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Do emotion-based processes affect decision-making without awareness? Evidence from a subliminal instrumental learning task.

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Abstract

Adaptive behavior enables individuals to avoid conflicts and attend more occasions that induce pleasure. According to the Somatic Marker Hypothesis (SMH; Bechara & Damasio, 2004; Bechara, Damasio, Tranel & Damasio, 1997), adaptive behavior can occur not only intentionally but also unconsciously - prior to acquiring explicit knowledge about the utility of an operation – by the activity of somatic markers which react as a warning sign when an individual encounter an event previously associated with a negative outcome.

In the present study, we attempted to investigate the possibility that somatic activation can guide decision-making even without awareness towards the stimuli itself. For this purpose, we attempted to replicate Pessiglione et al (2008) subliminal instrumental conditioning learning task, in which participants are required to decide whether to avoid or take risks based on the monetary outcome attached to subliminal cues (Experiment 1). In addition, following findings showing that OCD is associated with impaired ability to utilize somatic signals in decision making, we used the subliminal instrumental learning task again, this time while measuring the tendency to OCD and examining participants' performance under conscious versus unconscious conditions (Experiment 2). In both experiments, we found no evidence for unconscious instrumental conditioning learning. In accordance, OCD tendency influenced task performance, but only for consciously perceived cues. The results support the theoretical proposal that consciousness might be necessary component for complex learning processes, such as instrumental conditioning learning, and provide indirect evidence that it also a prerequisite for the regulating decision-making through somatic signals.

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Introduction

Learning from past experience is a critical component of adaptive behavior. It allows us to avoid choices that will cause potential suffering and to prioritize options that will elicit pleasure. This process can be achieved intentionally by monitoring the external response that accompany a particular event or behavior. For example, by comparing an expected response to an actual response, and changing behavior according to the mismatch. It has been proposed that performance monitoring is also occur covertly, as it reflected in the autonomic nervous system (Hajcak, McDonald, & Simons, 2003; Ullsperger, Danielmeier, & Jocham, 2014; Bechara & Damasio, 2004). According to the Somatic Marker Hypothesis (SMH), each behavioral option is associated with unconscious emotion-based somatic responses evoked by its previous consequences. The associated somatic responses are activated by the re-exposure of the option (e.g., by visual perception or thoughts) and either encourage or discourage the option, depending on its value (Bechara & Damasio, 2005; Bechara, Damasio, & Damasio, 2000). Correlations of activity related to errors and feedback were observed in skin conductance response (SCR; Bechara, Damasio, Tranel & Damasio, 1997, Bechara, Damasio, Damasio & Gregory, 1999, Bechara & Damasio, 2005, Suzuki et al., 2003), pupil dilation (Bierman et al 2004), and in transient cardiac deceleration (Poppa & Bechara, 2018, Ohira, 2010; Bechara, Damasio, Tranel & Damasio, 1997). In the context of the SMH, this autonomic response act as warning signals before a disadvantageous decision, to guide behavior in the context of uncertainty. For instance, it has been shown in a gambling task that SCR increased when participants considered a choice from risky decks of cards, as opposed to safe decks, even before acquiring explicit knowledge of the goodness or badness of the decision (Bechara & Damasio, 2005; Poppa & Bechara, 2018).

While autonomic performance monitoring appears to parallel or support the process of learning, preceding its behavioral manifestation in correct choices (However see Maia & McClelland, 2004 for different interpetation), The feasibility that somatic signals guide the decision-making process without awareness of the stimuli themselves is yet unknown. Data from neuropsychology and neuroimaging studies have shown that the ability to make advantageous decisions involves choices between actions leading to uncertain outcomes and the ability to calibrate between reward and punishment depending on the integrity of the ventromedial prefrontal cortex and interconnected circuits, including the basal ganglia, thalamus, and amygdala (Bechara, Damasio, Tranel, & Anderson, 1998; Bechara & Martin, 2004; Bechara, Tranel, & Damasio, 2000; van den Heuvel et al., 2005). Some theories claim that such process is feasible only when stimuli are above the awareness threshold, as conscious processing is characterized by large-scale activation deployed through prefrontal networks, while unconscious processing, appears to be limited to separate areas, and does not result in a global spread of activity (Baars, 2002; Dehaene & Changeux, 2011; Dehaene & Naccache, 2001). Assuming that subliminally stimuli are unable to elicit large-scale activity that allows for the integration of the processes described, the procedure of adjusting behavior according to internal somatic signs may appear contrary to the theory mentioned above.

Despite the limitations of subliminal processing, Pessiglion and colleagues (2008) demonstrated through a subliminal instrumental conditioning learning task that individuals can adjust their behavior according to the association between a subliminally presented stimulus and its outcome. In this study, participants were asked to decide in each trial whether to take a risk or avoid it, in a Go/No go method, basing on the context of a subliminal cue that preceded the decision phase (See figure 1A). Results showed that participants learned to advantageously modified their risk decisions, as expressed by refraining from risk taking when a cue that predict loss of money appeared and a tendency to take more risks when a reward predicting cue appeared (See figure 1B). In addition, when participants were asked to rank at the end of the experiment how much they liked each of the symbols, they ranked the preference according to their accompanied outcome. i.e., reward- predicting symbol was the most liked, followed by the neutral - predicting symbol, and finally the symbol that predicted punishment (See figure 1C).

Figure 1. Subliminal instrumental conditioning learning task

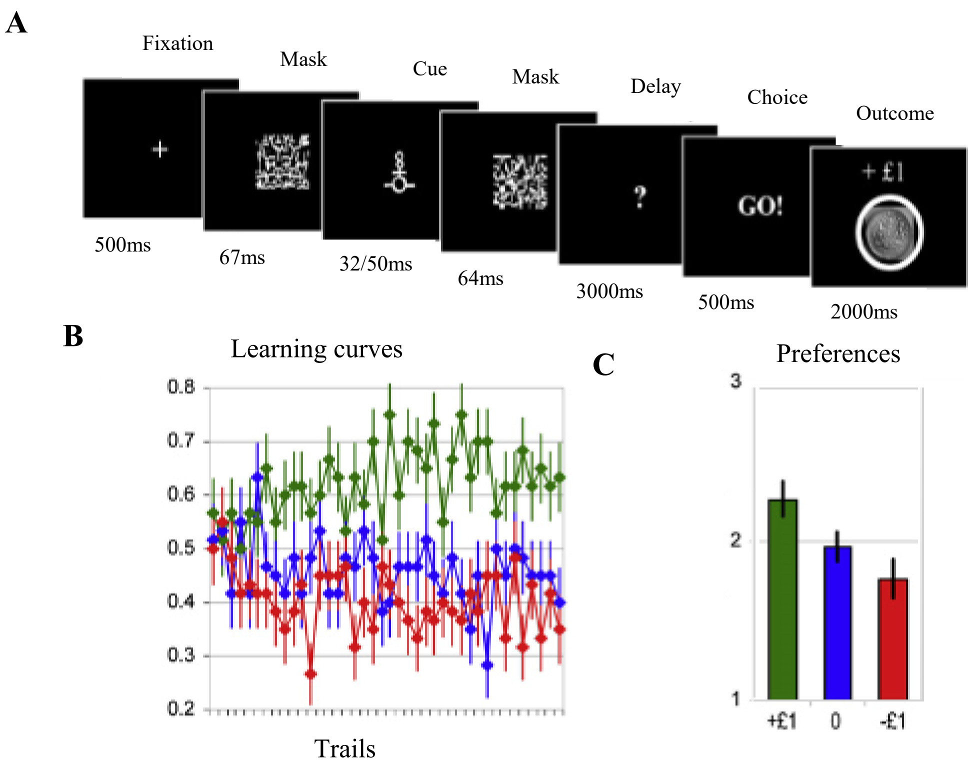

Figure 1 (A) Subliminal instrumental conditioning learning task. After a display of a masked cue, subjects had to choose wether to press or not to press a response button and subsequently observed the outcome. In this example "Go" appears in the screen because the subject has pressed the button, following the cue associated with a rewarding outcome. In this example, "Go" appears on the screen because the subject has pressed the button, following the cue associated with a rewarding outcome (winning £1). **(B)** Learning curves. Colors indicate cues for which button presses are rewarded (green), neutral (blue), or punished (red). Diamonds represents, across trials, percentages of subjects that pressed the button. **(C)** Preferences. After the conditioning phase, cues were unmasked and subjects rated them, from the most (3) to the least liked (1). The graphs show the average rating for reward (green), neutral (blue), and punishment (red) cues. Bars are intersubjects standard error of the mean.

These findings implies that participants' performance may be guided by an autonomous performance monitoring mechanism, in the absence of awareness of stimuli. However, in a recent study that conceptually replicated Pessiglione et al (2008) task, with the exception of assessing awareness after each trial, instead of separate awareness check test, it was found that participants exhibit transient moments of awareness on some trials. The researchers showed that after removal of those aware trials, evidence of subliminal instrumental learning failed to replicate (Skora et al 2021). Notably, in order to evaluate cues visibility, Skora et al (2021) asked participants to determine after each trial whether the masked cue was symmetrical or not and what is their confidence level in the response. Although this method examines consciousness more rigorously than Pessiglion et al (2008), it generates other methodological problem. This estimation may convert the instrumental conditioning task from a single to a dual task, since it requires of participants in each trial to both possess knowledge of the symmetrical trait of the stimulus and to learn the association between a context of a cue and it outcome. In doing so, the process of acquiring conditioning becomes more complex and may constitute an artifact for the lack of subliminal learning effect.

In the current study, we present two experimental attempts to investigate whether autonomic performance monitoring is engaged in an unconscious instrumental conditioning paradigm. experiment 1 attempt to directly replicate the findings of subliminal learning effect using the same procedure as Posiglione et al (2008), without modifications that may interfere with the process of acquiring the conditioning. But with minor methodological changes that enhance the efficacy of the task. Experiment 2 seek to further examine the likelihood that somatic responses regulate unconscious decision-making, by measuring tendency to OCD and contrasting participants' performance under conscious versus unconscious conditions. OCD is associated with both failure to produce somatic signals (Cavedini et al., 2012) and pathological impairment in the ability to monitor and evaluate internal sensations (Dittrich & Johansen, 2013; Lazarov, Dar, Liberman, & Oded, 2012). In consistent with the SMH claims regarding the importance of internal signals in the context of ambiguity, numerous studies showing that impairment in decision making under uncertainty is associated with OCD (see Nisticò, De Angelis, Erro, Demartini, & Ricciardi, 2021 for review) and may be a potential endophenotype marker for OCD (Dittrich & Johansen, 2013; Zhang et al., 2015). Therefore, we postulate that if somatic responses are engaged in unconscious instrumental learning, we should observe impair performances to high-OCD individuals in compare to low-OCD individuals, for either aware and unaware trials. In contrast, if somatic responses required conscious perception, we should observe impair performances to high-OCD individuals in compare to low-OCD individuals for aware trials, but not for unaware trials. Skora et al (2021) showed that when engaged in the unconscious instrumental conditioning task participants exhibit transient moments of awareness on some trials, allowing them to occasionally discriminate the nature of the masked stimuli Thus, we were able to achieve the required comparison by estimating stimuli awareness after each trial and contrasting aware and unaware trials from the same task.

Experiment 1

Experiment 1 sought to replicate Pessiglione (2008) findings, by preserving the structure, stimuli, and procedure of the subliminal instrumental conditioning learning task. The only divergence from Pessiglione et al procedure was made after the conditioning task. Newell and Shanks (2012) have pointed that although participants may actually see the cue during the experimental task, they might nonetheless respond not seeing it on a dichotomous scale because their judgment is uncertain, and they adopt a conservative decision criterion. Therefore, in the self-reporting phase, Participants were asked to report whether they liked/ recognized the symbols on a continuous scale ranging from 'no' (Value = 0) to 'yes' (Value = 100), instead of a dichotomous report of stimuli identification, as conduct by Pessiglione and colleague. In addition, Pratte & Rouder, (2009) showed that when there are difficulty differences between the separate task and the main task, lack of awareness premise may stem of low involvement of the participants in the awareness check, rather than truly invisibility of the stimuli. This scenario was observed in Pessiglion et al. (2008) study as while in the main task participants' responses towards the masked stimulus were accompanied by monetary payoff, the separate discrimination task included only subliminal stimuli - so participants did not receive feedback throughout the task. To overcome this problem, we modified the separate discrimination task so that after each trial a feedback indicated whether the participants were correct or incorrect in their response.

Methods

Participants

Twenty-four healthy students of Tel Aviv University, with reportedly normal or corrected-to-normal sight and no psychiatric or neurological history, volunteered to participate in the study for payment (~15$ per hour). Two subjects were excluded from the analysis, one due to insufficient involved participation in the study, resulting in low ratio of risk decisions in the experiment (less than 25%) and one due to above chance performance in the discrimination task. The remaining 22 subjects (nine males) were 19–32 years old (M =20.67, SD = 4.3).

Stimuli and materials

The experiment took place in a dimly lit room. All Stimuli were generated using Matlab (MathWorks, Natick, MA) with the Psychtoolbox extension (Kleiner, Brainard, & Pelli, 2007), and were presented on a 23-in. LED screen, using 1,920x1,280 resolution graphics mode. Responses were collected via the computer keyboard. Viewing distance was set at approximately 50 cm from the monitor. The experiment included 2 blocks of prime - discrimination task and 2 blocks of instrumental conditioning task. Each block consisted of three different symbols obtained from Agathodaimon font, all were 180x180 pixels in size. Therefore, 12 Agathodaimon letters were used in total for the experiment. The symbols were forward and backward masked by scrambled and mixed novel Agathodaimon fonts, also in a matrix size of 180 X 180 pixels. All stimuli were white on a black background

Experimental task and design

Each block began with the threshold of visual awareness determined individually for each participant using cues - discrimination task. In this task, a fixation cross displayed on the center of the screen for 500 MS. Then, two masked cues, 3 s apart, displayed on the center of the computer screen, each following a fixation cross. Each mask display appeared for 67 MS. Cue display appeared for 36 MS at the first block and for 50 MS at the second block. As there were 120 trials and 3 types of cues for each block, each cue was presented 40 times. Subjects had to report whether or not they perceived any difference between the two visual stimulations. The threshold is determined by the longest time interval in which participants presented a chance level performance. The display interval for most participants (i.e., 23 out of 24) was set at 50ms. The response was given manually, by pressing one of two keys assigned to ‘‘same’’ and ‘‘different’’ choices. Importantly, subjects had no opportunity to see the cues unmasked. Note that the three cues used in the perceptual discrimination control were different from those used in instrumental learning, to avoid subjects distinguishing cues on the basis of their learned values.

*Reinforcement learning task***.** The main task was adapted from the subliminal instrumental conditioning task used previously by Pessiglione et al (2008), in which participants learn to approach (Go response) or avoid (NoGo) the presented stimuli in accordance with the supraliminal outcome of their risk decisions. Participants first read the instructions, which were later explained again step by step. Then, they had to perform two blocks of the instrumental conditioning task. In each trial, a fixation cross appeared for 500ms, followed by a masked cue that displayed for either 36ms or 50ms, as adjusted to each participant. The same two masking patterns, one displayed before and the other after the cue, were used in all task session (Fig. 2). After showing the fixation cross and the masked cue, the response interval was indicated on the computer screen by a question mark. The interval was fixed to 3s and the response was taken at the end: Go if the key was being pressed, and No-go if the key was released. The response was written on the screen as soon as the delay had elapsed. Assignment of cues to the different task blocks, and associations of cues with the different outcomes, was fixed for all subjects to undergo the exact same experimental procedure. Subjects were told that one response was safe (you do not win or lose anything) while the other was risky (you can win 1 Shekel, lose 1 Shekel, or get nothing.(Subjects were also told that the outcome of the risky response would depend on the cue that was displayed between the mask images.

Familiarity and liking scale. At the end of the subliminal conditioning task, subjects were shown the cues unmasked one by one and asked to grade the extent to which they saw the stimuli (i.e., 'did you see the image during the experiment?') / Liked the stimuli (i.e., 'Do you like the image?) on a continuous scale ranging from ‘no’ (i.e., 0) to ‘yes’ (i.e., 100).

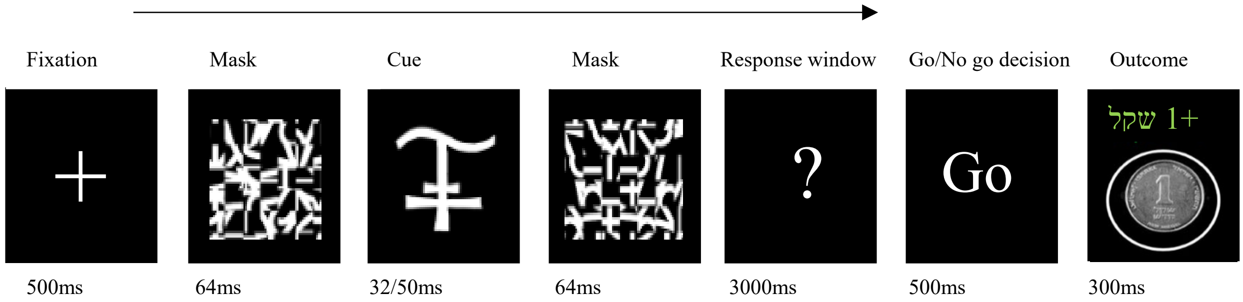

Figure 2. Sequence of events: Participants are presented with a single cue (rewarding or punishing), exhibited unconscious with forward-backward masking. After cue presentation, participants requested to make an approach (Go) or avoid (NoGo) response, following their intuition. Holding the Space button at the end of the response window will lead to a risk decision, and non-holding means avoiding risk and transition to the next trial. In this example, a participant executed the Go response following a rewarding cue and were rewarded with one Shekel coin.

Results

Exclusion criteria

In every individual, correct guessing on the awareness check did not differ from chance ($p > 0.05$, chi-square test). At group level, average percentage of correct responses for the 24 subjects was 50% ± 3.2%, d' = .01, which again was not different from chance ($p > 0.5$, two-tailed paired t test). One participant was excluded from the main task anlysis due to lack of Go responses (less than 25 %), yielding a final sample of 23 participants.

Performance in the conditioning task

Monetary payoff used as a dependent variable to assess the effects of subliminal learning. On average, participants performed more Go responses (57%) than NoGo responses (43%), regardless of cue type. Overall monetary payoff of subjects in the task did not differ than zero (M = 0.54 NIS, SD = 6.2 NIS, $p > .05$, one-tailed paired t test). Indicating that risk decisions were not taken differently for reward- predictive cues and punishment- predictive cues. Learning curves show that participants' decision-making improved from the second half of the experiment (i.e. More Go responses for reward versus punishment trials). However, this pattern is inconsistent and ends in 45% ± 6.8% of responses to reward-predictive cues (See figure 3 above). The effect of conditioning was subsequently assessed by conducting a repeated measures ANOVA analysis on participants responses, with task phase (above median /below median) and value (punish / reward) as within participants variables (See figure 3 below). Neither the main effect of value, nor the main effect of trial phase reached statistical significance (F (1,22) = .17, p > .05 ; F (1,22) = 2.62, p = .12). Although participants showed a tendency to make less risky decisions for cues that predict punishment compared to cues that predict reward in late trials compared to early trials (Mean difference = 2.18, SD = 5.83 ; Mean difference = 0.24 SD = 4.89, respectively).The interaction between trial phase and Value did not reach significant (F(1,22) = 1.22 , p > .05). Indicating that participants did not tend to take risks differently for positive versus negative cues in advanced stages of the experiment compared to early stages.

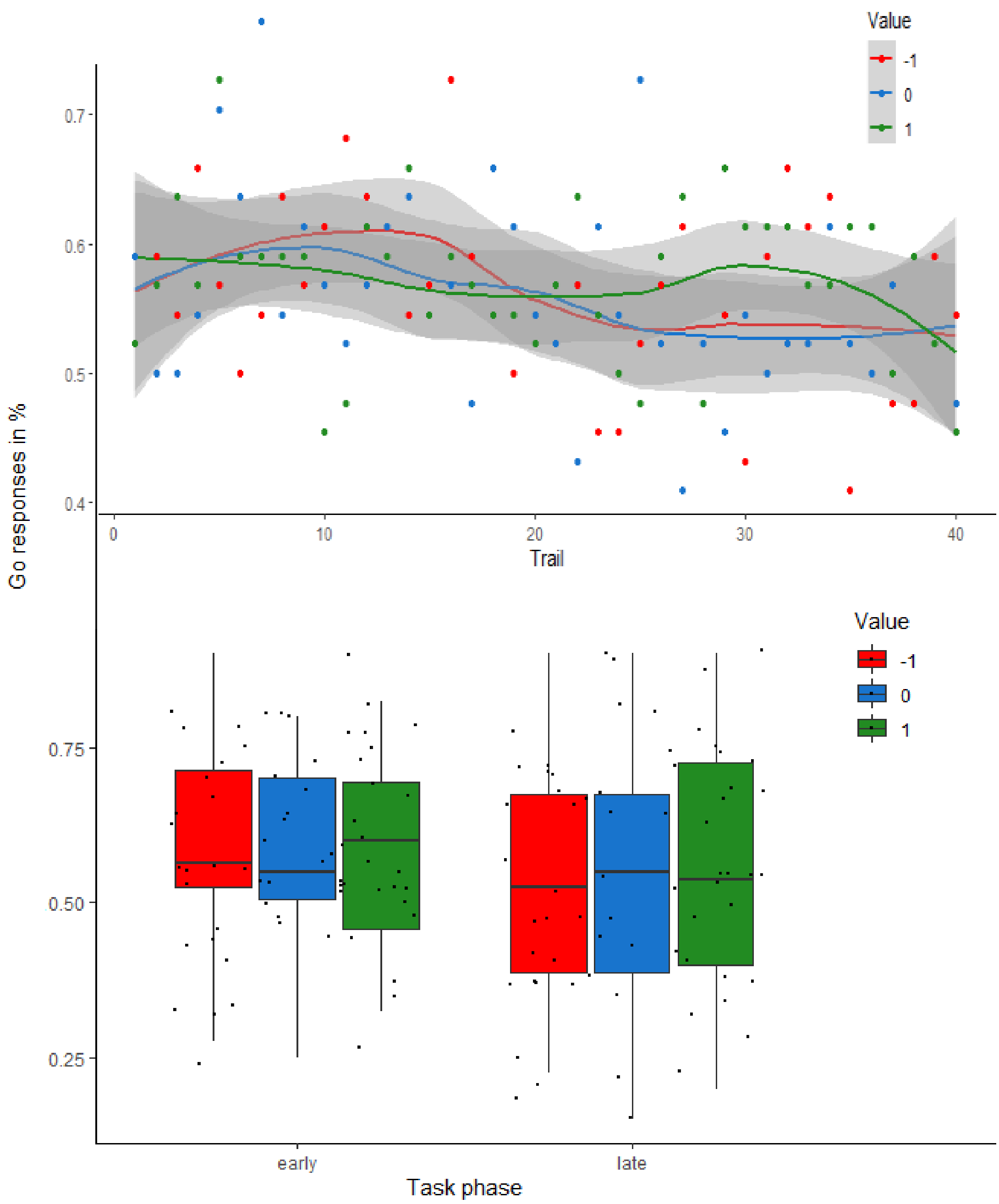

Fig. 3. Above Learning curves. Average proportions of Go responses. Colors indicate cues for which Go responses were rewarded (green), neutral(blue), or punished (red) with intersubjects average data

points. Ribbon represents a regression line (90% CI). **Below:** Learning bars. Percentages of Go response for rewarded (green), neutral (blue) and punished (red) trials with individual data points.

Liking and familiarity ratings

Most of the participants (i.e., 20 out of 23) reported that the cues were experienced by them as familiar (M = 37.38, SD = 16.47). Repeated-measures analyses of variance (ANOVAs) were conducted for liking of the three presented cues (rewarding, punishing, and unseen) and familiarity with them.

ANOVA revealed no significant main effect of cue type (reward, punishment, neutral) on liking ($F(2,63) = .344$, $p > .05$), or familiarity ($F(2,63) = 1.37$, $p > .05$). No differences were found in any of the pairwise comparisons between the three cues on liking (all $p > 0.05$) nor familiarity (all $p > 0.05$), suggesting that participants developed no increased liking of the reward-predicting cues over the punishment-predicting one and nor ability to distinguish between unseen cues and seen cues. Pearson correlation conducted to examine whether the average familiarity of the stimuli is expressed in participants decision making pattern in the gambling task. The correlation between familiarity and monetary payoff was significant ($r = 0.18$; $p < .05$). Indicating that greater familiarity of the symbols was reflected in more advantageous risk decisions.

Discussion

Experiment 1 attempted to directly replicate the unconscious instrumental conditioning task, used by Pessiglione et al (2008). The results demonstrate that no unconscious instrumental conditioning was achieved –participants were unable to distinguish between the stimuli and adjust their behavior accordingly (i.e. choose to Go or NoGo, respectively) and they did not show a higher preference at the end of the experiment to cues that predicted a monetary reward than cues that predicted monetary loss. These results do not support the feasibility of somatic signals to guide the process of learning in the absence of awareness and constitute a failure to replicate Posiglion and colleagues (2008) findings. For, although the findings were not significant, the average payoffs of participants were slightly higher than 0 (i.e., 0.54 Shekel) and a large variance was recorded in the performance of the task (SD = 6.2 Shekel). Thus, an alternative possibility for the absence of the effect is that some participants have learned to distinguish between the stimuli, however averaging the sample as a whole reflected lack of subliminal learning due to a source of interpersonal differences that was not taken into account.

Based on evidence of impairment in decision-making under uncertainty among OCD patients (Nisticò, De Angelis, Erro, Demartini, & Ricciardi, 2021), we hypothesized that the tendency to OCD in healthy patients may be a source of interpersonal differences in the performance of the subliminal instrumental conditioning learning task. Confirmation of this assumption strengthen the feasibility that somatic mechanisms mediate the instrumental conditioning learning process without awareness, as OCD is associated with impaired pathological to produce somatic signals (Cavedini et al., 2012) and appraise internal sensations (Dittrich & Johansen, 2013; Lazarov, Dar, Liberman, & Oded, 2012; Zhang et al., 2015).

Experiment 2

Experiment 2 sought to examine whether autonomic performance monitoring is engaged in an unconscious instrumental conditioning paradigm, by measuring OCD tendency and analyzing participants performances in conscious versus unconscious conditions. To differentiate between conscious and unconscious trials, we used the liminal prime-paradigm (Avneon & Lamy, 2018; Van den Bussche et al., 2013), in which perception of the cue is measured on every trial using a variant of the Perceptual Awareness Scale (PAS, Ramsøy & Overgaard, 2004). With PAS, observers report on the quality of their subjective experience, using a 4-point scale of visibility: (1) 'No experience', (2) 'Brief glimpse', (3) 'Almost clear image', and (4) 'Absolutely clear image'. Thereby allowing to monitor the levels of awareness on an ongoing basis and separate between trials which were genuinely outside of conscious awareness (0-visibility trials) to partly aware trials (above-0 visibility trials). The effectiveness of this method in distinguishing participants' awareness has been demonstrated in several studies showing that when individuals report the lowest level of stimulus visibility using PAS, their performance on an accompanying objective discrimination task is at chance, while task performances coincide with intermediate values reports were significantly above chance level (Lamy, Alon, Carmel, & Shalev, 2015; Lamy, Carmel, & Peremen, 2017; Ramsøy & Overgaard, 2004). Importantly, this method measures the conscious experience in a more exhaustive manner, as it does not limit by successful behavior. Also, it does not require the acquisition of additional knowledge and thus avoid forming a dual-task procedure.

Method

Participants

The subjects were 29 Tel Aviv University undergraduates who participated in the experiment for course credit. None of them had participated in Experiment 1. Three subjects were excluded from the analysis. One due to insufficient involved participation in the study, resulting in too few risk responses (less than 10%). One was not included in the experiment due to high accuracy rates in the perception task (correct responses = 67%, d' = .27 , X2 = 7.11, $p < .05$) And one did not meet the conditions of participation due to neurological history. The remaining 26 subjects (two males) were 19–35 years old (mean = 25.14, SD = 8.07), All reported having normal or corrected visual acuity and no psychiatric or neurological history

Apparatus, Stimuli, and Procedure

The apparatus, stimuli, and procedure were the same as in Experiment 1, except for the following changes. First, duration of cue display was fixed at 50 ms and not adapted to each individual, such that subliminal stimulations were identical for all subjects. Second, the prime-discrimination task occurred subsequent to the subliminal conditioning task, and included only one block in which the cue appeared for 50 ms. Finally, after each trial in the subliminal conditioning task, participants were required to report on a scale of 0–3, to what extent they saw the masked symbol.

Measures

Obsessive–compulsive tendencies were measured by the Obsessive–Compulsive Inventory-Revised (OCI-R; Foa et al., 2002). The OCI-R has 18 items scored on a 5-point Likert scale 0-4. It has six subscales: a) washing, b) checking, c) ordering, d) obsessing, e) hoarding, and f) mental neutralizing. The OCIR retained good psychometric properties from the original OCI questionnaire: it has high test-retest reliability (0.74-0.90), convergent (0.74- 0.98) and discriminant validity (0.53-0.85). The range of the overall score is 0-72.

Results

Exclusion criteria

In order to assure that analyses are conducted only on trials that were truly unconscious, all individuals trials in which participants reported partial perception of the masked image considered as aware and excluded (19.4% of the trials). 23 out of 28 participants consciously percived the cue at least once during the experimnet (M = 18.8% SD = 24.%). Except for a single participant whose performance was higher than a chance level in the discrimination task (d' = .27 , $X^2 = 7.11$, $p < .05$) and was excluded from the analysis, correct guessing on the discrimination task in every individual did not differ from chance. One participant were excluded due to lack of Go responses (less than 25%), yielding a final sample of 26 participants. Average OCI-R score of the remaining participants was 20.9 with a standard deviation of 10.65.

Evidence of learning: Performance in the conditioning task

First, mixed data (i.e., aware and unaware trials) were used to replicate the main findings of Experiment 1. Again, monetary payoff used as a dependent variable to assess the effects of subliminal conditioning. Similar to Experiment 1, Although a tendency towards gambling learning has been documented, the average monetary payoff of participants from gambling (M = 1.27, SD = 7.63) was not different than 0, $t(25) = 0.84$, $p > .05$, one sample t- test. Indicating that the risky response was equally chosen for reward predictive cues and punishment predictive cues. Learning curves showed no systematically improvement in risk-decisions as the experiment progressed, ending with 53% ± 6.9% of responses for reward predictive cues. In order to assess the feasibility of reinforcment learning without awareness, data were divided to unprecived trials (i.e, reported perception equal to 0) and partly percived trials (i.e, reported perception is greater than 0). This division of data led to asymmetrical amount of negative and positive cues in each sample, so monetory payoff could not be taken into account as a valid measure of success in the reinforcment task anymore. hence, we generated an alternative dependent variable named 'response diffrences' by substracing the percentage of risk-taking for punishment trials from the percentage of risk-taking for reward trials.This measure can be taken as evidence of successful learning (i.e., discrimination between the cues) if it is significantly above 0.

Response diffrences were not significantly greater than 0 for unaware trials (M =.00, SD = 0.1, $p > .05$, One sample t-test). Pearson's correlation was used to examine whether the lack of effect could be explained by interpersonal differences in the tendency to OCD. No correlation was found between tendency to OCD and risk-taking differences, $r (25) = .14$, $p > .05$. Indicating that without awareness participants do not show subliminal learning in the task, regardless of the tendency for OCD. In contrast, response diffrences were significantly greater than 0 for precived trials (M = .03, SD = .09 , $t(20) = 1.77$; $p < .05$, One sample t-test). On average, participants took 3% +- 9.4% more Go responses to reward-predicting cues compared to punishment-predicting cues, when a conscious perception of the cue was reported.

In order to further examine the relation between aware awaraness and tendency to OCD on the performance in the reinforcement task, a three-stage hierarchical multiple regression was conducted to predict responses differences from percentages of aware trials, OCD tendency and the interaction of the two factors. Aware trials entered at the first regression model to control for degree of stimuli perception across trials. OCD tendency was entered at model two, and the interaction of the two variables at model three. The Relationship variables were entered in this order since partial awareness seems to be a prerequisite for subliminal learning. Table X summarizes the analysis results.

Table 1

Summary of Hierarchical Analysis for variables predicting responses differences

Variable	B	t	R	R^2	ΔR 2
Model 1			.21	.03	-.00
Perception percentages	-.24	-1.22			
Model 2			.28	.08	-.00
Perception percentages	-.01	-.69			
OC tendency	-.22	-1.06			
Model 3			.54	.29	.20
Perception percentages	-.00	-.53			
OC tendency	.22	.89			
Perception percentages * OC tendency	-0.02	-2.59*			

Note. N = 25; *p < .05

The hierarchical multiple regression revealed that at Model one, percentages of aware trials did not significantly contributed to the regression model, $F(1,24) = .79$, $p > .05$ and accounted only for 3.8% of the variation in responses differences. Introducing the OCD tendency variable explained an additional 4.2% of variation in the responses differences and this change in R^2 was not significant, $F(2,23) = 0.96$, $p > .05$. finally the addition of the correlation between the variables to the regression model explained an additional 21% of the variation in response differences, and this change in R^2 was significant, $F(3,22) = 3.04$, $p = 0.05$. Therefore, the most important predictor of responses differences was the interaction between perception percentages and OCD tendency which uniquely explained 21% of the variation in responses differences, while all the variables together accounted for 29% of the variance in responses differences (see figure 3 below for illustration of the model).

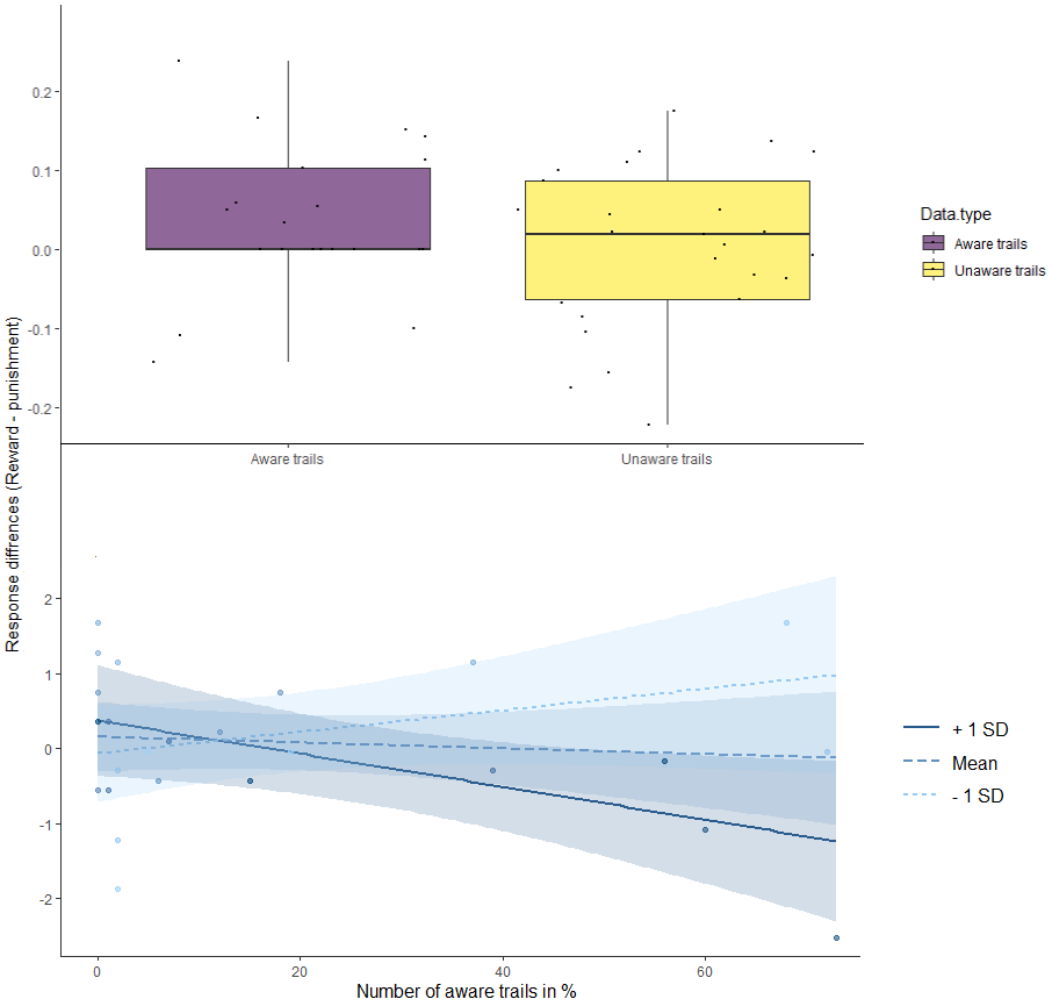

Fig. 4. Above: average response differences for unaware trials (i.e. yellow box) and aware trials only (i.e. purple box), with individual data points. Black line represents median of response differences. **Below:** average response differences for mixed trials (i.e. aware and unaware trials) according to OCD tendency, such that lighter blue represents a lower tendency for OCD. Average proportions of response differences plotted against the number of aware trials. Ribbon represents a regression line (90% CI).

To rule out the possibility that the response differences were driven by differences in visual acuity, we calculated the correlation between d' score in the discrimination task and OCD tendency. Pearson's correlation was small and insignificant ($r = -.03$; $p > .05$), suggesting no association between visual acuity and tendency to OCD.

Liking and familiarity ratings

Repeated-measures analyses of variance (ANOVAs) were conducted for liking of the three presented cues (rewarding, punishing, and unseen) and their familiarity. ANOVA revealed no significant main effect of cue type (rewarding, punishing, unseen) on liking ($F(2, 75) = .15$, $p = .85$), or familiarity ($F(2, 75) = .29$, $p = .74$). No differences were found in any of the pairwise comparisons between the three cues on liking (all $p > .05$), suggesting that participants developed no increased liking of the reward-predicting stimulus over the punishment-predicting one. Further, the relation between percentages of aware trials and stimuli identification assessed. A Pearson correlation test showed that the two were not significantly related ($r = .1$, $p > .05$), indicating that aware perception of the stimuli across the task did not contribute to the familiarity of the symbols when they were unmasked. The correlation between the average subjective identification of the symbols and monetary payoff was not replicated in the current experiment ($p > .05$).

Discussion

Experiment 2 attempted to investigate whether autonomous performance monitoring mediates subliminal instrumental learning, by examining the relationship between participant performance and OCD tendency, under conditions of absence of awareness and partial awareness. Results demonstrate that when participants had no conscious awareness of the stimuli (I.e., reported visibility = 0), no unconscious instrumental conditioning was achieved. Inability of participants to adjust an advantageous decisions strategy without awareness (I.e., equal risk-taking for cues that predict punishment and reward) was not found to be correlated with OCD tendency. This finding constitutes a failure to replicate Pessiglione et al (2008) unconscious instrumental conditioning learning effect, and constitute as evidence that somatic signals are incapable to regulate decisions, when stimuli are outside the consciousness threshold. Thus consistent with theories suggesting that conscious perception is required for the integration of different brain modules into uniform processing (Dehaene & Changeux, 2011; Dehaene & Naccache, 2001 ; Barrs 2002).

General discussion

In the present study, we examined the feasibility that somatic markers guides decisions without awareness, using Pessiglione (2008) instrumental conditioning learning paradigm. Evidence of success in the performance of the subliminal learning task will imply the presence of a somatic mechanism which monitors the value of different options and shapes the behavior covertly, irrespective of explicit knowledge. The absence of such a mechanism would however strengthen the evidence that instrumental learning cannot proceed without conscious awareness.

The current study findings provide no evidence for the feasibility of somatic signals to guild performance without awareness. In experiment 1, participants risk-decisions were not significantly different following cues predicting reward relative to punishment. Also, examining the Go response pattern did not indicate a tendency to adopt an adaptive risk-taking strategy as the experiment progressed. These findings were constituting a direct failure to replicate Pessiglione et al (2008) results. In Experiment 2, after exclusion of partially aware trials (I.e., cue visibility > 0), participants were completely unable to distinguish between reward and loss predicted trials (Go response differences = .00), irrespective of OCD tendency. These findings ruled out the possibility that interpersonal differences in OCD bias the average sample to chance performance, and implies that the masked stimulus was not processed to the extent allowing for integration with feedback and updating of stimulus values. Thus, are in line with theoretical frameworks that emphasize the role of conscious for uniform processing of information from distinct regions in the brain (Dehaene & Changeux, 2011; Dehaene & Naccache, 2001 ; Barrs 2002). Under those accounts, conscious awareness is related to long-lasting interactions between distant brain regions which enable the exchange of information between several spatially separated modules. In accordance with this theoretical framework and the findings of the present study, it is more plausible to assume that the subliminal learning effect shown in Possiglione et al (2008) was obtained due to influence of stimuli which were partially aware during the experiment, rather than unconscious pairing of unseen stimuli and supraliminal outcome.

Consistent with this assumption, Experiment 2 showed that in aware trials participants demonstrated an increased ability to differentiate between the rewarding and punishing stimuli. This result is in line with the suggestion that autonomic mechanism regulate individual's decisions under uncertainty. According to this account, consciously perceiving the stimuli permits the operation of the somatic signals (e.g. SCR), which covertly evaluate the utility of various options that otherwise would be indecipherable (Bechara & Damasio, 2005; Bechara, Damasio, & Damasio, 2000). This also accounts why partial awareness of stimuli did not predict performances as a major predictor, but only in interaction with OCD tendency (see table 1). High-OCD tendency individuals are susceptible to impairs in decision making under circumstances of ambiguity, due to poor ability to utilize somatic signals, as OCD is associated with both failure to produce somatic signals (Cavedini et al., 2012) and pathological impairment in the ability to monitor and evaluate internal sensations (Dittrich & Johansen, 2013; Lazarov, Dar, Liberman, & Oded, 2012). Thus, they are unable to translate partial awareness of stimuli into success in the gambling task.

However, there is an alternative explanation, based on an overt processing mechanism, that may govern the ability of participants to adjust their behavior. In line with previous evidence showing that individuals may consciously perceived subcomponents of stimuli during a subliminal task, without being able to identify the entire stimulus (de Gardelle, Sackur, & Kouider, 2009; Kouider & Dupoux, 2004). Another option is that partial awareness of the masked cue may enable to adopt an explicit rule -based strategy for decisions making (Johnstone & Shanks, 2001; Newell & Bright, 2002). for instance, by systematic matching configuration fragments of stimuli to outcome (e.g., the relatedness between identifying the appearance of a semicircle on the right side of the masked cue and the contingence monetary reward).

We strongly argue against this possibility, since studies suggest that individuals with OCD exhibit no deficit in explicit information processing (Deckersbach et al., 2002), and even demonstrate enhanced performances than control groups when it was encouraged to look for the underline rule of an implicit learning task (Soref, Liberman, Abramovitch, & Dar, 2018). The latest finding was interpreted by the authors as a preference for explicit – controlled processing for individuals with OCD over automatic processing. Therefore, if an explicit-systematic process guided the decision-making in the task, we would expect to observe a major effect for partial perception and a tendency to a positive interaction with OCD (i.e. Higher tendency would predict better results) and not negative as observed in the hierarchic regression. Hence, the first possibility of an overt processing mechanism does not seem plausible to account the contribution of partial awareness in the subliminal instrumental conditioning learning task.

Notably, the suggested account is based on indirect findings and a direct examination of the relationship between partial awareness and activation of somatic signals is required in order to confirm it. One way to do this is to measure the activation intensity of somatic signals (e.g., SRC) in a subliminal gambling task using the liminal paradigm and to examine the interaction between the reported perception and the activation pattern of the somatic signals. A direct confirmation of this hypothesis will be the first evidence to the best of our knowledge that somatic activation can guide decision making regardless of explicit knowledge of the stimuli.

Study findings should be considered in light of its limitations. First, due to the restrictions imposed following the COVID-19 virus, we failed to recruit large number of participants (i.e., N = 24 in experiment 1, N = 29 in experiment 2). For this reason, we chose to examine the differences between individuals according to the tendency to OCD, rather than differences between groups (e.g., above and below the median) as customary. In addition, sample size might be too small to obtain prime effect, influencing false findings that no subliminal effect was obtained (as demonstrated in Experiments 1 and 2). However, we do not support this notion, since our sample size in both studies were larger than Possiglione et al (2008) study, which obtained significant subliminal learning results. Furthermore, Skora's (2021) study demonstrated in a much larger sample size the lack of subliminal effect when the predicting cue is truly unseen. At the same time, a follow-up study based on a larger sample is needed to demonstrate the interaction between OCD tendency and partial awareness in the performances of the subliminal reinforcement learning.

To summaries, the present study replicated Pessiglione and collegue (2008) subliminal instrumental conditioning learning task (Experiment 1) and measured OCD tendency (Experiment 2) to investigate the feasibility that autonomic performance monitoring is engaged in unconscious instrumental conditioning. We found that participants were unable to differentiate between rewarding and punishing trials, suggesting that the autonomic performance monitoring is not engaged when the stimuli are not consciously perceived. In contrast when participants reported a conscious perception of the stimuli, they were able to distinguish between the stimuli. However, their extent of success in the task depended on the tendency to OCD. This interaction implies that somatic signals guide participants' decision-making, since high tendency to OCD is associated with impaired ability to use internal signals for decision-making.

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תקציר

התנהגות סתגלנית מאפשרת ליחידים להימנע מקונפליקטים ולהשתתף באירועים רבים יותר הגורמים להנאה. לפי היפותזת האותות הגופניים (SMH; Bechara & Damasio, 2004; Bechara, Damasio, Tranel & Damasio, 1997), התנהגות אדפטיבית יכולה להתרחש לא רק באופן מכוון אלא גם באופן לא מודע - לפני רכישת ידע מפורש על התועלת של פעולה - בעזרת פעילות של אותות גופניים המגיבים כסימן אזהרה כאשר אדם נתקל באירוע הנקשר בעבר לתוצאה שלילית.

במחקר הנוכחי, ניסינו לחקור את האפשרות שאותות גופניים יכולים להנחות קבלת החלטות גם ללא מודעות כלפי הגירויים עצמם. למטרה זו, ניסינו לשחזר את משימת למידת ההתניה האינסטרומנטלית של פוסיגליון ועמיתים (Pessiglione et al, 2008), בה משתתפים נדרשים להחליט אם להימנע או לקחת סיכונים על סמך התוצאה הכספית המצורפת לרמזים תת-הכרתיים (ניסוי 1). בנוסף, בעקבות ממצאים שהראו כי הפרעה טורדנית כפייתית(OCD) קשורה לפגיעה ביכולת להשתמש באותות גופניים בתהליך קבלת החלטות, השתמשנו שוב במשימת הלמידה האינסטרומנטלית סובלימינלית, הפעם תוך כדי מדידת הנטייה ל-OCD ובחינת ביצועי המשתתפים בתנאים מודעים לעומת תנאים לא מודעים (ניסוי 2). בשני הניסויים, לא מצאנו עדות ללמידה של התניה אינסטרומנטלית ללא מודעת. בהתאם, הנטייה ל-OCD השפיעה על ביצוע המשימות, אך רק כאשר הגירויים נתפסו באופן מודע. התוצאות תומכות בהצעה התיאורטית לפיה התודעה עשויה להיות מרכיב הכרחי עבור תהליכי למידה מורכבים, כגון למידה התניה אינסטרומנטלית, ומספקות ראיות עקיפות לכך שמודעות הינה תנאי מקדים לוויסות קבלת ההחלטות באמצעות אותות גופניים.

אוניברסיטת תל-אביב
הפקולטה למדעי החברה ע"ש גרשון גורדון
בית הספר למדעי הפסיכולוגיה

האם תהליכים מבוססי רגש משפיעים על קבלת החלטות ללא מודעות? עדות ממטלת למידה אינסטרומנטלית סובלימינלית.

חיבור זה הוגש כעבודת גמר לקראת התואר "מוסמך אוניברסיטה" – M.A. באוניברסיטת תל אביב

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