as a counter-attitud inal behavior. If he she opts for re o ing the e xer ise that was previousl answere incorrec b without putting so uch effort while re o ing it so that he she gets to the correct an-swer we sa that the stu ent chooses a perception change as a counter-attitud inal behavior e want that the stu ent chooses the attitu e an behavior change as a counter-attitud inal behavior after being stric en b the cognitive issonance so that he she learns eficientl the STEM subects e use different t pes of agents that a help the stu ent to oerco e the cognitive issonance which are a frien of the sa e age a teacer a robot RO OMO a tablet. The different agents use three different e stragies to ote the stu ent which are the o or in face an labeling techniu es

e e pect that an enlighten ing o tivating agent a e power the stu ent to a e a eas shortcut re uce the cognitive wor loa an follow the o-ivating essage s gui elines consisting on re oing the STEM quest ion that was previousl answere incorrec rather than a opting a perception or belief.

10Here we nec to start b an in ate re uest an then re-treat to a s aller re uest After the rst re uest is refuse the hu an will feel that he she nec s to change his her opinion since the initial re uest has change a att of reciprocity.

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change strategies.

The general aim of the second study is to examine the path through which appraisals of the motivation afforded by the agent appears to change = .01, F(3, 95) = 1.99, p = .161. Based on these results,

perceived motivation afforded by the agent appears to

4.2 Materials and Measures

were registered in Ibnu Sina College.

11 answering the quizz even if the questions are difficult.

sage so that we can ensure that the student keeps on

quizz, an agent speaks out loud a motivating mes-

that while answering each question of the mathemati-

were analogous to those of the previous one, except

The procedure and conditions of the second study

4.3 Procedure

The procedure and conditions of the second study

duce His athe atical preconceptions are e-

appointe His athe atical preconceptions are e-

feate an he e periences a iscrepanc between

write what he believes an the answer In such a case

a successfulness of the stu ent woul answer the

sa e uestion that was previousl a nswered incor-

All participants respon e to the ite s of the

perceive otivation uestionaire

4.4 Results and Discussion

a e the aggregate perceive otivation af-

for e b the agent ensure s score as a new vari-

able to the ata set containing the prospect an iet

learne helplessness an perceive cognitive conso-

in the previous stu

Descriptives for the ease of perceived otivation affor e b the agent ease are presente in Table 4 e rst e - a ine the correlations between the perceive otivation affor e b the agent s ease an the ea-

sures fro previous stu Table 5 e foun that

perceive otivation affor e b the agent was posi-

r = .47, p ≤ .001 an prospect r = 76 p ≤ .001

an negativel correlate with an iet r = -48 p ≤ .001 an ease-rhelplessness r = -49 p ≤ .001

To test whether appraisals of the perceive otivation affor e b the agent pre ietc

appraisals of perceive cognitive conso-

we perfor e a re-

gression anal sis. The regression o el accoute for appro iat 20 of the variance in perceive cognitive conso-

r = .47, p ≤ .001 an prospect r = .76, p ≤ .001

R² = 22 an R²adj = 21 As e pecte perceive ot-

ivation affor e b the agent was signi cant relate to perceive cognitive conso-

β = .48 t = 5.22

p ≤ .001

The regression o el was o erat rob-

ust across 100 split sa ple vali ations M. = .48

SDv = .079 M. = .22

t a ulple regression anal sis was con-

ucte with both the perceive otivation affor e b

the agent an the cognitive conso-

r = .47, p ≤ .001 an prospect r = .76, p ≤ .001

R² = 22 an R²adj = 21 As e pecte perceive ot-

ivation affor e b the agent was signi cant relate to perceive cognitive conso-

β = .48 t = 5.22

p ≤ .001

The regression o el was o erat robust across 100 split sa ple vali ations M. = .48

SDv = .079 M. = .22

t a ulple regression anal sis was con-

Table 4 Descriptives for the measure of perceived motivation afforded by the agent.

<table>
<thead>
<tr>
<th>Measure</th>
<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived motivation afforded by the agent</td>
<td>2.91</td>
<td>0.69</td>
<td>0.32</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Table 5 Correlations between the measures of perceived motivation afforded by the agent and the measures of cognitive consonance, prospect, anxiety, and learned helplessness.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Consonance</th>
<th>Respect</th>
<th>An</th>
<th>Lea Helplessness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived motivation afforded by the agent</td>
<td>4.77</td>
<td>76.48</td>
<td>-48</td>
<td>-49.47</td>
</tr>
</tbody>
</table>

Table 6 Summary of the correlations among the measures cognitive consonance, prospect, anxiety, and learned helplessness.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Total Effect</th>
<th>Intercept Effect</th>
<th>LLCI</th>
<th>LCLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived motivation afforded by the agent</td>
<td>-0.27</td>
<td>-0.127</td>
<td>-0.52</td>
<td>-0.02</td>
</tr>
<tr>
<td>Prospect</td>
<td>-0.38</td>
<td>0.241</td>
<td>-0.62</td>
<td>0.02</td>
</tr>
<tr>
<td>Anxiety</td>
<td>-0.21</td>
<td>-0.092</td>
<td>-0.41</td>
<td>0.24</td>
</tr>
<tr>
<td>Learned helplessness</td>
<td>-0.447</td>
<td>0.372</td>
<td>-0.78</td>
<td>0.214</td>
</tr>
</tbody>
</table>

The results of the mediation analysis show that the effect of perceived motivation afforded by the agent on cognitive consonance and its indirect effect through appraisals of prospect and anxiety is significant, suggesting that this effect is fully mediated by changes in prospect and anxiety. In sum, our results show that while perceived motivation afforded by the agent significantly affects the cognitive consonance of the student, this effect is no longer significant when changes in prospect and anxiety are taken into account.

5 THIRD STUDY

As motivation has a direct effect on the cognitive consonance appraisal, we have opted to use different agents in the previous study to verify which of the three different agents may lead to the highest motivation perception.

5.1 Method

66 Tunisian students participate in this study where we use different agents in the previous study (study 2). We decided to verify which of the three different agents may lead to the highest motivation perception.
Table 7 A table showing the second main effect investigation results (tablet vs robot; tablet vs human and robot vs human).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Comparison contrast (F, p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tablet vs robot</td>
</tr>
<tr>
<td>pleasure</td>
<td>149.3 &lt; 0.001 R</td>
</tr>
<tr>
<td>IAT</td>
<td>17.92 &lt; 0.001 R</td>
</tr>
<tr>
<td>Cog Diss</td>
<td>136.8 &lt; 0.001 R</td>
</tr>
<tr>
<td>quotient</td>
<td>26.09 &lt; 0.001 R</td>
</tr>
<tr>
<td>Looks</td>
<td>84.4 &lt; 0.001 R</td>
</tr>
</tbody>
</table>

RO OMO generates the motivating speech that it is comparative with the robot's convenient gestures but an hea gestures an the right tone The motivating speech use b the indifferent t pes of agents follows the techni ue labeling techni ue As a re in er the labeling techni ue involves assigning a label to the in ivi ual an then re ues a favor that it is consistent with the label For a plea telling to a stu ent I now ou are striving to sucess an eep insi e ou are har wor er In such case the stu ent has ore ten enc to live up with the positive label Thus one wa to a e a hu an pro uce the eise behavior is to assign positive label to hi her so that ou can rive hi her to live up with that label an aintain that positive consisten that serves the public i age of the person as well as his her self-este So there are four con itions the stu ent ta es part in which are the baseline con ition o motivating essege is af for e con ition 1 the tablet affor s the motivating essege con ition 2 the robot affor s a motivating essege an con ition 3 the hu an affor s a motivating essege Each two a s the stu ent co es to the classroom re o another set of quetions while we change the oitivating source

5.2 Materials and Measures

After the peri ent nishes the stu ent has to an swer quetionnaires such as the e plicit attitu e anti tos an er ins 2013 the i plicit attitu e i plicit association test IAT antos an er ins 2013 the cognitive issonance cogn iss Levin et al 2013 an the perceive pleasure s level ra le an Lang 1994 e consi ere other open ent variables

The uotient u ber of ti es the user re ees incorrect quetion b the nu ber of ti es the user a es an error It gives an i ea about when has the stu ent a ten enc to re o incorrect quetions to strive for science learning rather than u ping fro one quetion to another

Loo s nu ber of ti es the user wells with e e ga e between the 2 quetions

5.3 Results and Discussion

The motivating essege source agenc s level ha a ain effect in ter s of all the constructs with a -value < 0.001 Table7 shows that there were signi cant ifferences between the robot an tablet con itions with higher results in the robot s con ition for all the constructs Also Table7 shows that using a robot as a motivating source in con parison to using a hu an increases cog iss F 88.5 p-value 0.04 < 0.05 R an loo s F 71.08 p-value 0.001 R There were statistical ifferences in ter s of pleasure with higher results in the robot s con ition rather than in the hu an s con ition F 83.58 p-value 0.001 R IAT F 2.29 p-value 0.013 < 0.05 R an uotient F 2.6 p-value 0.009 < 0.01 R

6 CONCLUSION

Motivating a stu ent is co onl associate with a positive effect on the e perience of cognitive consonance et little is nown about the ps chologial processes through which perceive otivation a e ert its in uence on people s cognitive consonance perceptions e investigate the role of otivation in cognitive consonance perception using a wi e range of different agents t pes Across two stu ies we teste the i ea that otivation in uences appraisals of cognitive consonance through its effect on appraisals of cognitive consonance-relate characteristics i e prospect an iet an learne helplessness The ore an agent otivates the stu ent the ore he she gets clear i eas an scores high in ter s of cognitive consonance Finall we co pare ifferent agents t pes to verify which one of the a lea to better otivation an thus higher cognitive consonance Results show that using a robot a lea to better results
in terms of perceived motivation. Thus, the students having a robot as a motivating source adopt a positive counter-attitudinal behavior (attitude and behavior change) while they strive to answer the STEM questions that were previously answered incorrectly.

REFERENCES


