Pleasure Propagation to Reward Predictors

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Abstract— **Learning has always been one of the core mechanics in computer games. Players learn specific battle mechanics, control schemes, and much more, which enables them to progress further through the game and experience pleasure. Previous studies on learning often focused on the learning of predictors (cues) for reward and their motivational properties, but fail to address the impact on pleasure. For example, the cue of a smell of chocolate will already produce a pleasure feeling, which means that apart from the motivational learning of the smell cue, something affected pleasure generation as well. In this paper, we perform an experimental study to investigate this relation of learning and pleasure. The study, in which 38 test subjects participated, used smile reactions to rewards of showing funny pictures as a primary measure of pleasure. The findings of the study demonstrate that experiment repetition leads to an increase in pleasure at the cue, a decrease in pleasure at the reward, and a potential relation between motivation and pleasure change at the cue.**

I. INTRODUCTION

Learning is considered a key component of gaming, and some game designers (like [1]) even go so far to declare it the overall most important game mechanic. Understanding the basics of this human learning process allows us to design better means of generating games and learning experiences, whether for offline experiences, like movies and literature, or experiences that can dynamically adapt to the user, like computer games.

As part of our work in building a formal model of entertainment-related brain processes, such that this model can potentially be used/executed to generate experiences automatically, we specifically investigate the relationship of pleasure and cues in this paper.

There has been extensive previous work on the close relationship between learning and reward (e.g., see [2-4]). Every time the brain's reward system registers a reward outcome, a learning process takes place that assigns motivational properties to the sensory predictors of the reward (to the so-called "cues" or "secondary reinforcers"). For example, when a person consumes a chocolate bar, the internal reward of calories gained translates into a motivational drive to eat chocolate whenever the chocolate is seen or smelt again [5]. As a side note, these processes happen *subconsciously*, i.e., a person is not aware of it and has no direct means of introspection.

Apart from the motivational drive, a certain amount of pleasure may be triggered at the cue [3] (and again, a person can even be consciously unaware of his/her own facial expressions and emotional state towards the cue [6]). Prior to the presented study in this paper, the underlying mechanics of this pleasure propagation have not been subject of research, and apart from the common knowledge that some pleasure propagation obviously happens, nothing concrete is known so far. The study presented in this paper presents our first results in this direction.

II. METHODS

A. Participants

The 38 participants – 23 male and 15 female – were between the ages 19 to 24 years old. They were students from the National University of Singapore and came from different faculties. All participants were healthy and free from psychological disorders, assessed through a pre-screening interview. The participants were tested individually over a 30-minute session.

B. Factors and Measurement

The first important factor to be considered for the tests is the "pleasure" itself. For the purpose of the paper, we will not start a discussion of what pleasure actually is – for a discussion of our point of view on pleasure, please refer to [7]. As an indirect measure for pleasure, the recognition of facial expressions will primarily be used in this paper. Among experiential, behavioral and physiological measures, the correlation between self-reported hedonic experience and facial behavior has been the strongest [8, 9]. Specific facial muscle movements are essential to produce these facial expressions, which do not vary much among individuals and are universally recognized [10]. Electromyography (EMG) is used in our test study to measure pleasure by way of corresponding movements of the zygomaticus major "smile" muscle (left cheek; see Fig. 1). Indexing is used for a normalization of the time series across participants. For cross-check purposes, after a reward is received, test subjects are also asked to rate the reward on a scale of 1 to 7, which they have to complete within five seconds to avoid the problem of the influence of conscious reflection.

The second main factor, motivation, is the psychological drive to gain a specific reward. The resulting effort of the test subjects can be observed, and its intensity can be used as an indirect measure for motivation.

Factors such as the risk of getting the reward, and the time until the reward, may affect the learning process as well.

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Time delay leads to discounting of rewards [11, 12], and risk variables also come into play when determining the expected magnitude of reward [13]. The user test is thus designed in a way to minimize or eliminate these confounding factors.

Reward level (the magnitude of reward) serves as a control variable, with four different levels of reward being tested. To promote a proper EMG reaction, funny pictures are used as rewards. The pictures are selected at four levels of funniness (level 1 is the least funny and level 4 the most funny), with the level classification being derived from rankings at voting sites for funny pictures on the internet. Color cues are paired with the different reward levels: Green – Level 1; Blue – Level 2; Purple – Level 3; Red – Level 4.

Apart from EMG, various other psychophysiological measures are taken as well to check for potential relations. This includes blood volume pulse (BVP) measuring heart rate and amplitude, peripheral skin-surface temperature (Temp), skin conductance (SC) and respiration (Resp). The BVP and Temp sensors are placed on the 4th finger of the left hand, the SC sensor was placed on the 2nd and 3rd finger of the left hand, and the Resp sensor is fit around the chest area. Fig. 1 shows a participant with the psychophysiological equipment while he is performing the experiment. All psychophysiological measures are taken using ProComp 5 Infiniti equipment, extracting 256 samples per second. Apart from EMG, these psychophysiological measures will not be discussed in the following, however, as the analysis did not produce conclusive results. The very quick exposures and test games (in the range of seconds) were likely not long enough to produce meaningful readings.

Fig. 1. Bio-measure equipments on the participant.

Additionally, video recording of the screen, where the test participant interacts with the test software, as well as videos of the subject's face were taken during the full test.

C. Test Procedure

The test subjects participated in the tests individually. They were asked whether they are feeling comfortable and relaxed in their sitting position. The participants were then fitted with the bio-measure sensors.

Initial readings from the bio-measure sensors were taken and checked to make sure that there are no abnormalities in the readings and that all the sensors are properly connected. The graphs produced by the sensor readings were also shown to the participants. The participants were asked to perform certain actions so that they can understand how sensitive the sensors are. At the same time, the participants were also advised not to move his/her left hand. The participants were asked to remain expressionless, followed by a smile, to verify the change in the facial EMG data.

Briefings were given to the participants to clarify any unclear issues, measurements were started by synchronizing the measurement equipment, and the participants were left alone in the room to perform the user test.

The test for the participants was programmed in Macromedia Flash 8. The test consists of a series of subsections. For each subsection, the test participant is exposed to a color cue for 5 seconds, after which they will need to finish 35 mouse clicks within 10 seconds (see Fig. 2). If they are successful, they will be shown a funny picture corresponding to the cue level for 12 seconds. If they are unsuccessful, the same subsection is repeated. The process will continue until the participants successfully finished the 35 mouse clicks. The screen progress will hold for 5 seconds before the funny reward picture is displayed (see Fig. 3). These 5 seconds allow the participants' bio-measurements to stabilize from the clicking activity before the reward is shown. After seeing the funny reward picture, they were asked to rate the level of funniness of the picture on a scale of 1 to 7, with a time limit of 5 seconds (to minimize conscious evaluation interferences; see Fig. 4).

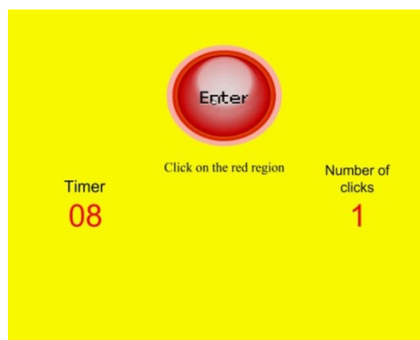

Fig. 2. Mouse click game.

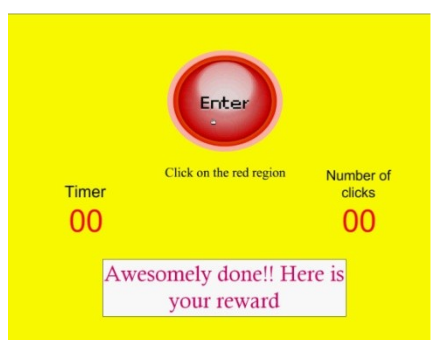

Fig. 3. Stabilization break of 5 seconds.

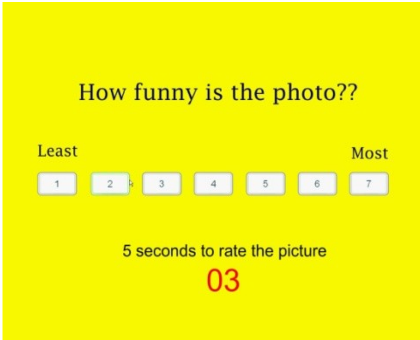

Fig. 4. Rating of the photo reward.

The overall test includes 16 subsections. Every level of reward is first tested for 3 times, after which each level is tested again for one time:

- 3 x Level 1 Cue and Reward (C1, R1, C2, R2, C3, R3)
- 3 x Level 2 Cue and Reward (C4, R4, C5, R5, C6, R6)
- 3 x Level 3 Cue and Reward (C7, R7, C8, R8, C9, R9)
- 3 x Level 4 Cue and Reward (C10, R10, C11, R11, C12, R12)
- 1 x Level 1 Cue and Reward (C13, R13)
- 1 x Level 2 Cue and Reward (C14, R14)
- 1 x Level 3 Cue and Reward (C15, R15)
- 1 x Level 4 Cue and Reward (C16, R16)

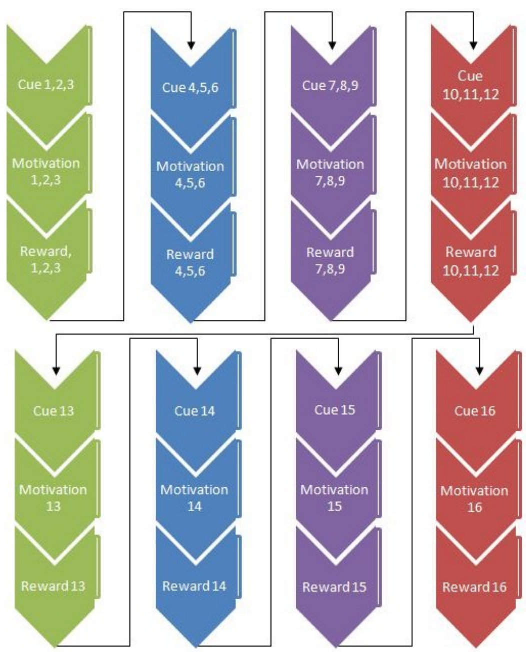

Fig. 5. Sequential flow of the user test.

The repetition of each level for 3 cycles allows analysis of the amount of pleasure generated at the color cue due to the learning of the previous reward. The sequential increase in reward level allows analysis of the amount of pleasure generated at the color cue with the different levels of reward.

A substantial drop in pleasure and motivation is expected to be seen at C13 as compared to C12. C13 is a cue for a reward of level 1, which is given directly after R12, which is a level 4 reward. A drop in pleasure will indicate that the participants have learnt about the association between the color cues and the level of reward. This is indeed confirmed later on.

III. Data Analysis and Discussion

For the analysis below, the data of the single participants was consolidated as averages (after indexing). As a side note, there is no notable difference in male and female responses.

A. Relationship between the facial EMG measurements and the rating of the pictures

To verify the validity of the EMG data for pleasure ratings, the ratings of the test participants are compared to their reported ratings (see Table I and Fig. 6 and 7).

Fig. 6 and 7 show similar trends (see also Fig. 8). This indicates that there is indeed a close relationship. The measurements from the facial EMG can thus indeed be taken as a good indirect measure for the amount of pleasure gained from the reward / funny photo. One important thing to note is that EMG readings and the ratings seem to have a tendency to drop for successive trials with rewards of the same level.

It can also be noted that there is a more distinct drop of EMG reading and ratings for Reward 6 and 15. A misleading classification of the internet ratings or the specific Singaporean demographic of the study participants might be a reason.

TABLE I Facial EMG for reward and rating of the pictures.

Level	Reward	Facial EMG for Reward	Reward S.D. (±)	Rating of pictures	Rating S.D. (±)
1	R1	1.80981	2.02548	2.46154	1.13890
	R2	1.85352	1.94366	2.46154	1.38329
	R3	2.38092	3.57128	3.30769	1.37639
2	R4	2.34712	2.48231	3.75000	1.29969
	R5	2.53764	3.40889	3.82927	1.60281
	R6	1.66867	1.26965	3.09756	1.70097
3	R7	3.49790	4.03697	4.14634	1.54496
	R8	2.70297	3.51050	4.12195	1.64680
	R9	2.84262	4.09951	4.17073	1.72196
4	R10	3.94333	5.58802	4.97500	1.22909
	R11	2.69478	3.24898	4.41463	1.81134
	R12	2.46426	4.03946	4.02500	1.70585
1	R13	1.54390	1.07554	3.67500	1.66757
2	R14	2.48312	2.74833	4.15000	1.38099
3	R15	1.71018	1.34795	3.41463	1.57234
4	R16	2.37978	2.72164	4.75000	1.49323

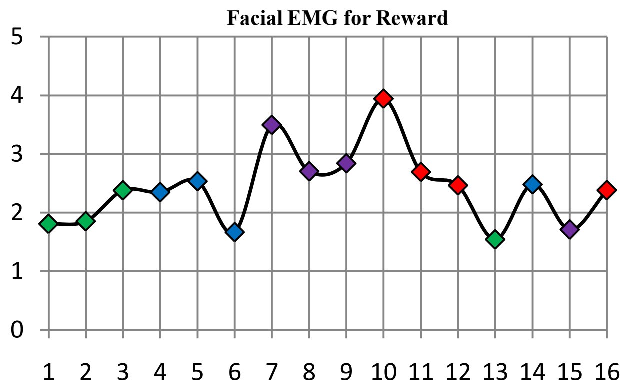

Fig. 6. Facial EMG for Rewards R1 to R16.

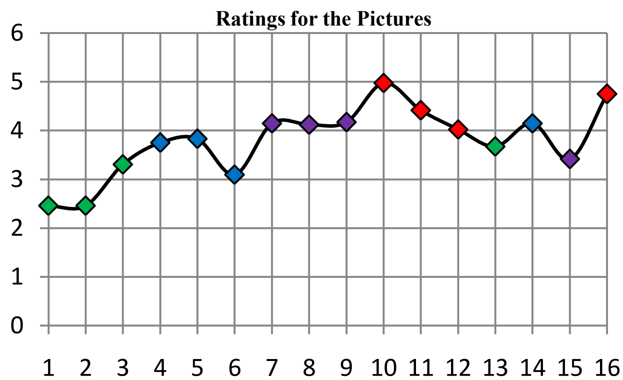

Fig. 7. Ratings for Rewards R1 to R16.

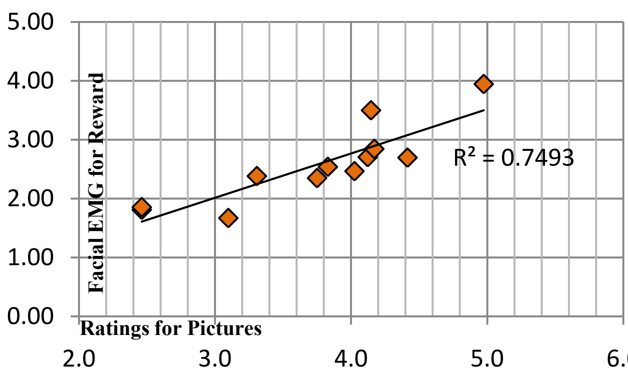

Fig. 8. Facial EMG for reward with respect to ratings for pictures.

B. *Relationship between Cue and Motivation*

According to previous work mentioned before, exposure to cues generates motivation. In this section, we investigate if the pleasure propagation follows a similar trend as the generated motivation. For this, we compare the speed of mouse clicks with the EMG at the time of the cue exposure (see Table II and Fig. 9 and 10). Fig. 9 and Fig. 10 show similarities in the trend except for 2 outliers, Cue 9 and Cue 10.

Overall, it may seem surprising that Cue EMG and motivation tend to increase for successive trials with rewards of the same level, in contrast to the decreasing Reward EMG and ratings.

TABLE II Facial EMG for cues and motivation.

	Facial EMG for Cues	Cue S.D. (±)	Motivation (1/time)	Motivation S.D. (±)
C1	1.00000	0.00000	0.13898	0.02855
C2	1.45893	0.84882	0.14964	0.02574
C3	1.34136	0.84037	0.14855	0.02497
C4	1.92100	1.38910	0.15356	0.02273
C5	2.05074	2.10594	0.15356	0.02490
C6	2.49182	1.35623	0.15185	0.02382
C7	1.51354	1.12424	0.15242	0.03720
C8	2.01515	1.52769	0.15472	0.03610
C9	2.55824	3.12733	0.16803	0.03477
C10	2.73372	3.23768	0.15414	0.02289
C11	2.64257	2.64690	0.15589	0.03306
C12	3.70527	5.74174	0.15891	0.02383
C13	1.97607	2.59407	0.15472	0.02283
C14	2.08126	1.69933	0.15891	0.02175
C15	1.98685	1.15654	0.1583	0.02642
C16	1.42368	0.87679	0.15472	0.02406

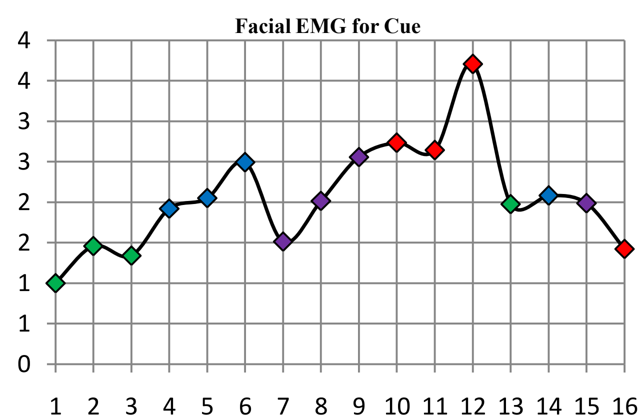

Fig. 9. Facial EMG for Cues C1 to C16.

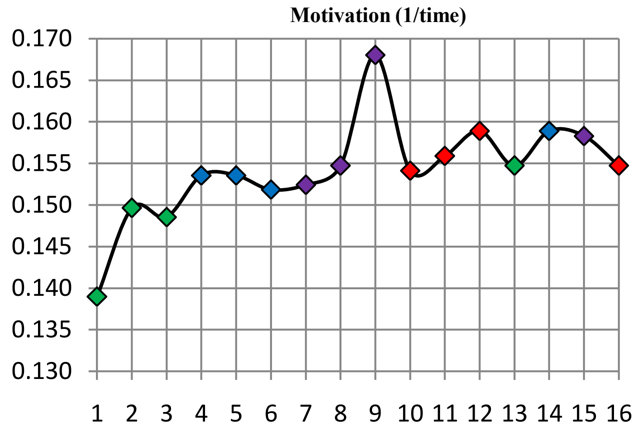

Fig. 10. Motivation.

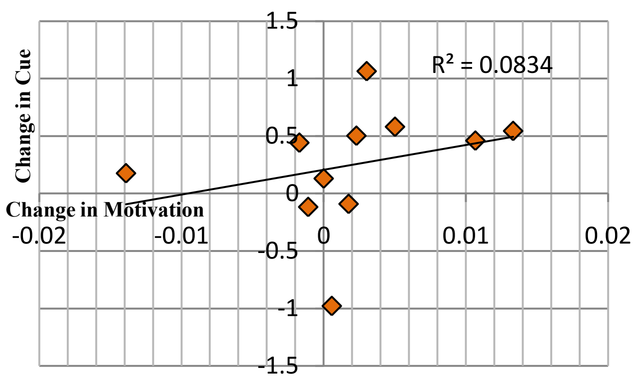

Fig. 11. Change in facial EMG for Cue with respect to change in Motivation.

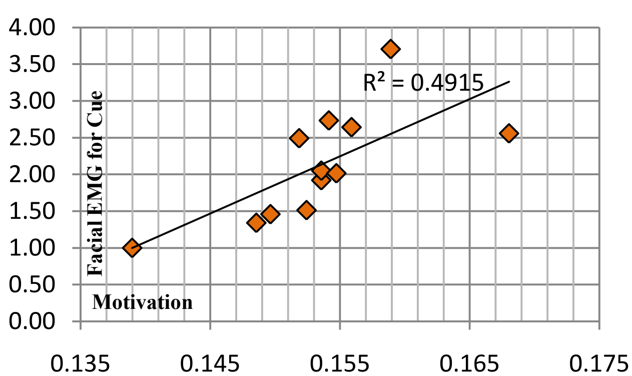

Fig. 12. Facial EMG for Cue with respect to Motivation.

Some more analysis can be drawn from Fig. 9. Firstly, the amount of pleasure for the 2nd part of the user test (Cues 13, 14, 15, 16) is mostly lower as compared to the amount of pleasure obtained from the cues at the individual levels. The learning process may be affected by the exposure to different cues before the cue is seen again.

The distinct drop in the pleasure at Cue 13 as compared to Cue 12 showed that the participants displayed less pleasure when they were re-exposed to a Level 1 Cue. This also supports that the participants have learnt about the association between the color cues and the level of reward.

In addition, Fig. 9 shows that there is a distinct drop of pleasure at Cue 16. In Fig. 2, it is evident that there is a distinct drop in pleasure at R15. This drop in pleasure at the reward has thus likely affected the amount of pleasure at C16.

C. Change in Cue and Reward

We are interested in the amount of pleasure that has been propagated to the cue from the pleasure at the preceding reward. Table III shows this relationship for the first 12 subsections of the test. Reward Change and Cue Change do however not seem to follow a particular pattern apart from growing with the absolute EMG readings.

TABLE III Cue and reward.

Reward N	Reward Change	Reward (EMG)	Cue (EMG)	Cue Change	Cue N+1
1	0.04370	1.80981	1.45893	-0.11757	2
2		1.85352	1.34136		3
4	0.19052	2.34712	2.05074	0.44108	5
5		2.53764	2.49182		6
7	-0.79494	3.49790	2.01515	0.54310	8
8		2.70297	2.55824		9
10	-1.24855	3.94333	2.64257	1.06270	11
11		2.69478	3.70527		12

Fig. 13 plots the changes against each other, but there does not seem to be an obvious pattern (unless Level 2 is an outlier). More research – potentially with more learning cycles – will need to be done to clarify the happenings.

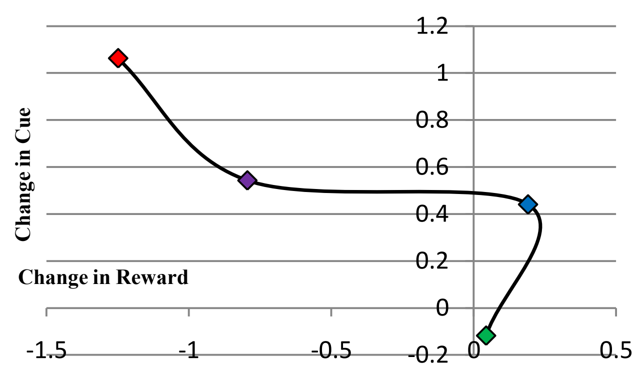

Fig. 13. Change in Cue with respect to Change in Reward.

D. Pleasure Prediction Error

One would expect the change in motivation to be related to the predication error between expected reward and actual reward. We can test a similar relationship between the pleasure at the cue and at the reward (see Table IV).

TABLE IV Motivation and "Pleasure Prediction Error (PPE)".

Cue N	Motivation Change (N+1) - (N)	Motivation	PPE (Reward N – Cue N)	PPE Change (N+1) - (N)	Reward N
1		0.13898	1.1352		1
2	0.01066	0.14964	0.1908	-0.9444	2
3	-0.00109	0.14855	1.3338	1.1431	3
4	0.00501	0.15356	0.2481	-1.0858	4
5	0	0.15356	0.7195	0.4714	5
6	-0.00171	0.15185	-1.0392	-1.7586	6
7	0.00057	0.15242	4.7297	5.7689	7
8	0.0023	0.15472	2.7234	-2.0064	8
9	0.01331	0.16803	0.4423	-2.2810	9
10	-0.01389	0.15414	1.3957	0.9533	10
11	0.00175	0.15589	-0.0594	-1.4551	11
12	0.00302	0.15891	-3.3500	-3.2906	12

Plotting the Change in Cue against the Change in Pleasure Prediction Error, Fig. 6 indeed seems to suggest a linear relationship.

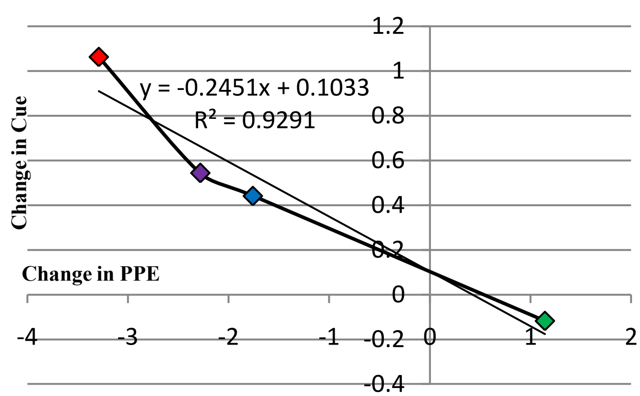

Fig. 14. Change in Cue with respect to Change in Pleasure Prediction Error.

The trend line in Fig. 6 is plotted using linear regression. The regression statistics are given in Table V. The R^2 value is 0.9291. Thus, the model shows that 92.91% of the variance in the Change in Cue can be explained by the Change in PPE. There is a strong correlation between change in Cue and change in PPE. From the analysis of variance (ANOVA) table, the statistical significance of the linear model is high with $p = 0.036125 < 0.05$.

TABLE V Regression statistics.

Multiple R	0.963875
R Square	0.929056
Adjusted R Square	0.893584
Standard Error	0.157813

TABLE VI ANOVA table.

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.652293	0.652293	26.19118	0.036125
Residual	2	0.04981	0.024905		
Total	3	0.702104			

IV. Conclusions

In this paper, we analyzed the relationship between pleasure and predictor/cue learning. Not only were we able to verify the belief that pleasure becomes attached to the cues, but additionally, that the increase in pleasure at the cue goes along with a decrease in the pleasure at the reward. Note that the decrease in pleasure cannot be explained by a satiation process, as motivation is not decreasing.

From the corresponding trend of changes in pleasure at the cue and changes in the difference between pleasure at cue and reward, it seems likely that pleasure is no independent variable but a function related to motivation and reward. Studies with many more learning iterations need to be undertaken. Furthermore, it would be interesting to see what happens in case of reward extinction, what happens to the distribution of pleasure for multiple cues, if all pleasure types behave similarly, if there is a correspondence with motivation in relation to risk and other discounting, if there are differences in short- and long-term impact… the list of future work in this area is obviously very long.

Our study has shown some interesting results and hopefully kick-starts more research in this area. The results have a profound impact on entertainment experiences with learning components, predominantly games, and will help to improve future designs and support automated generation methods with mechanics for explicitly controlled cue learning and pleasure generation/propagation.

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