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A General Mechanism for Long Term Non-Reinforced Behavioral Change

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Abstract: Achieving a long-lasting behavioral change is a major challenge that can have a large impact on the quality of life. Recently, it has been shown that using the cue-approach task (CAT), preferences for snack food items could be modified without external reinforcement. In the task, the mere association of images of snack food items with a neutral auditory cue and a speeded button press resulted in increased preferences for the associated items. We examined the generality and long term endurance of the mechanism underlying this non-reinforced behavioral change. In a series of nine independent experiments with 236 participants we used multiple cues of different modalities and a variety of conceptually different stimuli including snacks, affective images, faces and fractals. Our results show a consistent preference modification for all stimuli of neutral and positive (but not negative) valence, regardless of cue modality. More importantly, in five follow-up sessions performed one to six months after training, behavioral change was maintained and durable. Our results provide evidence of a replicable general mechanism for non-reinforced long lasting behavioral change, extending beyond cue modality and stimulus type. This mechanism can be utilized to improve our understanding of non-reinforced learning processes as well as for development of novel clinical behavioral change applications.

Keywords: cue-approach; decision making; behavioral change; preferences; emotion.

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1. Introduction

Behavioral change is an essential tool to improve health and quality of life, from treating addictions to eating and mood disorders (Butler, Chapman, Forman & Beck, 2006; Higgins et al., 1995; Lang, Wing, Venditti, Jakicic & Polley, 1998). Scientific research on behavioral change has focused mainly on the potential of reinforcement learning as a means for changing behavior and preferences in the short term, but its long term efficacy is unclear (Bjork, 2001; Bouton, 1993; Cahill & Perera, 2011; Higgins et al., 1995; Wood & Neal, 2007). Other studies focused on changing behavior by altering the presentation of the decision problem. However, such studies have also failed to address long-term efficacy (de Martino, Kumaran, Seymour & Dolan, 2006; Slovic, 1995; Tversky & Kahneman, 1986).

Recently, Schonberg et al. (2014) developed a novel paradigm named the Cue-Approach Task (CAT), which has been used to change preferences for snack foods, without external reinforcement, context change or self-control. In the task, participants first indicate their preferences for a set of stimuli by specifying their willingness to pay (WTP) for each item in an auction procedure. Then in the CAT training session, some of the items are chosen to be consistently associated with a neutral auditory cue and a speeded button press response (these stimuli are termed *Go items*), whereas other stimuli are presented without a cue (*No-Go items)*. Following training, preference modification is evaluated in a probe phase by asking participants to choose a snack they would like to eat at the end of the experiment from pairs of items with similar initial value. In these pairs only one item is a Go item, previously associated with the cue. The mere association of snack food images with a neutral auditory cue and a speeded button press during cue approach training, resulted in enhanced preferences for Go items, which was maintained two months later (Bakkour et al., 2016; Schonberg et al., 2014).

Currently it is assumed that the underlying mechanisms of CAT rely on attention, similar but not identical to the attentional boosting effect (Swallow & Jiang, 2010) where memory for task-irrelevant stimuli was enhanced when stimuli co-appeared with a target cue. Previous studies with the CAT (Bakkour et al., 2016) found that top-down attentional processes seem to play a crucial part in the behavioral change effect as when training procedure did not require participants to devote attentional effort, the behavioral change did not occur. It was also found that pressing with no cue, did not induce behavioral change, suggesting that the association of stimuli with cue as well as the motor response are necessary in order to induce behavioral change (Bakkour et al., 2016). The effect does not depend on low level motor circuits, as preferences for Go items maintained also when probe choices were done using independent motor output system, such as eye movements (Bakkour et al., 2016).

To date, the CAT was only tested using a neutral auditory cue with snack food items which are familiar, appetitive consumable stimuli. Providing evidence for a general mechanism that can be used to modify preferences beyond specific features of the stimulus or cue will be of great importance, both for understanding the underlying mechanisms of non-reinforced behavioral change, as well as for the applicability in behaviors beyond food consumption such as treatment of mood disorders.

In the current investigation, we conducted nine independent behavioral experiments aimed to examine the generality of the mechanisms underlying CAT's non-reinforced behavioral change. We used new cues and different types of stimuli of various familiarity and relevance to participants. First, in Experiments 1-2, we tested whether the modality of the cue (Ng & Chan, 2012; Stein, London, Wilkinson & Price, 1996) or its neutrality are necessary features for behavioral change. We used local snack food items, as in previous research (Bakkour et al., 2016; Schonberg et al., 2014), that participants were familiar with and had pre-existing preferences for. However, in these experiments the neutral auditory cue used in previous studies was replaced by a neutral visual cue (in Experiment 1) or an aversive auditory cue (Experiment 2). Second, we wanted to examine the effect stimuli's valence, therefore we used stimuli of positive (Experiments 3-4) and negative (Experiments 5-6) valence from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2008). In these experiments, we used a neutral auditory cue (Experiments 3 and 5) and a neutral visual cue (Experiments 4 and 6). Although the specific IAPS stimuli were not familiar to participants like the snacks, their affective context is common and apprehensible to most participants. While previous research using snack food items only tested efficacy in changing preferences for positive stimuli, using IAPS stimuli we were able to directly examine the importance of the stimulus valence by using both negative and positive stimuli. Third, in Experiment 7 we aimed to test non-reinforced behavioral change with ecologically valid stimuli using unfamiliar face images. Faces are important social stimuli that are known to elicit preferences (Aharon et al., 2001; Kranz & Ishai, 2006). However, participants had no pre-existing experiences with these faces and due to their neutral expression, they were expected to evoke less perspicuous emotional responses in comparison to appetitive snacks and IAPS stimuli. Faces serve as important stimuli processed by a unique neural network (Downing, 2007; Kanwisher, McDermott & Chun, 1997). Finally, in Experiments 8-9, we used images of fractal art which are novel and conceptually abstract stimuli. Fractals are artificial computer generated stimuli, formed from geometric patterns. Participants were unfamiliar with such abstract stimuli, which unlike other stimuli are also difficult to associate with semantic knowledge.

In addition to using various cues and stimuli, a central aim of the current investigation was to examine the long-term durability of non-reinforced behavioral change. Demonstrating that the behavioral change effect is durable over a long period of time could point to its potential applicability in inducing long-term change. In order to examine long-term maintenance over time, we invited participants from five experiments for an additional follow-up session. In this session, we assessed the long-term effect following a period of one month (Experiment 7), two months (Experiments 1-2), four months (Experiment 8) and six months (Experiment 9) after training.

Based on previous CAT experiments (Bakkour et al., 2016; Schonberg et al., 2014), we hypothesized that cue-approach training would result in increased preferences for Go items (i.e. items that were previously associated with a cue and a response) over No-Go items with similar initial preferences. We also predicted that this behavioral change would be more robust for high-value items (items for which a participant had a higher pre-existing preference) than for low-value items.

2. Methods

Participants

A total of 236 healthy participants completed their participation in one of nine independent experiments. In five experiments (Experiments 1-2 and 7-9), 84 participants (average of 67% retention rate of the first sample) agreed to return for an additional follow-up session one to six months following their original participation date (for a demographic description of each experimental sample see Table 1). All participants had normal or corrected to normal vision and hearing and gave their informed consent to participate in the experiments in return for monetary compensation or in some cases in return for course credit (course credit was used only in Experiments 3-6). The study was approved by the ethics committee of Tel Aviv University (Experiments 1-2, 7-9) and by the ethics committee of The Hebrew University of Jerusalem (Experiments 3-6).

Our target sample size of n=25 for each experiment was selected based on power analysis of 80% calculated from previous experiments with the CAT (Schonberg et al., 2014) and an additional pilot study conducted in our lab (unpublished; power analysis is available online at osf.io/h36vr). Final sample sizes in each sample ranged from 25-29 (effects reported remain consistent also when participants beyond n=25 are removed).

In addition to the reported 236 participants, another 22 participants across nine experiments were excluded from final analyses, as reported in Table 1 and Supplementary Table 1. Twelve participants were disqualified due to poor performance in training, an exclusion criteria adopted from previous CAT studies (Bakkour et al., 2016; Schonberg et al., 2014); six participants due to technical problems with the apparatus running the experiment; two participants requested to quit; one participant entirely avoided choices of low-valued snacks during probe phase and one participant due to extreme intransitivity in initial preferences (transitivity score from initial preferences evaluation was 3.67 SD below the group mean).

Materials

Stimuli. Five different stimuli sets were used, each containing 60 identically sized color images of either popular Israeli snack food items (dataset created in our lab for Experiments 1-2; “Snack food Items Dataset”, 2017), positive images (Experiments 3-4) or negative images (Experiments 5-6) from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2008), unfamiliar faces (used in Experiment 3; adapted from Vieira, Bottino, Laurentini & De Simone, 2014) and fractal art (Experiments 1-2; “Fantastic Fractals”, 2013).

For Experiments 1-2 conducted with familiar snack food items, we prepared a new stimuli dataset of familiar snacks (“Snack food Items Dataset”, 2017). Snacks images were of identical size (576 × 432 pixels) and presented on homogenous black background. For the IAPS experiments, images were selected based on the norms published by Lang et al. (2008). For the positive IAPS experiments (Experiments 3-4) we used

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affective images, which were rated as inducing positive affect (valence M = 7.10 on a 1 to 9 scale, SD = 0.43; arousal M = 5.16 on a 1 to 9 scale, SD = 0.46). For the negative IAPS experiments (Experiments 5-6) we used images perceived as negative affective stimuli (valence M = 2.87, SD = 0.55; arousal M = 5.50, SD = 0.78). In the negative affective experiments we also used three additional stimuli not from the official IAPS dataset, which were found to induce negative affect in another independent study (Bigman, Sheppes & Tamir, in press). All IAPS stimuli were rescaled into identical size (533 × 400 pixels). The face stimuli (Laurentini & De Simone, 2014) used in Experiment 7, included 30 male and 30 female front-facing face images, posing a neutral expression with limited facial hair and make-up. The original images were graphically edited using Adobe Photoshop. All face stimuli were cropped to identical size (400 × 500 pixels) and the original green background was replaced with a homogenous gray background. In order to maintain similar position and relative proportion of the stimuli, faces were centered and aligned according to the location of the pupils (see example in Figure 1a.). Computer-generated fractal art stimuli ("Fantastic Fractals", 2013) used in Experiments 8-9 included 60 identical sized (576 × 432 pixels) color images.

Cues. We used three types of training cues: In Experiments 3, 5 and 7-9, we used a neutral auditory cue comprised of a 180-ms sinusoidal wave tone, identical to the one used in Schonberg et al. (2014); in Experiments 1, 4 and 6, a visual cue of a 180-ms semi-transparent Gabor was used (see example in Figure 1c-d); in Experiment 2 we used an aversive 300-ms auditory cue created with a cotangent function (auditory cues provided as Supplementary Code).

Stimuli presentation. Stimuli were presented using MATLAB (Mathworks, Inc. Natick, MA, USA), Psychtoolbox (Kleiner et al., 2007) and Python-based Pygame (Shinners, 2011) packages, on 21.5 inch iMac or PC with 21 inch screen. In order to induce an aversive cue in Experiment 2 the sound was played in a controlled high volume using Plantronics BackBeat Pro noise-canceling headphones.

Procedure

Baseline evaluation of subjective preferences. Participants' baseline subjective preferences for each one of the stimuli in a given experiment were evaluated individually using two methods: an auction procedure in experiments with consumable snack food stimuli (Experiments 1-2), and a forced choice binary ranking procedure for non-consumables (used in Experiments 3-9). Based on these valuations, stimuli were rank ordered individually for each participant, from the most liked item (rank 1) to the least liked item (rank 60).

Auction procedure for snack food items. In experiments with snack food items (Experiments 1-2), participants underwent an auction task based on the Becker, DeGroot and Marschak (BDM; 1964) auction procedure to obtain their willingness to pay (WTP), as in previous CAT studies (Bakkour et al., 2016; Schonberg et al., 2014). Prior to their participation in the experiment, subjects were asked to fast for at least four hours. Upon arrival to the laboratory, participants received a sum of 10 New Israeli Shekels (~2.5$ US equivalent) to be used in an auction task. In this task, snack food items were presented individually on the screen one at a time. Participants selected their bid for each item on a visual analog scale using a mouse (see Figure 2a). Participants were explicitly told that offering the amount they are willing to pay for each item was the best strategy for the task. At the end of the experiment, one trial was chosen at random to be played out for real purchase from the experimenter. The computer randomly generated a counter bid (ranging from 0 – 10, 0.5 increments). In case the participant's bid was higher than the computer's, he or she had won the bid and were required to buy the item in return for the computer bid price; otherwise, the participant could not purchase the item, but was left with the money designated for the auction at the beginning of the experiment.

Binary ranking for non-consumables items. In experiments with non-consumable stimuli (i.e. IAPS, faces and fractals; Experiments 3-9), we used a forced-choice binary ranking procedure. In this task, the 60 stimuli were randomly paired with each other to form 300 unique pairs. For each pair of stimuli participants had 2500-ms to choose their preferred stimulus, followed by a 500-ms choice confirmation and 500-ms

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fixation cross (see Figure 2a). In order to maintain balanced exposure, each stimulus was presented in exactly 10 pairs during the binary ranking phase.

Choices were then quantified into ranking scores. Based on the assumption of choice transitivity from the Rational Choice Theory (von Neumann & Morgenstern, 1944), we used the outcomes from the set of binary choices in order to deduce individual preferences toward the presented set of stimuli (e.g., if stimulus A is preferred over B, and stimulus B is preferred over C, then their respective ranks follows A≻B≻C). To maximize ranking validity and specificity we used the Colley Matrix algorithm (Colley, 2002), designed to solve ranking problems with a relatively small number of binary outcomes. This ranking procedure resulted in a ranking list of the 60 stimuli, based on each participant's individual preferences. From these rankings, we quantified a transitivity score for each participant and excluded participants who demonstrated extreme intransitive choice patterns (3 SD below the group mean).

Cue-approach training. Following the baseline evaluation of subjective preferences task, participants underwent a 40-minutes long cue-approach training procedure, during which a consistent association was formed between some of the stimuli and a cue, followed by a response (see Figure 2b). Each stimulus in the training set was presented individually on the screen for 1000-ms, once during each training run. Stimuli were randomly ordered and followed by a jittered fixation cross with an average duration of 2000-ms (SD = 1243-ms; range of 1000 - 6000-ms, 1000-ms intervals).

We used two formats of training designs, both were 40-mintues long, but the number of training runs in each design was different. In the first, shorter-training design (used in Experiments 3, 5 and 8), the training set consisted of all 60 stimuli, presented in 12 training runs. In the second, longer-training design (used in Experiments 1, 2, 4, 6, 7 and 9), the number of training runs was increased to 20 and the duration of each run was reduced by presenting only a subset of 40 stimuli, consisting of 20 high-value (ranked 3-22, above the median rank) and 20 low-value items (ranked 39-58).

One third of the training set items (20 out of 60 items in the shorter-training design) or 30% of items (12 out of 40 items in the longer-training design) were associated with the Go cue. Participants were instructed to respond to the Go cue by pressing a keyboard button as fast as possible, before stimulus offset. The stimuli associated with the Go cue are hereby referred to as Go items, and the items that appeared in the training with no cue are referred to as No-Go items. Participants were not informed in advance that the association of stimuli with the cue was consistent or which items would be Go items.

Items were assigned to be associated with the Go cue based on the previous baseline preferences evaluation task. Two sets of high-value stimuli with identical mean ranks and two sets of low-value stimuli with identical mean ranks were obtained (see Supplementary Figure 1). For each participant, one high-value set and one low-value set were chosen to be consistently associated with the cue (Go items), whereas all other stimuli appeared without a cue (No-Go items). The Go-cue appeared following a delay of ~750-ms from stimulus onset. To maintain a balanced difficulty level across the training phase, the delay was updated according to participants' performances. Hits and misses of cue resulted in an increase of 16.67-ms or decrease of 50-ms in the Go cue delay, respectively (1:3 ratio in delay adjustment rate). A minimal and maximal delay of 0-918 ms was set to ensure that cue onset always occurred during stimulus presentation.

Probe. Following cue-approach training, in the probe phase, preference change was evaluated. On each probe trial, two items appeared on the right and left of a central fixation cross, and participants were asked to select their preferred stimulus. In each pair, both items were of similar initial value (either high-value or low-value), but only one item was a Go item, previously associated with the cue and button press during training. For each pair, participants had a 1500-ms to respond, followed by a 500-ms choice confirmation and a fixation cross for a jittered duration with an average of 3000-ms (range of 1000-11000-ms, 1000-ms intervals; see Figure 2c).

In the design used in Experiments 3, 5 and 8, probe choices of each value category (high and low value) included eight Go items which were compared to eight No-Go items of equal mean rank, for a total of 64

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(8x8) unique comparisons per value category. In the second design used in Experiments 1, 2, 4, 6, 7 and 9, probe choices included six Go and six No-Go items for a total of 36 (6x6) unique probe comparisons in each value category (Supplementary Figure 1). In addition to these comparisons, 'sanity check' trials were also incorporated in the probe phase, as conducted in previous CAT experiments (Bakkour et al., 2016; Schonberg et al., 2014). In the 'sanity check' trials, participants were asked to choose between pairs of items in which one item was of initial high value and the other of initial low value (both Go or both No-Go items), in order to reassure the validity of the initial preference evaluation procedure. The probe phase included two runs. On each run, all unique probe pairs were presented in a random order. Thus, each unique pair was presented twice during the probe phase. In Experiments 1-2, conducted with snack food items, choices were made for actual food consumption. Participants were informed in advance that one trial would be selected at random, and that they would receive the item selected on that trial at the end of the experiment. This ensured participants performed incentive-compatible choices.

Memory. At the end of the experiment, participants performed an Old/New and Go/No-Go recognition tasks. The results of these tasks are beyond the scope of this paper.

Follow-up. In Experiments 1-2 and 7-9, participants returned after a predetermined mean period of either one, two, four or six months (for the exact mean interval durations in each experiment see Table 1). In the follow-up sessions, participants completed the probe and memory tasks again. For each participant, follow-up tasks included the same stimuli and probe-choices he or she had previously performed during the original session, presented in a new random order of choices. All participants were notified in advance about the follow-up session and were encouraged to return. Those who agreed to return, received additional monetary compensation.

3. Results

To assess preference changes following training, we used a two-tailed logistic regression to analyze the proportion of trials in the probe phase in which participants preferred the Go item over the No-Go item. In each pair, both items were of similar initial preference based on the initial evaluation phase. We hypothesized that the cue approach effect would enhance preferences for the Go items on more than 50% of trials (above chance level, log-odds of 0). Analyses were conducted separately for pairs of high-value items and pairs of low-value items, similar to previous work using CAT (Schonberg et al., 2014; Bakkour et al., 2016). The results of all the experiments are summarized in Table 2. The experimental data are available online at osf.io/puxhx.

Different Cues: Experiments 1-2

In the first two experiments, we tested the generality of the mechanism using multiple cues. In both experiments, we used highly familiar local snack food items, as in previously conducted studies (Schonberg et al., 2014; Bakkour et al., 2016). In Experiment 1, we replaced the original neutral auditory cue with a neutral visual cue (modifying the cue modality), and in Experiment 2, Go items were associated with an aversive auditory cue (modifying the cue neutrality).

Following training with a neutral visual cue in Experiment 1, participants preferred the high-value Go items over the No-Go items (mean proportion = 61.7%, log-odds = 0.55, 95% CI [0.22, 0.87], $p < .001$). However, we found only a trend of enhanced preferences for low-value Go items (mean proportion = 55.6%, log-odds = 0.26, 95% CI [-0.05, 0.57], $p = .096$, see Figure 3 and Table 2). Training with a visual cue resulted in a more robust preference modification for high-value snack food items than for low-value items (log-odds = 0.26, 95% CI [0.12, 0.40], $p < .001$).

In Experiment 2 with an aversive auditory cue, probe results indicated a significant, yet less distinct enhanced preference for high value Go items (mean proportion = 58.4%, log-odds = 0.38, 95% CI [0.04, 0.73], $p = .030$) and a distinct enhanced preference for low-value Go items (mean proportion = 61.2%, log-odds =

0.52, 95% CI [0.19, 0.84], p = .002), with a more robust preference change for low-value items (log-odds = -0.17, 95% CI [-0.31, -0.02], p = .022, see Figure 3).

Long-term maintenance. In a follow-up session of Experiment 1, conducted after approximately two months (M = 51.8 days) from initial training, preferences for the high-value Go items persisted (mean proportion = 56.9%, log-odds = 0.30, 95% CI [0.02, 0.58], p = .038), while preferences for low-value Go items were not different from chance (mean proportion = 53.2%, log-odds = 0.17, 95% CI [-0.16, 0.50], p = .317). The more robust preference for high-value snack food items was also found in the follow-up session (log-odds = 0.15, 95% CI [0.00, 0.30], p = .049).

In Experiment 2, following a mean period of two months (61.5 days) from training with an aversive auditory cue, preferences for high-value Go items were maintained (mean proportion = 59.4%, log-odds = 0.42, 95% CI [0.04, 0.81], p = .031). For the low value items, we observed a trend of enhanced preferences for Go items (mean proportion = 59.0%, log-odds = 0.43, 95% CI [-0.03, 0.89], p = .066), with no difference between high-value and low-value probe choices (log-odds = 0.03, 95% CI [-0.16, 0.21], p = .780).

Affective Stimuli: Experiments 3-6

Our previous and current results suggested that CAT can affect preferences for favorable snack food items, as well as using cues of different modalities. Next, we manipulated the affective valence of stimuli. We tested the efficacy of CAT on modification of preferences for affective stimuli of positive and negative valence. Four experiments were conducted using either positive IAPS stimuli (Experiments 3-4), or negative IAPS stimuli (Experiments 5-6). Positive and negative valence experiments were conducted once with an auditory (Experiments 3 and 5), and once with a neutral visual cue (Experiments 4 and 6). We did not perform follow-up sessions in these experiments.

In Experiments 3-4, following association of positive IAPS stimuli with neutral auditory and visual cues, participants significantly preferred Go over No-Go items, both in the high-value (Experiment 3: mean proportion = 59.0%, log-odds = 0.48, 95% CI [0.11, 0.85], p = .011; Experiment 4: mean proportion = 61.6%, log-odds = 0.50, 95% CI [0.30, 0.70], p = 1.4E-6) and in the low-value probe choices (Experiment 3: mean proportion = 61.2%, log-odds = 0.72, 95% CI [0.20, 1.24], p = .007; Experiment 4: mean proportion = 66.7%, log-odds = 0.74, 95% CI [0.50, 0.98], p = 1.2E-9; see Figure 4 and Table 2). Differences between high and low value probe choices were trending toward more robust effects for low value items in Experiment 3 (log-odds = -0.1, 95% CI [-0.20, 0.01], p = 0.067), and significantly more robust for low value items in Experiment 4 (log-odds = -0.23, 95% CI [-0.36, -0.10], p = 5.3E-4).

In Experiments 5-6, conducted with negative IAPS stimuli, participants displayed no preferences for the Go items, neither in the high-value pairs (Experiment 5: mean proportion = 51.6%, log-odds = 0.07, 95% CI [-0.17, 0.30], p = .582; Experiment 6: mean proportion 55.8%, log-odds = 0.30, 95% CI [-0.07, 0.68], p = .116), nor in the low-value pairs (Experiment 5: mean proportion = 50.5%, log-odds = 0.02, 95% CI [-0.26, 0.31], p = .877; Experiment 6: mean proportion = 53.3%, log-odds = 0.18, 95% CI [-0.18, 0.53], p = .322). No significant differences between high and low value probe choices were found (Experiment 5: log-odds = 0.05, 95% CI [-0.05, 0.15], p = 0.316; Experiment 6: log-odds = 0.11, 95% CI [-0.02, 0.25], p = 0.104).

Unfamiliar Faces: Experiment 7

In Experiment 7, we tested CAT with unfamiliar neutral face stimuli. Participants from Experiment 7 were invited for a follow-up session one month after training (33.2 days). In the probe phase of Experiment 7, participants preferred high-value Go items over high-value No-Go items (mean proportion = 69.8%, log-odds = 0.95, 95% CI [0.62, 1.27], p = 8.8E-9); as well as low-value Go items over low-value No-Go items (mean proportion = 68.5%, log-odds = 1.09, 95% CI [0.51, 1.67], p = 2.3E-4; see Figure 5 and Table 2). No differences were found between high- and low-value probe choices (log-odds = 0.07, 95% CI [-0.08, 0.22], p =0.345).

Long term maintenance. In a one-month follow-up, enhanced preferences for Go items were maintained both in the high-value (mean proportion = 66.8%, log-odds = 0.80, 95% CI [0.41, 1.19], p = 4.8E-5) and the low-value probe choices (mean proportion = 62.1%, log-odds = 0.77, 95% CI [0.09, 1.45], p = .027).

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The effect was more robust for high-value than low-value probe choices (log-odds = 0.23, 95% CI [0.06, 0.41], p = 0.007).

Unfamiliar Fractals: Experiments 8-9

In Experiments 8-9, we used unfamiliar abstract fractal art stimuli, and examined the long-term maintenance in follow-up sessions four months (116.2 days) and six months (183.9 days) after training.

Following cue approach training with fractal stimuli in Experiment 8, participants consistently preferred the high-value Go items over the high-value No-Go items (mean proportion = 66.3%, log-odds = 0.94, 95% CI [0.44, 1.44], p = 2.4E-4); similarly, participants consistently preferred the low-value Go items over the low-value No-Go items (mean proportion = 61.1%, log-odds = 0.65, 95% CI [0.17, 1.14], p = .009; see Figure 5). Similar results were replicated in Experiment 9, in which participants preferred the high-value Go items over No-Go items (mean proportion = 62.0%, log-odds = 0.62, 95% CI [0.21, 1.04], p = .003); as well as the low-value Go items over the low-value No-Go items (mean proportion = 66.9%, log-odds = 0.93, 95% CI [0.46, 1.39], p = 8.5E-9; see Figure 5). In Experiment 8, the preference change effect was more prominent in high-value choices (log-odds = 0.27, 95% CI [0.16, 0.38], p = 2.1E-6), whereas in Experiment 9, the preference change effect was stronger in low-value choices (log-odds = -0.24, 95% CI [-0.39, -0.09], p = 0.001).

Long term maintenance. In a four-month follow-up session of Experiment 8, enhanced preferences were maintained for the high-value Go items (mean proportion = 58.1%, log-odds = 0.36, 95% CI [0.04, 0.69], p = .029), but not for the low-value Go items (mean proportion = 54.5%, log-odds = 0.21, 95% CI [-0.12, 0.54], p = .210). Results were stronger for high value probe choices (log-odds = 0.15, 95% CI [0.02, 0.28], p = 0.026).

In a six-month follow-up of Experiment 9, behavioral change was maintained in both value categories, as participants consistently preferred both the high-value Go items (mean proportion = 60.8%, log-odds = 0.48, 95% CI [0.05, 0.92], p = .030), as well as the low value Go items (mean proportion = 60.8%, log-odds = 0.48, 95% CI [0.04, 0.92], p = .032). No difference was found between high and low-value probe choices (log-odds = 0.01, 95% CI [-0.17, 0.19], p = .917)

4. Discussion

In the current work, we present evidence for a general non-reinforced mechanism for long-term behavioral change, tested across multiple cues and stimuli. We showed that the mechanism underlying the cue approach task, previously shown to change preferences for snack food items by an association with a neutral auditory cue, can be generalized beyond a specific cue and stimulus type. In nine independent experiments, we found that we can induce a behavioral change on various positive and neutral stimuli including snacks, positive IAPS pictures, neutral faces and fractals. Importantly, we demonstrated that the behavioral change induced by the short 40 minutes training procedure is durable and remains effective over long periods of time, varying from 1-6 months after training.

Generalization across Cue Types

In Experiments 1-2, using familiar local snack food items with visual and auditory aversive cues, we show that the CAT effect is not limited to a specific cue feature. In Experiment 1, we showed that using a visual cue rather than the original neutral tone led to similar results as in previous CAT studies. We found increased preferences for high-value Go items, but only a similar non-significant trend for low-value Go items. Thus, our results suggest that modifying the modality of the cue from a neutral auditory cue to a visual cue does not impair the behavioral change effect.

In Experiment 2, we tested whether the cue must be neutral, by replacing the neutral auditory cue with an aversive auditory cue. Counterintuitively, an association with an aversive auditory cue, which may be expected to decrease preferences for associated items via classical conditioning (Neumann & Waters, 2006), resulted in enhanced preferences for both high and low-value Go items. Using an aversive cue also resulted in a significant preference modification for the less liked low-value snack food items. This was

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surprising given that in other CAT experiments conducted with snack food items there was no change or less preference change for low-value food items (Bakkour et al., 2016; Schonberg et al., 2014). Future research could directly test the effect of high versus low valued stimuli using additional aversive cues, such as unpleasant tactile or electric stimulation.

Generalization across Stimuli Types

We used wide range of stimuli types that varied from the concrete and familiar to the abstract and novel. We were able to induce non-reinforced behavioral change for an array of conceptually distinct stimuli, from consumable snacks, to IAPS pictures, neutral unfamiliar faces and finally, abstract fractal art stimuli. In Experiments 3-6, we addressed the importance of stimuli's affective valence, using positive and negative valence stimuli from the IAPS database (Lang, Bradley & Cuthbert, 2008). In Experiments 3-4, using positive affective stimuli, preference modification was prominent both for high and low value stimuli. However, in Experiments 5-6, using negative affective stimuli (with auditory and visual cues, respectively), preferences were not modified following training. Using the visual cue in Experiment 6 helped us to ensure that participants were looking at the stimuli during training, despite their negative valence. These findings point to an important boundary condition of the CAT paradigm, showing that non-reinforced behavioral change can be used to change preferences for positive but not negative affective stimuli.

In addition to assessing generalizability to positive and negative affective stimuli, we also tested modification of preferences toward unfamiliar face stimuli (Experiment 7) and fractals (Experiments 8-9). We were able to show that CAT was effective in increasing preferences for Go items over No-Go items, both in high-value and low-value probe choices. The ability to change preferences for abstract stimuli, such as fractals, demonstrates the generality of the non-reinforced behavioral change mechanism underlying CAT. Taken together, these findings may suggest that the mechanism underlying the learning process may be applied to modify preferences for a large variety of stimuli of neutral or positive, but not negative, valence.

The Mechanism Underlying the Training Process

In previous studies conducted with snack food items (Bakkour et al., 2016; Schonberg et al., 2014), preference change was shown to be differential to different value categories, with robust changes in preferences for high-value snacks, yet less distinct changes in preferences for less desired low-value snacks. However, in the current investigation, in samples using non-consumable items (IAPS, faces and fractal) we did not observe such a differential effect. This might suggest that the greater change for higher-valued items is linked to the unique features of snack food stimuli. Our results imply that the mechanisms underlying CAT can be used to modify preferences for the entire value range of unfamiliar stimuli, for which participants had no previous experience. Our null results in the negative IAPS experiments, may resemble the differential effect for high-value versus low-value snack food items. These findings hedge the boundaries of the learning mechanism, suggesting that it may be specific to positive rather than negative stimuli, even when using an aversive cue. Taken together the lack of ability to change preferences for lower value items suggests a potential thresholding mechanism, such that non-reinforced change can only affect items above a certain initial preference level (McGuire & Kable, 2014).

Long Lasting Behavioral Change

In five of the experiments, we included a follow-up session 1-6 months after training. In all cases, the behavioral change effect persisted over time, demonstrating enhanced preferences for high-value Go items over high-value No-Go items. These results point to the high durability of behavioral change induced without external reinforcement or context changes. A relatively short 40 minutes training session successfully affected preferences, which then persisted over long periods of time, up to six months, with no maintenance procedures between these time points. Thus, this non-reinforced mechanism could be valuable for designing effective real-world applications that could induce long-lasting impact.

Future Implications

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The work presented here serves as a foundation for further studies of non-reinforced behavioral change as well as real-world applications. The ability to study behavioral change towards face stimuli opens possibilities for neuroimaging research utilizing the uniquely elicited neural response pattern to faces in the brain (Kanwisher, McDermott & Chun, 1997; Rossion et al., 2003; Winston, Henson, Fine-Goulden & Dolan, 2004). Applicable implementation of CAT can be used to enhance desired behaviors over less desired ones, not limited to food consumption. In the clinical field, several psychological disorders such as depression and anxiety are characterized by a cognitive bias toward negative affective social stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & van IJzendoorn, 2007; Surguladze et al., 2005). Attentional bias modification treatments for these disorders have been tested in an attempt to improve clinical symptoms (Browning, Holmes, Charles, Cowen & Harmer, 2012; Hakamata et al., 2010). Similarly, the general mechanism underlying CAT may be used to induce a counter-bias and enhance preferences for positive affective stimuli. Such preference modification may, in turn, lead to congruent changes in positive mood with beneficial long term therapeutic effects.

5. Conclusions

The current work provides empirical evidence for a general mechanism for non-reinforced long-lasting behavioral change. Cue-approach training yielded prominent results with multiple cues on all positive and neutral stimuli tested. The durable effects, consistent across various stimuli and cues, persisted for a long period of one to six months without any maintenance procedure required. Our results suggest that non-reinforced behavioral change holds great opportunities to develop novel applications with long term efficacy that can be used to enhance desired behavior in a wide array of domains.

Supplementary Materials: No Supplementary Materials is provided.

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Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results

References

1. Aharon, I., Etcoff, N., Ariely, D., Chabris, C. F., O'Connor, E., & Breiter, H. C. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron*, *32*(3), 537–551. http://doi.org/10.1016/S0896-6273(01)00491-3
2. Bakkour, A., Leuker, C., Hover, A. M., Giles, N., Poldrack, R. A., & Schonberg, T. (2016). Mechanisms of choice behavior shift using cue-approach training. *Frontiers in Psychology*, *7*(MAR), 1–12. http://doi.org/10.3389/fpsyg.2016.00421
3. Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological Bulletin*, *133*(1), 1–24. http://doi.org/10.1037/0033-2909.133.1.1
4. Bigman, Y. E., Sheppes, G., & Tamir, M. (n.d.). When Less is More: Effects of the Availability of Strategic Options on Regulating Negative Emotions. *Emotion*, *In Press*.
5. Bjork, R. A. (2001). Recency and Recovery in Human Memory. *The Nature of Remembering: Essays in Honor of Robert G. Crowder. Science Conference Series.*, (January 2001), 211–232. http://doi.org/10.1037/10394-011
6. Bouton, M. E. (1993). Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin*, *114*(1), 80–99. http://doi.org/10.1037/0033-2909.114.1.80
7. Browning, M., Holmes, E. A., Charles, M., Cowen, P. J., & Harmer, C. J. (2012). Using attentional bias modification as a cognitive vaccine against depression. *Biological Psychiatry*, *72*(7), 572–579.

http://doi.org/10.1016/j.biopsych.2012.04.014

8. Butler, A. C., Chapman, J. E., Forman, E. M., & Beck, A. T. (2006). The empirical status of cognitive-behavioral therapy: A review of meta-analyses. *Clinical Psychology Review*, *26*(1), 17–31. http://doi.org/10.1016/j.cpr.2005.07.003
9. Cahill, K., & Perera, R. (2011). Competitions and incentives for smoking cessation. Cochrane Database of Systematic Reviews, (4), Issue 4. Art. No.: CD004307. http://doi.org/10.1002/14651858.CD004307.pub4.Copyright
10. Colley, W. (2002). Colley's bias free college football ranking method: The colley matrix explained. *Princeton University*, 1–23.
11. de Martino, B., Kumaran, D., Seymour, B., & Dolan, R. J. (2006). Frames, Biases, and Rational Decision Making in the Human Brain. *Science*, *313*(5787), 684–687. http://doi.org/10.1126/science.1127205
12. Downing, P. E. (2007). Face Perception: Broken into Parts. *Current Biology*, *17*(20), R888–R889. http://doi.org/10.1016/j.cub.2007.08.008
13. Fantastic Fractals. (2013). Retrieved from http://fantastic-fractals.com
14. Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., … Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry*, *68*(11), 982–990. http://doi.org/10.1016/j.biopsych.2010.07.021
15. Higgins, S. T., Budney, A. J., Bickel, W. K., Badger, G., Foerg, F. E., & Ogden, D. (1995). Outpatient behavioral treatment for cocaine dependence: One-year outcome. *Experimental and Clinical Psychopharmacology*, *3*(2), 205–212.
16. Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *17*(11), 4302–4311. http://doi.org/10.1098/Rstb.2006.1934
17. Kleiner, M., Brainard, D., Pelli, D., Ingling, A., Murray, R., & Broussard, C. (2007). What's new in Psychtoolbox-3. *Perception*, *36*(14), 1.
18. Kranz, F., & Ishai, A. (2006). Face perception is modulated by sexual preference. *Current Biology*, *16*(1), 63–68. http://doi.org/10.1016/j.cub.2005.10.070
19. Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual*. *Technical Report A-8*. Gainesville, FL.
20. Lang, W., Wing, R. R., Venditti, E., Jakicic, J. M., & Polley, B. A. (1998). Lifestyle Intervention in Overweight Individuals With a Family History of Diabetes. *Diabetes Care*, *21*(3), 350–259.
21. McGuire, J. T., & Kable, J. W. (2014). Go means green. *Nature Neuroscience*, *17*(4), 489–490. http://doi.org/10.1038/nn.3680
22. Neumann, D. L., & Waters, A. M. (2006). The use of an unpleasant sound as an unconditional stimulus in a human aversive Pavlovian conditioning procedure. *Biological Psychology*, *73*(2), 175–185.
23. Ng, A. W. Y., & Chan, A. H. S. (2012). Finger Response Times to Visual, Auditory and Tactile Modality Stimuli. *Proceedings of the International MultiConference of Engineers and Computer Scientists*, *II*, 1449–1454.
24. Rossion, B., Caldara, R., Seghier, M., Schuller, A. M., Lazeyras, F., & Mayer, E. (2003). A network of occipito-temporal face-sensitive areas besides the right middle fusiform gyrus is necessary for normal face processing. *Brain*, *126*(11), 2381–2395. http://doi.org/10.1093/brain/awg241
25. Schonberg, T., Bakkour, A., Hover, A. M., Mumford, J. a, Nagar, L., Perez, J., & Poldrack, R. a. (2014). Changing value through cued approach: an automatic mechanism of behavior change. *Nature Neuroscience*, *17*(4), 625–30. http://doi.org/10.1038/nn.3673
26. Shinners, P. (2011). PyGame–python game development. Retrieved from http://www.pygame.org/
27. Slovic, P. (1995). The construction of preference. *American Psychologist*, *50*(5), 364–371. http://doi.org/10.1037/0003-066X.50.5.364
28. Snack-Food Items Dataset. (2017). Retrieved from http://schonberglab.tau.ac.il/resources/snack-food-image-database/
29. Stein, B., London, N., Wilkinson, L., & Price, D. (1996). Enhancement of Perceived Visual Intensity by Auditory

Stimuli: A Psychophysical Analysis. *Journal of Cognitive Neuroscience*, *8*(6), 497–506. http://doi.org/10.1162/jocn.1996.8.6.497

30. Surguladze, S., Brammer, M. J., Keedwell, P., Giampietro, V., Young, A. W., Travis, M. J., … Phillips, M. L. (2005). A differential pattern of neural response toward sad versus happy facial expressions in major depressive disorder. *Biological Psychiatry*, *57*(3), 201–209. http://doi.org/10.1016/j.biopsych.2004.10.028
31. Swallow, K. M., & Jiang, Y. V. (2010). The Attentional Boost Effect: Transient increases in attention to one task enhance performance in a second task. *Cognition*, *115*(1), 118–132. http://doi.org/10.1016/j.cognition.2009.12.003
32. Tversky, A., & Kahneman, D. (1986). Rational Choice and the Framing of Decisions. *The Journal of Business*, *59*(4), 251–278. http://doi.org/10.1086/296365
33. Vieira, T. F., Bottino, A., Laurentini, A., & De Simone, M. (2014). Detecting siblings in image pairs. *The Visual Computer*, *30*(12), 1333–1345. http://doi.org/10.1007/s00371-013-0884-3
34. Von Neumann, J., & Morgenstern, O. (1944). *Theory of games and economic behavior*. Princeton university press.
35. Winston, J. S., Henson, R. N. A., Fine-Goulden, M. R., & Dolan, R. J. (2004). fMRI-Adaptation Reveals Dissociable Neural Representations of Identity and Expression in Face Perception. *Journal of Neurophysiology*, *92*(3), 1830–1839. http://doi.org/10.1152/jn.00155.2004
36. Wood, W., & Neal, D. T. (2007). A new look at habits and the habit-goal interface. *Psychological Review*, *114*(4), 843–863. http://doi.org/10.1037/0033-295X.114.4.843

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Tables and Figures

Table 1

Demographics

Experiment	Go-cue	Sample Size (Excluded)	Females (Proportion)	Mean Age (*SD*)	Follow-up	
					Sample Size	Mean Interval [a] (Range)
Exp. 1: Snacks	Visual	25 (1)	16 (64%)	22.24 (2.30)	21	51.8 (34-69)
Exp. 2: Snacks	Auditory Aversive	25 (5)	15 (60%)	24.40 (2.15)	14	61.5 (31-105)
Exp. 3: Positive IAPS	Auditory	27 (1)	17 (63%)	24.11 (2.62)	-	-
Exp. 4: Positive IAPS	Visual	29 (3)	18 (62%)	23.27 (2.08)	-	-
Exp. 5: Negative IAPS	Auditory	28 (5)	21 (75%)	25.04 (2.53)	-	-
Exp. 6: Negative IAPS	Visual	27 (3)	20 (74%)	23.67 (2.60)	-	-
Exp. 7: Faces	Auditory	25 (1)	18 (72%)	25.16 (2.44)	18	33.2 (22-56)
Exp. 8: Fractals	Auditory	25 (3)	15 (60%)	23.04 (1.92)	15	116.2 (73-170)
Exp. 9: Fractals	Auditory	25 (2)	19 (76%)	24.20 (3.33)	16	183.9 (171-203)

[a] Mean interval in days from training to follow-up session.

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Table 2

Probe Results - Mean Proportion of Trials Participants Chose Go Items Over No-Go Items

Experiment	Go-Cue	Training Runs	Mean Proportion Go items were Chosen: First session, High-Value	First session, Low-Value	Follow-up Session, High-Value	Follow-up Session, Low-Value
Exp. 1: Snacks	Visual	20	61.7%, p = .001	55.6%, p = .096	56.9%, p = .038	53.2%, p = .317
Exp. 2: Snacks	Auditory Aversive	20	58.1%, p = .030	61.8%, p = .002	59.4%, p = .031	59.0%, p = .066
Exp. 3: Positive IAPS	Auditory	12	59%, p = .011	61.2%, p = .007	-	-
Exp. 4: Positive IAPS	Visual	20	61.6%, $p = 1.4E^{-6}$	66.6%, $p = 1.2E^{-9}$	-	-
Exp. 5: Negative IAPS	Auditory	12	51.6%, p = .582	50.5%, p = .877	-	-
Exp. 6: Negative IAPS	Visual	20	55.8%, p = .116	53.3%, p = .322	-	-
Exp. 7: Faces	Auditory	20	69.8%, $p = 8.8E^{-9}$	68.5%, $p = 2.3E^{-4}$	66.8%, $p = 4.8E^{-5}$	62.1%, p = .027
Exp. 8: Fractals	Auditory	12	66.3%, $p = 2.4E^{-4}$	61.1%, p = .009	58.1%, p = .029	54.5%, p = .213
Exp. 9: Fractals	Auditory	20	62%, p = .003	66.9%, $p = 8.5E^{-5}$	60.8%, p = .03	60.8%, p = .032

Note. Reported *p-values* indicate a significant deviation from 50% chance level in a two-tailed logistic regression analysis.

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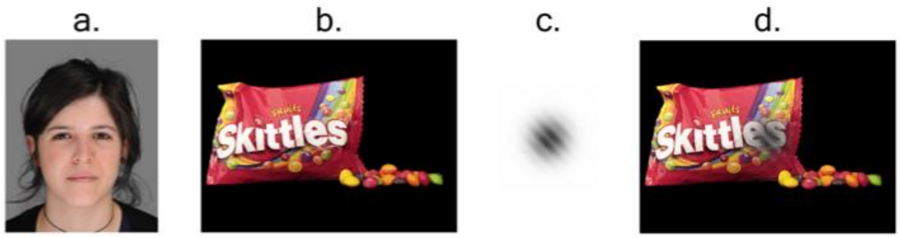

Figure 1. Stimuli and cue examples. 1a. Example of a face stimulus with neutral expression used in Experiment 7. 1b. Example of snack food stimulus used in Experiments 1-2. 1c. Semi-transparent Gabor used as a visual cue in Experiments 1, 4 and 6. 1d. Example of snack food stimulus with the visual cue overlaid on it as presented during the experiment.

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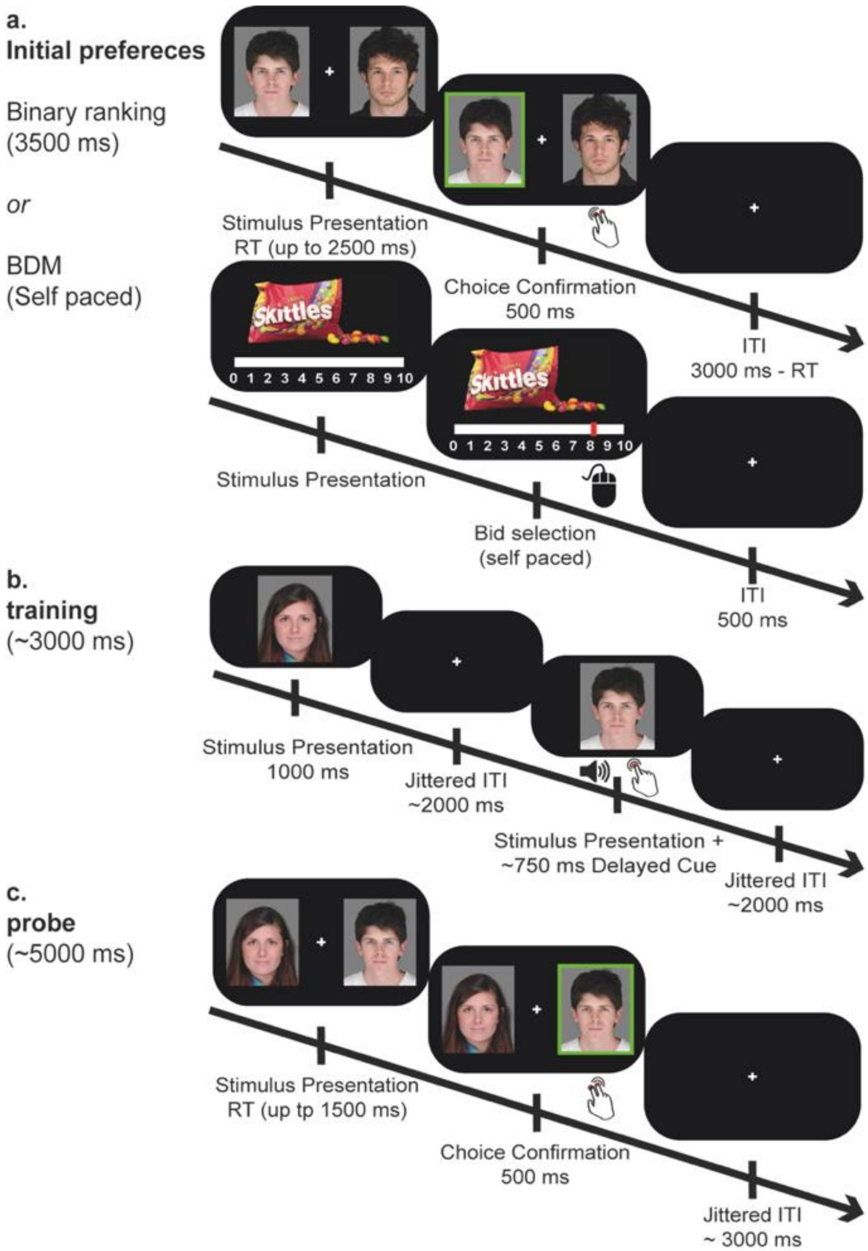

Figure 2. An example of the experimental procedure outline using face stimuli. Mean trial duration written in parenthesis, tilde sign indicates varying duration. 2a. Initial preferences evaluation using either a binary ranking procedure (for non-consumables) or a BDM auction procedure (for snack food items, in Experiments 1-2). 2b. In the training phase, Go items were consistently paired with a cue and a speeded button press. 2c. In the probe phase participants chose their preferred stimulus between pairs of items with similar initial value, where only one is a Go item, previously associated with a cue during training.

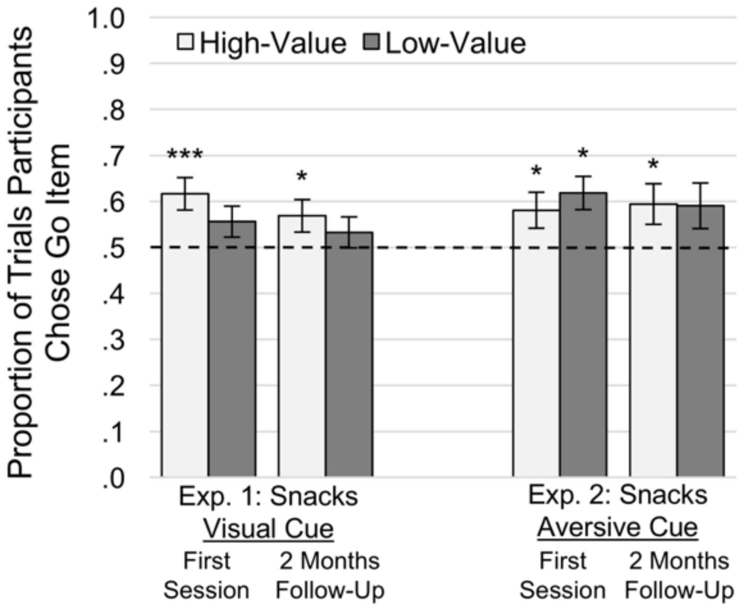

Figure 3. Probe results of Experiments 1-2 with snacks with visual and aversive auditory cues. Mean proportion of trials participants chose Go items over No-Go items for high value and low-value probe pairs. Dashed line indicate chance level, error bars represent standard error of the mean. Asterisks reflects proportions significantly different from chance in a two-tailed logistic regression analysis. *** $p < .001$, ** $p < .01$, * $p < .05$

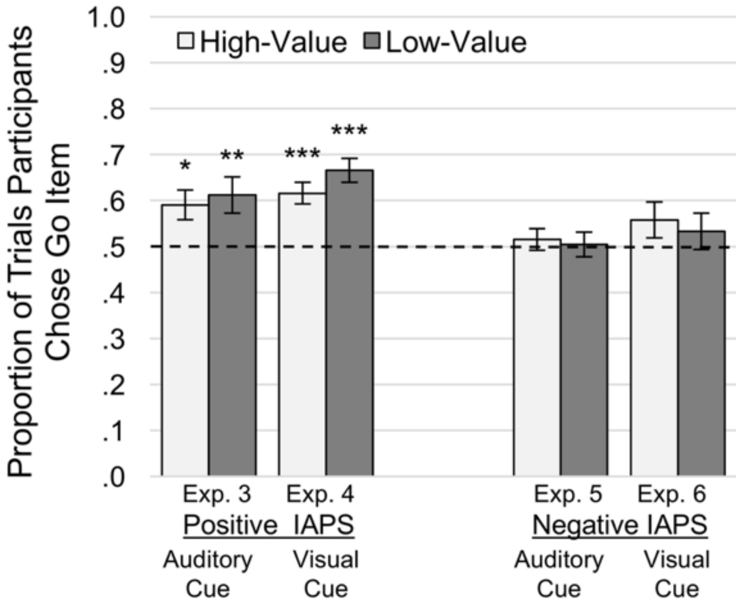

Figure 4. Probe results of Experiments 3-6 with positive and negative affective stimuli.

Mean proportion of trials participants chose Go items over No-Go items for high value and low-value probe pairs. Dashed line indicate chance level, error bars represent standard error of the mean. Asterisks reflects proportions significantly different from chance in a two-tailed logistic regression analysis.

*** $p < .001$, ** $p < .01$, * $p < .05$

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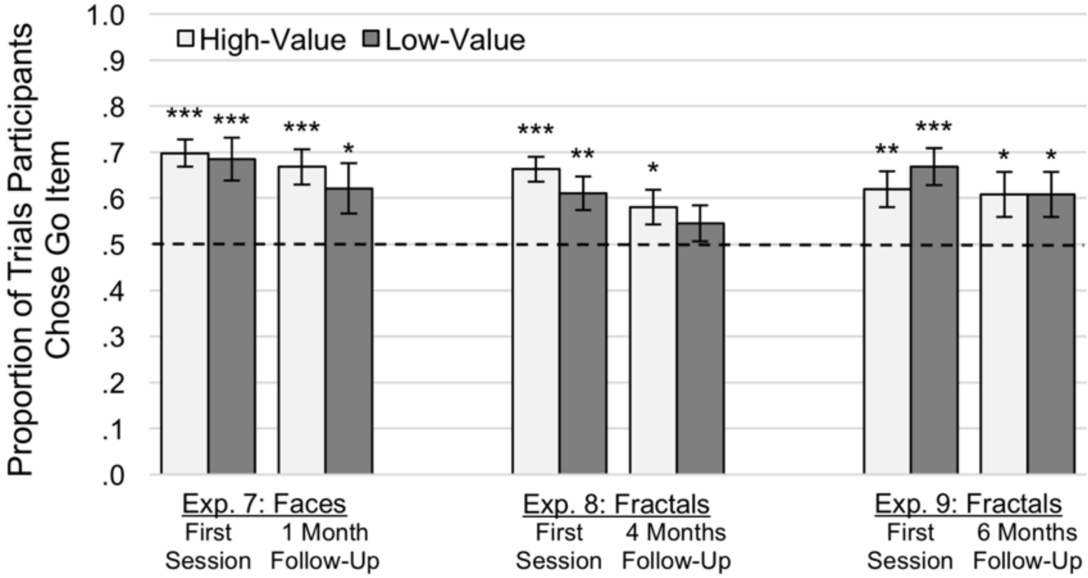

Figure 5. Probe results of Experiments 7-9 with neutral faces and fractals stimuli.

Mean proportion of trials participants chose Go items over No-Go items for high value and low-value probe pairs. Dashed line indicate chance level, error bars represent standard error of the mean. Asterisks reflects proportions significantly different from chance in a two-tailed logistic regression analysis;

*** $p < .001$, ** $p < .01$, * $p < .05$

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Supplementary Materials

Supplementary Table 1

Participants Disqualification Criteria

Experiment	Go-Cue	Sample Size (Excluded)	Number of Disqualified Participants
Exp. 1: Snacks	Visual	25 (1)	1 - Training [a]
Exp. 2: Snacks	Auditory Aversive	25 (4)	3 - Apparatus [b] 1 - Avoided probe choices of low-value items
Exp. 3: Positive IAPS	Auditory	27 (0)	
Exp. 4: Positive IAPS	Visual	29 (3)	1 - Participant requested to stop 2 - Training
Exp. 5: Negative IAPS	Auditory	28 (5)	1 - Participant requested to stop 4 - Training
Exp. 6: Negative IAPS	Visual	27 (3)	3 - Training
Exp. 7: Faces	Auditory	25 (1)	1 - Training
Exp. 8: Fractals	Auditory	25 (3)	2 - Apparatus 1 - Intransitive ranking
Exp. 9: Fractals	Auditory	25 (2)	1- Apparatus 1- Training

Note. A total of 22 participants were disqualified from analysis due to reasons mentioned above.

[a] The most common cause of disqualification was behavior during training. Participant that during training phase stopped responding to the Go-cue for prolonged periods of time. This exclusion criteria was adopted from previous cue-approach published work (Bakkour et al., 2016; Schonberg et al., 2014).

[b] Another frequent reason for disqualification was due to technical problems with the apparatus running the experiment.