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Approach Motivation as Incentive Salience: Perceptual Sources of Evidence in Relation to Positive Word Primes

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Abstract

Four experiments (total *N* = 391) examined predictions derived from a biologically-based incentive salience theory of approach motivation. In all experiments, judgments indicative of enhanced perceptual salience were exaggerated in the context of positive, relative to neutral or negative, stimuli. In Experiments 1 and 2, positive words were judged to be of a larger size (Experiment 1) and led individuals to judge subsequently presented neutral objects as larger in size (Experiment 2). In Experiment 3, similar effects were observed in a mock subliminal presentation paradigm. In Experiment 4, positive word primes were perceived to have been presented for a longer duration of time, again relative to both neutral and negative word primes. Results are discussed in relation to theories of approach motivation, affective priming, and the motivation-perception interface.

Keywords

Affect; Priming; Approach Motivation; Incentive Salience; Perception

Lewin (1935) was among the first to contend that positive stimuli are psychologically represented, albeit implicitly and perhaps unconsciously, as those to be approached. Similar dynamics have been proposed in subsequent literatures involving classical conditioning (Bower & Miller, 1960), emotional states (Watson, Wiese, Vaidya, & Tellegen, 1999), self-regulation processes (Carver & Scheier, 1998), limbic functions (Gray, Kumari, Lawrence, & Young, 1999), and cybernetic mechanisms (Powers, 2005). Such dynamics, though, have been of a largely metaphoric type among humans (Elliot & Thrash, 2002) relative to lower animals (Schneirla, 1959). In addition, people are unlikely to literally move forward when presented with positive stimuli in routine laboratory tasks (Lang, Bradley, & Cuthbert, 1997).

Nonetheless, we hypothesized that positive stimuli would induce *perceptions* consistent with approach-motivated behaviors. This prediction systematically follows from the incentive salience theory of dopamine functioning, reviewed next. At the outset, we mention that we did not assess or manipulate dopamine levels in the present studies because it is exceedingly difficult to do so among human participants. On the other hand, this theory makes predictions of the present type that had not been previously examined. In this respect, the theory should be considered a conceptual or heuristic one in the present context, much as animal models based on BIS-BAS mechanisms have contributed greatly to multiple areas of human psychology despite difficulties in assessing their biological substrates (Corr, 2008).

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Approach Motivation as Dopamine Functioning—Dopamine appears to play a central role in approach motivation (Depue & Collins, 1999). Mice bred to be dopamine-rich exhibit higher levels of approach behavior and reward consumption (Yin, Zhuang, & Balleine, 2006). Animals bred to lack the ability to synthesize dopamine have been shown to exhibit severe deficits in relation to the same or similar behaviors (Robinson, Sotak, During, & Palmiter, 2006). Dopamine agonists such as amphetamine facilitate the motoric pursuit of desired foods (Wyvell & Berridge, 2000), whereas dopamine antagonists (i.e., chemicals blocking dopamine's functions) impair such pursuit (Wise, 2004).

Berridge (e.g., 2007) has summarized multiple findings of this type and in turn has concluded that dopamine activity facilitates "wanting" positive stimuli. Panksepp (1998) similarly linked dopamine activity to a "seeking" system responsible for pursuing and obtaining desirable stimuli/outcomes (for another review, see Depue & Collins, 1999). Thus, although there are multiple theories of dopamine's effects (e.g., Horvitz, 2002; Koob & Le Moal, 2006; Schultz, 2004), there is a sufficient basis of evidence for the idea that dopamine activity codes both the desirability of positive stimuli and facilitates approach motivation and behavior within the context of such positive stimuli (Berridge, 2009).

Dopamine effects have been easiest to examine in animal models. However, there are sufficient reasons for thinking that operations of the dopamine system underlie tendencies toward approach motivation among human beings as well. Positive stimuli activate dopamine-rich brain structures such as the nucleus accumbens in neuroimaging studies (e.g., Gottfried, O'Doherty, & Dolan, 2002). Such levels of brain activation, in turn, predict behaviors consistent with approach motivation (Knutson & Cooper, 2005). Diseases that systematically attack the dopamine system, such as Parkinson's disease, also systematically undermine goal-directed reward-pursuit behaviors (e.g., Israel & Bergman, 2008). Finally, there are now some sources of data suggesting that especially reward-motivated individuals seem to be characterized by higher levels of basal dopamine activity (e.g., Wacker, Chavanon, & Stemmler, 2006).

Thus, there are reasons to think that a dopamine-related perspective of affective processing might offer novel insights. Positive primes, potentially of a wide type, should activate dopaminergic systems, which may in turn prime proximity-seeking perceptions and/or cognitions. Predictions are grounded in a more specific theory of dopamine function.

Incentive Salience Theory—A prominent view of dopamine function links it to incentive salience processes: An appetitive stimulus triggers increased activity in various brain regions – such as the ventral pallidum (Tindell, Berridge, Zhang, Peciña, & Aldridge, 2005) – which in turn "boosts" the stimulus signal so that the relevant object captures attention and renders approach-consummation behavior more likely (Berridge, 2007). Many of the neural predictions of this theory have been confirmed in rodent studies (Berridge, 2007).

Several other results from this research program are relevant to the present predictions. First, it has been shown that dopamine-sensitive brain regions react to positive stimuli in a short-term, trial-to-trial manner (Tindell et al., 2005). For this reason, it is plausible that affective word primes might operate similarly. Second, it has been shown that neutral symbols and cues can be classically conditioned, triggering approach-related tendencies themselves even in the absence of rewards of a more substantial biological type (Smith, Tindell, Aldridge, & Berridge, 2009). For this reason, positive words are likely to prime the approach-motivation system despite the fact that words do not deliver substantial biological rewards (Bradley & Lang, 1999).

Third, it has been shown that pre-exposure to an appetitive stimulus “primes” the approach-motivated system, which remains activated for some time thereafter (Berridge, 2009). For this reason, it is reasonable to suggest that that positive word primes would bias subsequent perceptions of an incentive salience type. Altogether, then, we deemed it likely that positive words cues, presented in a trial-to-trial manner, would co-opt the “wanting” system (Mahler & Berridge, 2009), with significant implications for subsequent perceptual processes.

Incentive Salience Predictions—We sought to examine relatively subtle influences on incentive salience processes. Toward this end, affective word primes were used. There is a fairly large literature on the affective priming effects of words, but one almost exclusively focused on what has been termed “affective priming” – e.g., the extent to which positive word primes facilitate or speed subsequent positive evaluations (for reviews, see Fazio, 2001; Klauer & Musch, 2003). The present experiments were different in that we sought to investigate the influence of positive word primes on subsequent processes of a very different type.

Incentive salience theory clearly implicates perceptual enhancements as a function of activation of this system (Berridge, 2009; Mahler & Berridge, 2009). Accordingly, perceptual judgments of a salience-related type were examined in the present experiments. From a perception-related standpoint, a stimulus is salient to the extent that it is perceived to be larger (e.g., Witt & Proffitt, 2005) or longer lasting (Witherspoon & Allan, 1985) than is/was the case. Perceptual salience is likely to have other manifestations as well (e.g., perceived brightness), but magnitude overestimations most directly follow from incentive salience theory (Berridge, 2007). In all experiments, it was hypothesized that positive word primes would cause perceptual enhancements consistent with incentive salience theory.

Experiment 1

The dopamine system has been shown to operate in a trial-to-trial manner (Tindell et al., 2005). We modeled this trial-to-trial specificity in an affective priming task in which positive, neutral, and negative words were randomly ordered rather than blocked. Experiment 1 examined a first prediction: Positive words should appear to be larger than neutral or negative words. Results along these lines would be consistent with the hypothesized relationship between word valence and activation of an implicit approach-seeking system.

Method

Participants and Procedures—Sixty-nine undergraduates from North Dakota State University (NDSU) volunteered to participate in this experiment in return for course credit. Participants were generally informed that the experiment concerned word categorizations and perceptions and that these were two independent tasks that they would perform on each trial. They were then assigned to private rooms equipped with a PC, microphone, mouse, and keyboard.

Word Stimuli—Affective primes consisted of 168 positive (e.g., lust, treat, warmth), neutral (concentrate, paper, seat), and negative (e.g., fear, neglect, waste) words, with 56 words of each valence. Such words were chosen from the database of Bradley and Lang (1999), who asked a large number of individuals to rate words along a 9 point negative-positive valence scale. Positive (M = 7.27) and negative (M = 2.78) words were selected such that they were equally extreme, as defined in terms of distance from the midpoint of the scale, with neutral words clustered around the midpoint (M = 5.05). Norms for arousal were also considered such that positive (M = 5.32) and negative (M = 5.53) words were as equal as possible with respect to this stimulus quality.

There is a strong positive relationship between word valence and word frequency in the English language (Osgood, Suci, & Tannenbaum, 1957) and other languages as well (Matlin & Stang, 1978). Kucera and Francis (1967) word frequency norms were available for 55 positive, 50 neutral, and 54 of the negative word primes used in the present experiments. An ANOVA with word as the unit of analysis indicated that word frequency values varied as a function of word valence in relation to our stimuli, $F(2, 156) = 9.41$, $p < .01$. On the other hand, all affective primes were chosen such that they were easily categorized in terms of valence (Bradley & Lang, 1999) and it is not clear whether, how, or why word frequency would influence the incentive salience processes examined here. In any case, it was deemed useful to control for word frequency in secondary analyses conducted in all experiments.

Dependent Task—Each of the affective words was shown once, resulting in a total of 168 trials. At the beginning of each trial, a reference array consisting of the letter "Z" printed in 17 different font sizes was presented on the left side of the computer screen. Font sizes varied from 8 to 24 point in increments of 1. The letter "Z" was chosen because it was absent from any of the affective words and therefore participants could not perform an exact perceptual match on any of the trials. Font sizes within the reference array were presented in either ascending or descending order, counterbalanced across participants. Figure 1 presents a screenshot of the task.

A brief pause followed the initial presentation of the reference array, after which a randomly chosen affective word was presented at center screen. A six inch gap always separated the word and the nearest letter of the reference array. Stimuli were presented in capital letters to ensure that all letters (of a given font size) were of equal height. Each word was also randomly assigned one of seven font sizes (10, 12, 14, 16, 18, 20, or 22). Font size was varied to increase the variability of size estimates and to check for appropriate responding on the task.

To encourage affective processing of the words, participants first categorized each word as "good", "bad", or "neutral" by voice key. After a vocal response was registered, a mouse cursor appeared in the center of the screen. Participants were given 5 seconds to use the mouse to select the reference "Z" perceived to be of the same font size as the presented word, which still remained on the screen. After participants made a font size selection, the next trial began.

Results

Data Cleaning and Dependent Measure Computation—The data for one participant were deleted because he/she failed to respond within the time limit (a generous 5 seconds) on a fairly sizable percentage of the trials (> 25%). Data for six additional participants were deleted because their size estimations were greater than 2.5 *SD*s from the mean, indicating probable carelessness. Results are therefore based on 62 (30 female) responders. Because the affective words differed substantially in font size, the trial-specific dependent measure was scored in terms of a perceptual bias – i.e., the font size perceived minus the actual font size of the presented word. Such bias scores averaged 1.6 font size units, a general bias that was significant, $t(61) = 11.88$, $p < .01$. This general bias is discussed below, but it in no way qualifies our predictions based on word valence.

Results with Participant as the Unit of Analysis—To examine whether and, if so, how word valence influenced such perceptual bias scores, a repeated measures ANOVA (positive versus neutral versus negative) was conducted. As hypothesized, size estimates significantly differed by Word Valence, $F(2, 61) = 10.65$, $p < .01$, partial $\eta^2 = .15$. This is a large effect size (Cohen, 1988). Means for this significant affective priming effect are reported in Figure 2.

Pairwise ANOVAs were then performed to compare particular word valence conditions. The positive/neutral comparison resulted in a significant difference, F (1, 61) = 19.96, $p < .01$, partial $\eta^2 = .25$, as did the positive/negative comparison, F (1, 61) = 11.03, $p < .01$, partial $\eta^2 = .15$. Unexpectedly, the neutral/negative comparison was also significant, F (1, 61) = 4.55, $p < .05$, partial $\eta^2 = .07$. In general terms, though, and consistent with incentive salience theory, font size overestimation was greater for positive stimuli relative to neutral or negative stimuli.

Results with Word as the Unit of Analysis—Replicating results across participant-level and word-level data provides a much stronger basis for the generality of an effect than either level considered alone (Clark, 1973). In addition, it was deemed important to show that the priming effects of stimulus valence were independent of word frequency. Accordingly, for each of the 159 words for which word frequency values were available, we calculated a word-specific bias score – i.e., the extent to which the word was seen as larger than it actually was, collapsed across participants.

We then performed a multiple regression with two predictors. The first was the valence of the word, as quantified on the basis of the continuous word norms reported by Bradley and Lang (1999). The second was the log frequency of the word in English language texts, based on the norms of Kucera and Francis (1967). Word Valence was a significant predictor of size overestimates, t (156) = 10.07, $p < .01$. Thus, the influence of stimulus affect on font size overestimation cannot be due to the priming effects of some particular words, but rather can be ascribed to broader dimensional relations (Clark, 1973). On the other hand, when controlling for word valence, Word Frequency was a non-significant predictor of font size overestimations, t (156) = −1.35, $p > .10$. Thus, our effects are independent of word frequency considerations.

Discussion

The very first processes involved in incentive salience are likely to be perceptual in nature, owing to dopamine's posited role in boosting signals following, or in the context of, positive stimuli (Tindell et al., 2005). Experiment 1 found that such "front end" perceptual processes – here, perceived size – do indeed appear to be sensitive to the valence of affective primes. This theory-derived but novel perceptual bias was particularly pronounced in the context of positive word cues, robust across both participant-level and word-level analyses, and independent of word frequency. Experiment 1 therefore provides initial results consistent with an incentive salience view of approach motivation and its primes (Berridge, 2007).

Two other findings from Experiment 1 deserve further comment. There was a robust tendency to perceive all words as larger than they actually were. This effect likely occurred because all words were task-relevant – i.e., all had to be evaluated. If so, size estimates may be sensitive to task-relevance. This interpretation is speculative, though, because we did not manipulate the task-relevance of the words. Regardless, the idea that font size estimates may be sensitive to this more general factor is a hypothesis worth pursuing, particularly so because a major function of the frontal lobes is to enhance task-relevant inputs (Miller & Cohen, 2001).

The perceptual enhancement of positive words was pronounced relative to neutral and negative words. Such findings rule out emotional arousal factors, which would have resulted in larger size estimates for positive and negative words relative to neutral ones. On the other hand, there was a tendency for size estimates to be higher for neutral than negative words.

This was somewhat unexpected and the reliability of this effect was further examined in Experiments 2–4. To foreshadow, this comparison was non-significant in all subsequent experiments and therefore the results, in total, converge on the *particular* effects of positive affective primes.

Experiment 2

Incentive salience effects are typically examined in terms of Pavlovian conditioning paradigms (Berridge, 2007). In such paradigms, pre-exposure to rewards (e.g., food, amphetamine) have been shown to enhance the response of dopamine-rich brain areas to subsequent stimuli of an unconditioned, neutral type (Berridge, 2004; Tindell et al., 2005; Toates, 1986). We designed an affective processing task to model such Pavlovian conditioning processes in human experimental terms. In the Experiment 2 task, participants first evaluated word primes and then estimated the size of presented boxes of a very mundane and non-evaluative type. To the extent that results using rodent models (e.g., Berridge, 2007) translate to the present context, boxes should appear larger – i.e., more perceptually salient – following positive affective primes relative to neutral and negative affective primes.

Method

Participants and Procedures—General instructions and procedures were identical to those reported in Experiment 1. A new sample of 126 undergraduates from NDSU received course credit by their participation.

Dependent Task—Experiment 2 sought to show that positive affective primes bias the perceived size of subsequent objects that are not themselves affective in nature. We primed participants with the same affective words used in Experiment 1. Subsequently, participants were asked to estimate the size of a white-outlined box against a black background. There were 168 trials such that each affective prime word was presented once.

At the beginning of each trial, a reference array of 12 boxes was presented at the bottom of the screen. The smallest box was 70 pixels (approximately ½ inch in size) and the largest was 114 pixels (approximately 1 inch in size). The size of the boxes varied systematically such that there was a 4 pixel difference between each box size and the next. The order in which the boxes were presented was counterbalanced across participants, either from smallest to largest or largest to smallest from left to right on the computer screen.

After a short delay, an affective prime word was presented at center screen, always in the same 18 point font. The word was removed after 1 second and participants were asked to vocally categorize the word as “good”, “neutral”, or “bad” depending on its affective connotation. When a vocal response had been registered, one of 5 boxes was presented in the center of the screen. All boxes were identical except for their pixel size (76, 84, 92, 100, or 108). Participants were asked to determine the size of the presented box by using the computer mouse to select the reference box that best matched it in perceived size.

Results

Data Cleaning and Dependent Measure Computation—The data from five participants were deleted because their box selectio3ns were over 2.5 *SD*s from the mean, likely indicating careless responding. Results are thus based on 121 (73 female) responders. As in Experiment 1, the dependent measure sought to quantify the extent to which stimuli – in this case, boxes – appeared to be larger than they actually were. Accordingly, a bias score was computed for each trial by subtracting actual box size from the box size perceived. On average, box sizes were overestimated by 0.90 pixels, t (121) = 3.91, $p < .01$.

Results with Participant as the Unit of Analysis—We performed an ANOVA in which the valence of word primes (negative versus neutral versus positive) was the predictor of subsequent box size overestimates. As hypothesized, there was a main effect for Word Valence in this analysis, F (2, 120) = 11.31, $p < .01$, partial $\eta^2 = .09$, a medium effect size (Cohen, 1988). Such size overestimates, as they vary by affective prime valence, are graphically displayed in Figure 3.

Pairwise comparisons were performed to better understand the locus of the three-level valence priming effect. Perceptual bias scores following positive word primes were larger than following neutral, F (1, 120) = 20.22, $p < .01$, partial $\eta^2 = .14$, or negative, F (1, 120) = 14.66, $p < .01$, partial $\eta^2 = .11$, word primes. On the other hand, the neutral/negative comparison was not significant, F (1, 120) < 1, partial $\eta^2 < .01$. Such pairwise comparisons establish that positive stimuli, in particular, biased subsequent size estimations.

Results with Word as the Unit of Analysis—As in Experiment 1, we sought to show that the perceptual priming effects of word valence replicated at the word as unit level of analysis. Simultaneously, we sought to show that this was true with word frequency values controlled. Bias scores (here, box size overestimates) were computed for the 159 words for which word frequency values were available. Predictors were continuous variations in valence (Bradley & Lang, 1999) and log word frequency values (Kucera & Francis, 1967). A multiple regression was performed.

Word Valence was again a significant predictor of size overestimations, t (156) = 2.62, $p < .01$. Because this was true when controlling for word frequency values, the results cannot be attributed to this factor. Interestingly, word frequency values also predicted biases in box size estimates in the same regression, t (156) = 3.46, $p < .01$. This effect was not observed in Experiment 1, but it does suggest that more frequent and presumably fluent words might bias some perceptual size estimates.

Discussion

In animal models, it has been shown that neutral stimuli previously paired with unconditioned rewards (e.g., food, amphetamine) acquire subsequent reward-value. Specifically, such neutral stimuli have been shown to result in stronger neural responses in dopamine-rich brain regions (Tindell et al., 2005) and higher levels of exploratory behavior (Mahler & Berridge, 2009) when subsequently presented alone – i.e., without their prior rewarding context. Such effects have been understood in terms of incentive salience conditioning processes, whereby a previously neutral stimulus attracts attention and processing resources to the extent that it was associated with substantial rewards in the past (Berridge, 2007; 2009).

In Experiment 2, we designed a very simplified version of such conditioning procedures. Specifically, we were interested in whether the presentation and evaluation of positive word primes would shift subsequent perceptions in an enhancement-related direction. This proved to be the case, as neutral boxes were judged erroneously larger in size to the extent that primes were of a positive affective type. The results from Experiment 2 thus extend those of Experiment 1 in a manner consistent with conditioning effects on incentive salience (Berridge, 2007; 2009).

Two other results are worth discussing, albeit briefly. Boxes were generally perceived to be larger than they actually were. We ascribe this effect to the fact that they were task-relevant

– i.e., they had to be attended to and size-estimated. Thus, again, size overestimates might prove to be sensitive to task-relevance. In Experiment 2, word frequency values biased size estimates in a larger direction. However, this effect was not observed in Experiment 1 (or, conceptually, in the experiments reported below). In any case, we showed that positive words primed higher subsequent size overestimates independent of this word frequency factor.

Experiment 3

Dopamine rich brain structures such as the ventral pallidum appear to play dual roles in enhancing sensory inputs associated with reward and biasing behavior in an approach-related direction (Smith et al., 2009). To isolate processes thought to facilitate approach behavior independent of actual perceptions, Experiment 3 used a paradigm in which individuals were led to believe that subliminal boxes had been presented in the context of affective prime words. Such boxes were not in fact presented. To the extent that expectancy processes of a salience type can occur in the absence of relevant perceptual input, participants should be biased to indicate that larger boxes had been presented in the context of positive word primes, relative to neutral and negative word primes. Following incentive motivation theory (Berridge, 2007), we hypothesized a biasing effect of this type.

Method

Participants and Procedures—A new set of 116 undergraduates from NDSU participated in this experiment. General procedures were identical to those of the two prior experiments. Participants were fully debriefed following the study.

Dependent Task—Participants were informed that our interest was in subliminal perception and intuitive processes related to it. In support of this cover story, participants were told that individuals can often exhibit significant accuracy in subliminal perception, despite the uncertainty likely to be involved. Such a cover story should be generally compelling, as people often trust their intuitions even when they are not supported by relevant perceptual data (Wegner, 2002; Wilson, 2002).

Each of the 168 trials in the task began with an affective prime word presented at center screen. After 600 ms the word was removed for 50 ms and then returned for an additional 600 ms. Participants were told that a smaller or larger box was presented at the word location during the 50 ms blank period between word exposures, though no such boxes were actually shown.

Following the second 600 ms exposure of the relevant prime word, two squares were presented at center screen. One was 1 cm × 1 cm and the other was 1.5 cm × 1.5 cm. On each trial, participants had to intuit which of the two boxes had been subliminally presented. Responses were made by using a computer mouse to select the box they thought had been presented. Whether the smaller of the two response boxes was left or right of center screen was randomized across trials. After participants made a response, they were asked to indicate the valence of the prime word by saying “good”, “neutral”, or “bad” into a computer microphone. After a short subsequent delay, the next trial began.

Results

Data Cleaning and Dependent Measure Computation—Participants had been informed that subliminal boxes of smaller versus larger sizes would be presented somewhat equally often. For this reason, tendencies to invariantly or near-invariantly select one box over the other would suggest that the participant did not understand the instructions. Eleven participants were deleted for such extreme scores (> 2.5 *SD*s from the mean). Results are thus based on 105 (44 female) responders. For each participant and prime type, we computed a mean to reflect the proportion of times that the larger (0 = smaller; 1 = larger) box was inferred to have been subliminally presented. There was a general tendency to infer that the larger box had been presented more frequently (M = 58.6%), t (104) = 7.65, $p < .01$.

Results with Participant as the Unit of Analysis—We hypothesized that positive words would prime a greater frequency of large box selections. Repeated-measures ANOVA, with word valence as the independent variable and large box proportion scores as the dependent variable, examined this hypothesis. There was a main effect for Word Valence in this analysis, F (2, 104) = 4.15, $p < .05$, partial $\eta^2 = .04$. The effect size is smaller than in Experiments 1 and 2 and is in the neighborhood of a medium sized effect (Cohen, 1988). Means for the main effect are displayed in Figure 4.

Pairwise ANOVAs were then performed. The positive/neutral comparison was significant, F (1, 104) = 3.85, $p = .05$, partial $\eta^2 = .04$, as was the positive/negative comparison, F (1, 104) = 7.98, $p < .05$, partial $\eta^2 = .07$. On the other hand, the neutral/negative comparison was not significant, $F < 1$, $p > .40$, partial $\eta^2 = .01$. Hence, and consistent with incentive salience theory, positive primes were uniquely responsible for the word valence main effect.

Results with Word as the Unit of Analysis—We sought to show that the biasing effects of positive affective primes generalize to the word-as-unit level of analysis. A multiple regression was performed in which continuous variations in word valence (Bradley & Lang, 1999) and log word frequency values (Kucera & Francis, 1976) were entered as simultaneous predictors of the proportion of large boxes inferred (N = 159). Word Valence was a significant predictor in this multiple regression, t (156) = 3.43, $p < .01$, but Word Frequency was not a significant predictor, t (156) = −1.01, $p > .30$.

Discussion

Dopamine appears to be involved in both the enhancement of sensory signals previously paired with reward (Tindell et al., 2005) and motor behaviors of an approach-related type (Smith et al., 2009). The incentive salience theory of dopamine's functions aims to simultaneous capture such dual influences (Berridge, 2007; 2009). In Experiment 3, we sought to isolate incentive salience processes of a purely output-related type. We were able to do so through the use of a novel paradigm in which participants were asked to infer whether smaller or larger boxes were presented independent of visual support for such inferences.

As hypothesized, boxes were inferred to be larger when their purported presentation occurred in the context of positive affective primes. These results suggest that the findings of Experiments 1 and 2 are not purely perceptual in nature as they appear to include a response-related component as well. On the other hand, the effect size for word valence in Experiment 3 was smaller than the effect sizes observed in Experiments 1 and 2. Thus, we contend that positive primes appear to enhance salience in both perceptual and output related manners, consistent with the dual perceptual and motor pathways by which rewards appear to prime incentive salience states in animal models of dopamine functioning (Berridge, 2007; 2009).

Experiment 4

Experiments 1–3 used size estimates to examine incentive salience processes. This is an especially intuitive criterion of perceptual salience, but not the only one. Accordingly, Experiment 4 sought to extend the results of Experiments 1–3 by asking for temporal estimates instead. To the extent that positive affective words are perceptually salient, they may be perceived to occur for a longer temporal duration, relative to neutral and negative words. This hypothesis was systematically examined in Experiment 4.

Method

Participants and Procedures—One hundred and nineteen undergraduates from NDSU participated in Experiment 4. Responses were again collected in private cubicle rooms in groups of 6 or less.

Dependent Task—The affective prime words used in Experiments 1–3 were used in Experiment 4 as well. There were 168 trials, one for each of the prime words involved. At the beginning of each trial, a randomly selected word was presented at center screen for anywhere between 1000 ms and 3000 ms, its exact duration selected by the computer program at random within this temporal interval. After each word was removed from the screen, participants estimated its presentation duration along a rating bar anchored by 0.5 seconds on the left and 3.5 seconds on the right. To make a response, participants used a computer mouse to select a location along the rating bar that corresponded to the length of time they believed the word was presented on the screen. Subsequent to such duration estimates, participants vocally categorized the word presented as “good”, “neutral”, or “bad”, again to facilitate affect encoding. After evaluating each trial-specific stimulus, there was a brief delay before the next stimulus word was presented.

Results

Data Cleaning and Dependent Measure Computation—The data for 4 participants were deleted because their temporal estimates were implausible, defined in terms of average temporal estimates that were more than 2.5 *SD*s from the overall mean, leaving 115 (53 female) participants. The (500 ms to 3500 ms) rating bar was highly sensitive and responses were re-coded in terms of millisecond values, with pixels translated into millisecond duration estimate values in a linear fashion. Because words varied in their actual duration, we computed a bias score dependent measure by subtracting the actual duration of each word from its estimated duration. Irrespective of word valence, durations were overestimated by 224 ms, a significant general tendency, t (114) = 10.50, $p < .01$.

Results with Participant as the Unit of Analysis—We hypothesized that positive primes, perhaps uniquely so, would predict temporal overestimates. A repeated-measures ANOVA was conducted to examine this prediction. As hypothesized, there was a main effect for Word Valence, F (2, 114) = 26.29, $p < .01$, partial $\eta^2 = .19$, a large effect size (Cohen, 1988). Means for such temporal overestimates are displayed in Figure 5. Follow-up pairwise ANOVAs were then performed. The positive/neutral comparison was significant, F (1, 114) = 39.41, $p < .01$, partial $\eta^2 = .26$, as was the positive/negative comparison, F (1, 114) = 31.59, $p < .01$, partial $\eta^2 = .22$. On the other hand, the neutral/negative comparison was not significant, F (1, 114) = 1.97, $p > .10$, partial $\eta^2 = .02$.

Results with Word as the Unit of Analysis—We computed temporal bias scores for each word, averaged across participants. We then performed a multiple regression in which continuous variations in word valence and log word frequently were simultaneously regressed in the prediction of such temporal biases in a word-as-unit analysis. In this multiple regression, Word Valence was a robust predictor of temporal bias scores, t (156) = 8.53, $p < .01$. On the other hand, Word Frequency was a non-significant predictor of temporal overestimates, t (156) = 1.48, $p > .10$. Such results are consistent with the results of Experiments 1–3 and establish that our valence priming effects are independent of word frequency considerations, while also significant at the word-as-unit level of analysis.

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Discussion

We sought to translate the incentive salience theory of dopamine function, previously examined in animal models (Berridge, 2009), to predictions of the sort that could be more readily examined among human observers. Perceptions of size seemed to us to best capture the "salience" construct. Accordingly, the extent to which positive affective primes biased size estimates was systematically examined in Experiments 1–3, with all results converging on a novel relation between positive primes and larger size estimates.

The strength and consistency of the results from Experiments 1–3 encouraged us to examine incentive salience processes in another manner. What is salient should also appear to be presented for a longer temporal duration (Witherspoon & Allan, 1985). Accordingly, Experiment 4 examined whether positive word primes would be perceived to be presented for a longer duration than neutral and negative words primes. This proved to be the case, robustly so across participant- and word-level analyses, and independent of word frequency effects. The results of Experiment 4 therefore extend those of Experiments 1–3 beyond a size as salience mapping.

General Discussion

Four experiments sought to translate an incentive salience theory of approach motivation developed to understand dopamine functioning in animal models (Berridge, 2009) to affective and perceptual processing tendencies among human beings. Salience was objectively defined in terms of front-end perceptual processes, either in terms of perceived size (Experiments 1–3) or duration (Experiment 4). In addition, object-specific (Experiments 1 & 4) and prime-induced (Experiments 2 & 3) perceptions were examined. In all experiments, positive affective primes were either viewed to be more perceptually salient or primed perceptual judgments of a salience-related type. Such results replicated across paradigms, participant-level and word-level analyses, and remained significant when controlling for word frequency. In the General Discussion, we consider the findings from multiple angles and present future directions of research as well.

Relation to Other Theories and Findings

Lewin (1935) proposed that positive stimuli in the environment elicit proximity-seeking tendencies of an implicit goal-related type. Similar dynamics have been proposed in relation to cybernetic theories of approach motivation (Carver & Scheier, 1998; Powers, 2005). The present results can be viewed as confirmation of such perspectives in low-level perceptual terms: To the extent that positive stimuli or any stimuli for that matter induce implicit approach tendencies, they may be expected to result in perceptions consistent with a reduced distance between the self and the relevant object. Object size is an obvious candidate for investigating such implicit goal-directed processes because approaching objects renders them larger in retinal and visual terms. The results of Experiment 1 are thus consistent with cybernetic theories of approach motivation. However, the results of Experiments 2–3 extend these findings by showing that positive stimuli appear to prime such perceptions for at least a short period of time thereafter, as proposed by incentive salience theory (Berridge, 2009).

We found that positive affective primes resulted in perceptual estimates associated with approaching a stimulus (e.g., larger perceived size), but negative affective primes did not result in perceptual estimates associated with avoiding a stimulus (e.g., smaller perceived size), both relative to a neutral word priming condition. We suggest that this disassociation may be the result of the different behavioral strategies linked to approach and avoidance motivation. Positive stimuli are to be approached and not avoided (Carver & Scheier, 1998). On the other hand, negative stimuli may prime either avoidance (e.g., "flight") or approach (e.g., "fight") tendencies (Yehuda & McEwen, 2004). In addition, it is likely that stimuli targeting different discrete negative emotions (e.g., anger versus fear or disgust versus fear) might result in different motivational tendencies and potentially resulting perceptual effects (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Stefanucci & Proffitt, 2009). We encourage this direction of research. In any case, the findings are entirely consistent with incentive salience theory, which posits a systematic relationship between positive stimuli and approach-motivated perceptual tendencies (Berridge, 2007).

Fazio, Sanbonmatsu, Powell, and Kardes (1986) conducted a landmark study in which it was shown that the brief presentation of positive versus negative word primes activated evaluations of a corresponding type (e.g., positive primes sped the evaluation of positive targets). A great deal of related research has occurred since then (Fazio, 2001). Klauer and Musch (2003) provide an excellent analysis of this literature. Briefly, they suggest that what has been termed "affective priming" may be understood in terms of response-compatibility processes of the type also involved in non-evaluative tasks such as the Stroop task (Kornblum, Hasbroucq, & Osman, 1990). The present results cannot be understood in such terms. Although participants evaluated prime stimuli, the target task – either to estimate size or duration – was one that should be immune to such Stroop-like compatibility effects because of its very different nature.

The "affect as information" model is another prominent one in the social psychology literature. Positive mood states, relative to negative mood states, often lead individuals to rely to a greater extent on heuristics such as person perception stereotypes (Schwarz & Clore, 2007). It is difficult to see how such a model could explain the present results for three primary reasons. Manipulated mood states last a fairly long time – probably at least 10 minutes (Gerrards-Hesse, Spies, & Hesse, 1994). Our effects, however, involved trial-to-trial variations in stimulus affect. The heuristics emphasized by this literature involve accessible thoughts and concepts, not visual or temporal perceptions. Finally, mood influences on cognition are typically eliminated or reversed to the extent that participants are aware of the source of their affect (Clore et al., 2001). By contrast, individuals in our studies were decidedly aware of the source of their affect because they were explicitly asked to evaluate the words prior to making perceptual judgments. The results, then, seem to fall outside the explanatory scope of this model.

In recent years, social psychologists have increasingly focused on the motivation-cognition interface (Shah & Gardner, 2008). A small minority of this work has focused on perceptual dependent measures consistent with the New Look movement of the 1950s (Bruner, 1951). Study 1 of Veltkamp, Aarts, and Custers (2008) found that subliminally priming individuals with thirst words (e.g., "drinking") led them to estimate that a glass of water was of a larger vertical size, but only if they were thirsty. Study 1 of Balcetis and Dunning (2006) manipulated motivation by telling individuals that they would be asked to taste a desirable versus undesirable beverage depending on whether a subsequent presented stimulus was a letter versus a number and then presenting an ambiguous stimulus that could be perceived as either a letter ("B") or a number ("13"). The ambiguous stimulus was perceived as a letter to the extent that a letter would lead to drinking the more pleasant beverage and as a number to the extent that a number would lead to drinking the more pleasant beverage. The present findings were different in that deprivation and task-relevance were not assessed or manipulated, positive stimuli were of a wide type, and priming effects were observed in a short-term trial-to-trial manner.

Additional Considerations and Future Directions

The positive incentives manipulated in animal studies are often very strong – e.g., amphetamine injection in reward-related brain areas or the presentation of food among severely food-deprived rodents. It is a mistake to view results from this animal model in terms exclusive to such strong manipulations, though. Quite the contrary, even very neutral cues – such as a sound or a place – trigger dopamine release to the extent that they have previously been paired with rewards (Wise, 2004; Wyvell & Berridge, 2000). We contend that positive words, despite their relatively mundane nature, co-opt this neural system because of their signal value in predicting rewarding events and emotional states (Osgood et al., 1957). This contention comports with results of the type reported by Chen and Bargh (1999).

Dopamine activity amplifies or "boosts" the signal of appetitive stimuli, the psychological consequence of which is enhanced incentive salience (Berridge, 2009). The most straightforward perceptual translation of salience, especially to the extent that it primes approach tendencies, should be greater perceived size. It was for this reason that Experiments 1–3 focused on size perceptions, though Experiment 4 extended such results by focusing on temporal perceptions. Nonetheless, future studies might examine other perceptual qualities such as greater perceived contrast and/or greater perceived color saturation.

Dopamine levels are exceedingly difficult to assess or manipulate among human beings. Yet, there are research strategies that can be used and should be used in future studies of the present type. Animal models have shown that dopamine modulates eye blink rate and eye blink rate – as a basal individual difference among human beings – has proven informative in understanding some outcomes linked to dopamine function such as creativity (Chermahini & Hommel, 2010). Accordingly, it would be useful to examine whether blink rate moderates the biases found in the present experiments. There are also individual differences in several alleles contributing to dopamine levels (Forbes et al., 2009) that – too – may moderate the priming effects of positive words on approach-related perceptions. Finally, dopamine antagonists can be administered in research protocols (Wacker et al., 2006). If we are correct, the administration of such dopamine antagonists should reduce the magnitude of our priming-based perceptual biases.

It is possible that certain positive primes might trigger incentive salience processes to a greater extent than others. For example, concrete positive words referring to real-world objects (e.g., "people") might prime the incentive motivation system to a greater extent than abstract words not referencing real-world objects (e.g., "prestige"). Or, perhaps, nouns (e.g., "cake") might result in greater biasing effects of the present type than adjectives. (e.g., "cozy"). Such distinctions among positive stimuli, and their perceptual priming effects, would seem worth examining in future experiments. Doing so would presumably involve systematic manipulations of types of positive stimuli, which were not the focus of the present experiments.

Altering stimulus content even more dramatically may have additional utility. For example, to the extent that an individual prefers Pepsi over Coke, the former object may be overestimated in size to a greater extent than the latter. Further, Robinson and Berridge (2003) suggested that incentive salience processes might underlie and cause drug addictions. If so, size or duration overestimates of addiction-related stimuli (e.g., words related to drinking & alcohol) may serve as an implicit probe of addiction-related processes beyond those based on selective attention or affective associations (Wiers & Stacy, 2006).

In social cognitive studies, several manipulations have been posited to trigger higher levels of implicit approach motivation. These include manipulations of regulatory focus (Förster & Werth, 2009), muscular activity (Cacioppo, Priester, & Berntson, 1993), and anger (Carver & Harmon-Jones, 2009). We suggest that paradigms of the present type may complement other cognitive paradigms (e.g., Higgins & Tykocinski, 1992) in understanding the processing basis of such manipulations, particularly so because the present paradigms were based on a biological model of considerable scope and explanatory value (Berridge, 2007; 2009).

Paradigms of the present type could also be used to understand processes associated with personality tendencies and individual differences. Extraversion has been theoretically linked to higher levels of implicit approach motivation (Elliot & Thrash, 2002) and the anhedonic subtype of depression has been theoretically linked to lower levels of implicit approach motivation (Watson et al., 1995). We suggest that the present procedures may be of use in probing such individual differences on the basis of front-end reward-sensitive perceptual processes. In addition, it would be of utility to examine individual differences in the biases observed here in their ability to predict emotional reactivity to positive events in the laboratory and everyday life (Zelenski & Larsen, 1999). Work of this type is underway.

A final question is whether biased perceptions of the present type would facilitate approach-related actions. They clearly should *motivate* such actions according to both rodent (Berridge, 2007; Miller, 1944) and human (Cacioppo, Gardner, & Berntson, 1999; Förster, Higgins, & Idson, 1998) literatures. As to whether misperceptions would result in clumsy motoric efforts, we suggest that they would not. Motoric processes (such as grasping) are mediated by a neural system that is surprisingly accurate and independent of subjective misperceptions (Goodale, 2008; Taylor & Zwaan, 2010). Accordingly, the misperceptions documented here would be unlikely to result in clumsy motoric attempts to approach, grasp, or otherwise obtain positive stimuli.

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Figure 1. An Example Trial from Experiment 1

Note: This is a positive word. Its font size is 16, the exact midpoint of the comparison array.

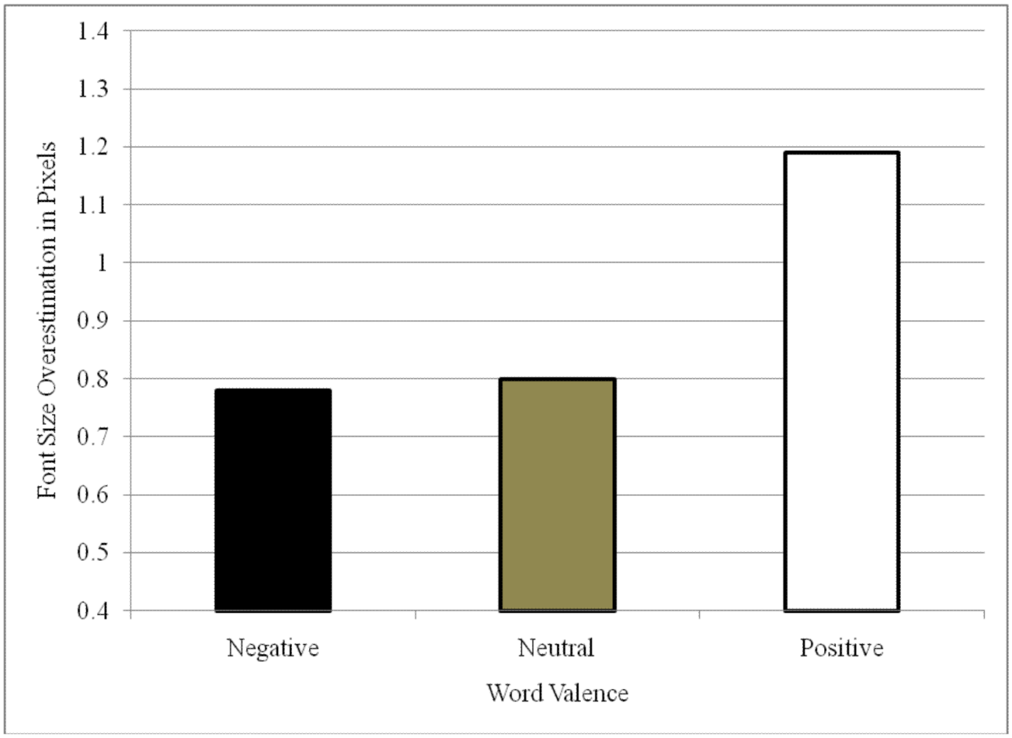

Figure 2.
Font Size Overestimation by Valence Prime Type, Experiment 1

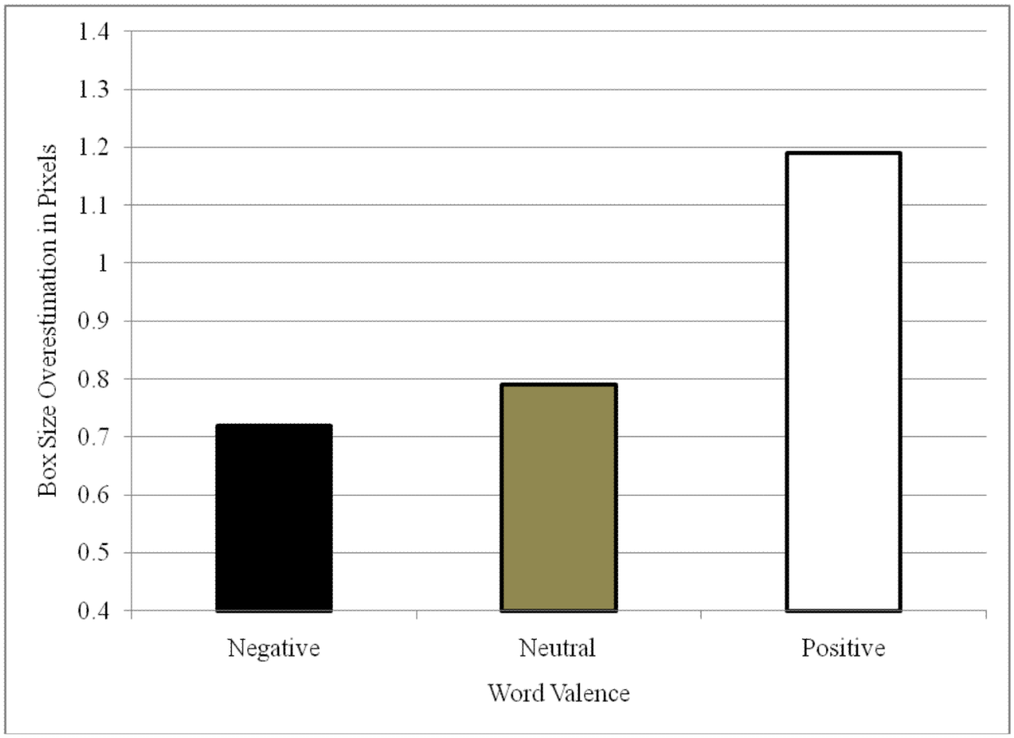

Figure 3.
Box Size Overestimation by Valence Prime Type, Experiment 2

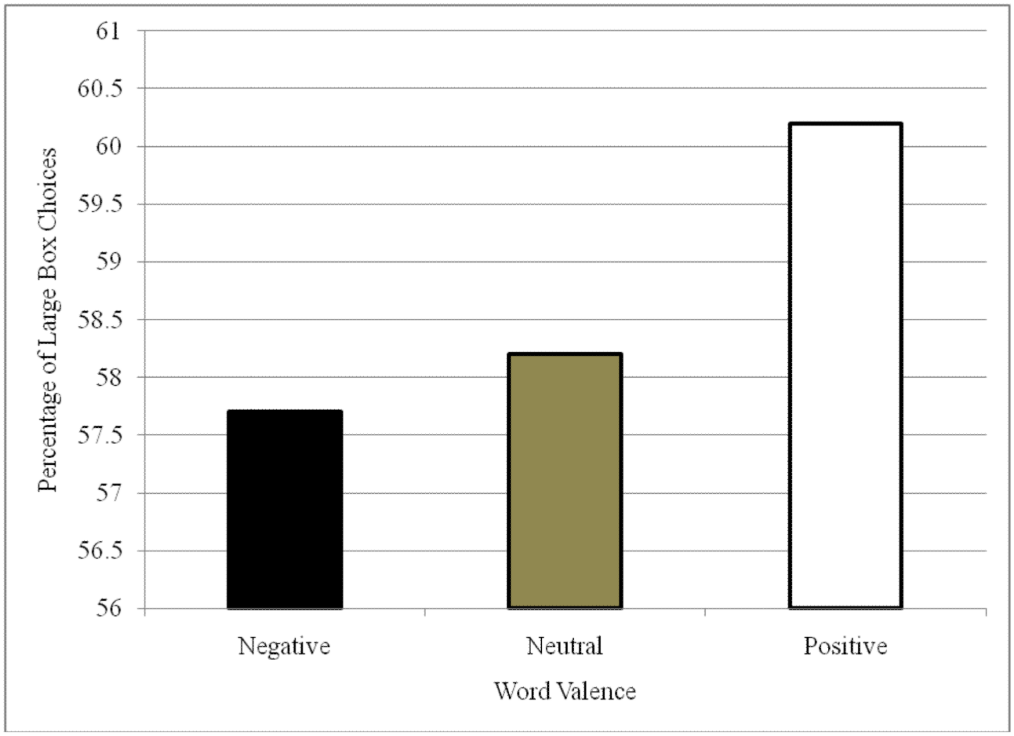

Figure 4.
Percentage of Large Box Choices by Valence Prime Type, Experiment 3

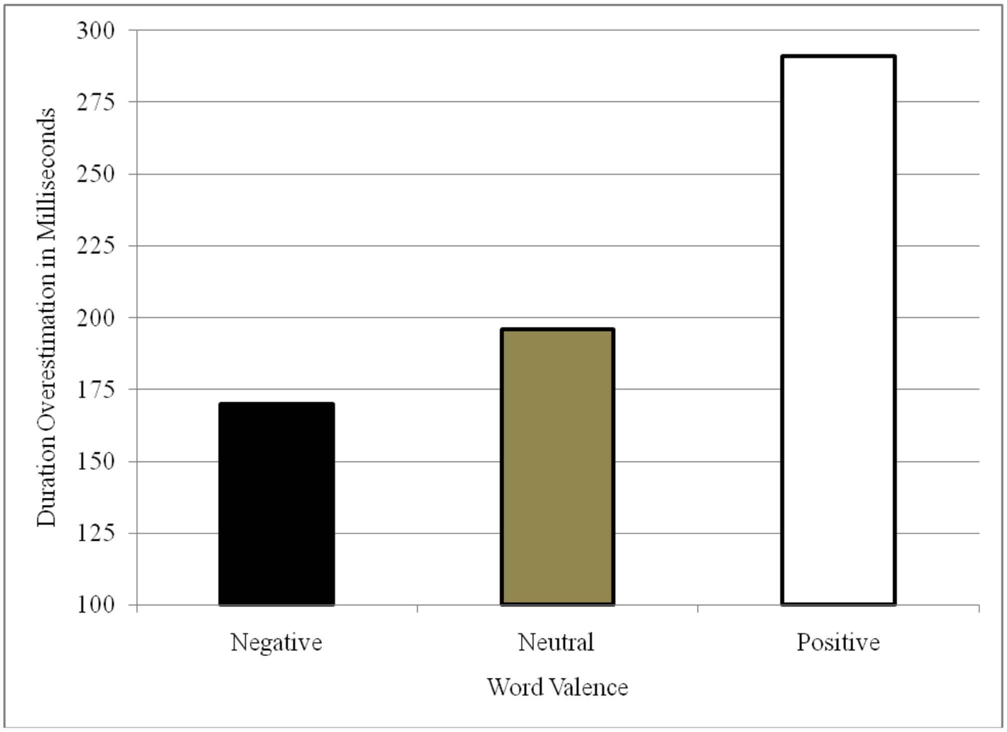

Figure 5.
Stimulus Duration Overestimation by Valence Prime Type, Experiment 4