Current Directions in Psychological Science

http://cdp.sagepub.com/

Human Reward Pursuit : From Rudimentary to Higher-Level Functions

Erik Bijleveld, Ruud Custers and Henk Aarts

Current Directions in Psychological Science 2012 21: 194

DOI: 10.1177/0963721412438463

Current Directions in Psychological Science
21(3) 194–199

DOI: 10.1177/0963721412438463
http://cdps.sagepub.com

Human Reward Pursuit: From Rudimentary to Higher-Level Functions

Erik Bijleveld[1], Ruud Custers[1,2], and Henk Aarts[1]
[1]Utrecht University and [2]University College London

Abstract

Human reward pursuit is often found to be governed by conscious assessments of expected value and required effort. Yet research has also indicated that rewards are initially valuated and processed outside of awareness by rudimentary brain structures. Building on both of these findings, we propose a new framework for understanding human performance in the service of reward pursuit. We suggest that people initially process rewards unconsciously, which can boost effort and facilitate performance. Subsequently, people may process rewards more fully, which allows them to make strategic decisions on the basis of task conditions and to consciously reflect on the rewards. Intriguingly, these specific processes associated with full reward processing can cause its effects on performance to diverge from those of initial reward processing. In this article, we review recent research that supports this framework. Finally, we discuss how our framework may lead to a refined yet broadly applicable understanding of the human pursuit of rewards.

Keywords

reward pursuit, consciousness, performance

Human beings are regularly confronted with the opportunity to attain rewards for which they need to work. In psychology, such reward pursuit is often conceptualized and examined in terms of people's assessments of the *expected value* of rewards (Eccles & Wigfield, 2002; Feather, 1982). When determining which reward to pursue and how much effort to invest in pursuing it, people are assumed to weigh the *value* of a reward against its *expectancy* (e.g., a person's likelihood of attaining it) and its *demands* (e.g., the effort required to attain it). This analysis is often thought to require consciousness because it relies on higher-level functions, such as value learning and information integration. Recent findings, however, have indicated that many of its underlying functions may also operate outside awareness (Custers & Aarts, 2010; Hassin, Bargh, Engell, & McCulloch, 2009; Olson & Fazio, 2001). In line with these discoveries, we propose that rewards first undergo *initial processing* outside awareness, and then undergo *full processing*, which entails their conscious perception. In this article, we address how these two stages of reward processing shape reward pursuit.

The idea that stimuli initially receive basic, preconscious processing is not new (Bargh, 2006). For example, unconsciously perceived stimuli have been shown to influence performance on tasks that require semantic processing (e.g., Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006). Along similar lines, fear-inducing stimuli are thought to prompt action before they enter conscious awareness via a rapid initial route (which relies on subcortical brain structures), only to be processed more fully via a slower but more thorough route (which relies on both subcortical and cortical brain structures; LeDoux, 1996). In line with these demonstrations and theorizing, we propose a new framework for understanding the human pursuit of rewards that specifies how performance in the service of reward pursuit is supported by consecutive unconscious and conscious processes. Drawing on research from neuroscience and psychology, our framework (summarized in Table 1) specifies how and when these unconscious and conscious processes lead to distinct behavioral consequences.

We propose that people first process rewards in rudimentary, subcortical brain structures—most notably, the striatum. Whereas this initial processing can generate information for further deliberation (Camerer, Loewenstein, & Prelec, 2005), we propose that it can also facilitate task performance directly by prompting the recruitment of effort in the service of reward attainment. Notably, this initial processing can operate in the absence of conscious awareness of the reward. After this initial valuation, rewards may undergo full processing—that is, processing that also engages higher-level cognitive functions located in the cortex. Only when such full processing takes place are people consciously aware of the reward. This

Corresponding Author:
Erik Bijleveld, Department of Psychology, Utrecht University, P.O. Box 80140, 3508TC Utrecht, The Netherlands
E-mail: e.h.bijleveld@uu.nl

Table 1. Framework for Understanding Human Reward Processing and Its Effects on Task Performance

Type of reward processing	Required intensity of reward	Phenomenological experience of reward	Functionality and potentially involved brain structures	Behavioral outcomes
Initial	Low	Reward is not consciously experienced	Rudimentary: VS and its immediate outputs	Facilitation of performance
Full	High	Reward is consciously experienced	Rudimentary: VS and its immediate outputs; higher-level: MPFC, ACC, DLPFC	Facilitation of performance; strategic decision making and reflections on rewards

Note: VS = ventral striatum; MPFC = medial prefrontal cortex; ACC = anterior cingulate cortex; DLPFC = dorsolateral prefrontal cortex.

conscious awareness allows them to change the strategies they employ to attain the reward, and to reflect on its meaning. These processes, which are specific to full reward processing, may have distinct effects on behavior that go beyond the mere recruitment of more effort.

In the following sections, we will further characterize the qualities of initial and full reward processing; discuss a series of recent studies that have employed a novel monetary-reward priming paradigm to analyze and compare the effects of initial and full reward processing, providing evidence for the present framework; and describe how our framework may broadly contribute to the understanding of human choice behavior and performance in the context of reward pursuit.

Initial Reward Processing

To understand the neural underpinnings of reward pursuit, researchers have examined the brain structures that are engaged when people invest effort to attain rewards. It has often been shown that when people initially establish the value of rewards, they rely on subcortical brain structures that are part of the dopamine system. One of these structures in particular, the striatum (which encompasses the nucleus accumbens), reliably mirrors the reward value of stimuli in the environment, such as stimuli related to food, sex, drugs, and money (Delgado, 2007). Thought to have arisen early in evolution, the striatum is generally not considered to be associated with consciousness (e.g., Dehaene et al., 2006; but see Merker, 2007). In line with this idea, a study on cocaine users showed that reward-related stimuli (i.e., cocaine-related visual cues) engaged the striatum even though they were presented at low intensity, too briefly to be consciously reportable (Childress et al., 2008). This finding indicates that initial valuations of rewards rely on rudimentary brain functions and that they require little perceptual input about the reward to take place—at least, less than is needed for the reward to be consciously detectable.

Nevertheless, such initial valuations have important implications for people's behavior, because they can directly boost the effort that people expend to attain rewards. In one experiment (Pessiglione et al., 2007), participants could earn rewards by performing an effortful task. On each trial, participants first saw the reward at stake: a high-value or low-value British coin, which participants could earn by forcefully squeezing a handgrip. The harder they squeezed, the greater the proportion of the coin's value they received. Critically, the duration of the presentation of the coins was varied so that they could either be processed only initially (17 or 50 milliseconds) or fully (300 ms). Strikingly, it was found that at the shorter durations—which did not allow for conscious perception of the coins—people still squeezed harder when the coins were of higher value. In line with findings from the study on cocaine users (Childress et al., 2008), the brain areas that were associated with this behavior were subcortical and rudimentary. Thus, initial reward-valuation processes can directly facilitate performance on tasks (Table 1)—in this case, it increased crude physical force.

Another study addressed the possibility that, upon initial processing of a reward cue, people invest effort only in conditions in which an expense of effort is in fact required (Bijleveld, Custers, & Aarts, 2009). If true, this would suggest that people can unconsciously integrate information about effort requirements and reward value, a possibility in line with research showing that animals carry out such integrations in rudimentary brain structures (i.e., the striatum; Phillips, Walton, & Jhou, 2007). Using a monetary-reward priming paradigm used in previous work (Pessiglione et al., 2007), we (Bijleveld et al., 2009) tested this idea by rewarding participants for performing either a nondemanding or a demanding task (i.e., they had to retain either three or five digits). While participants performed the task, we recorded their pupil dilation as an unobtrusive measure of effort. As expected, findings indicated that the prospect of rewards—even when they were processed only initially—boosted mental effort, but only when it was required (i.e., only when participants faced a demanding task; see Fig. 1). Thus, even on a rudimentary level, people are capable of adaptively responding to reward cues: They take into account not only the value of the reward at stake, but also the effort required to attain it in a given situation. This conclusion is in line with the idea that people have a profound tendency to expend effort only when they need to and conserve it when they can (Bijleveld, Custers, & Aarts, in press; Brehm &

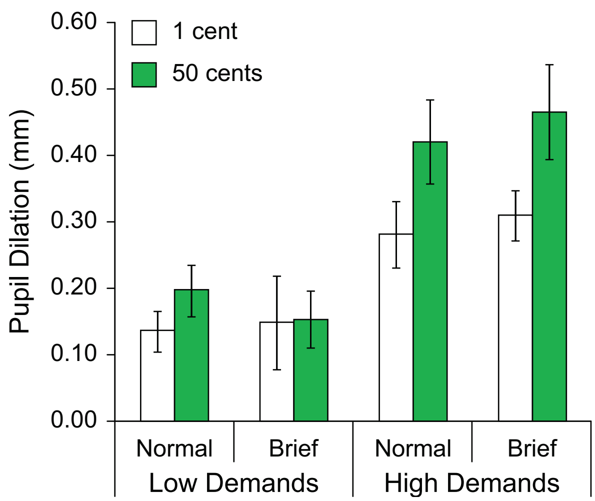

Fig. 1. Pupil dilation (in millimeters, mm)—a measure of mental effort—as a function of reward value (1 cent or 50 cents), the duration of reward presentation (normal or brief), and the demands of the task (low or high). These results indicate that even when people process rewards only initially (because of brief presentation, in this case), they exert mental effort toward the pursuit of rewards in an adaptive way (i.e., only when effort is actually required to attain the reward). Adapted from "The Unconscious Eye-Opener: Pupil Size Reveals Strategic Recruitment of Resources Upon Presentation of Subliminal Reward Cues," by E. Bijleveld, R. Custers, and H. Aarts, 2009, *Psychological Science, 20*, pp. 1313–1315. Copyright 2009, Association for Psychological Science. Adapted with permission.

Self, 1989; Gendolla, Wright, & Richter, 2011; Hull, 1943; Kool, McGuire, Rosen, & Botvinick, 2010).

Full Reward Processing

Rewards may also be processed more fully. In terms of the brain structures that are engaged, full reward processing may involve higher-level cognitive functions located in the frontal cortex, in addition to the rudimentary structures already engaged by initial reward processing. These regions likely include the medial prefrontal cortex (which is involved in integrating signals in the brain to make strategic decisions), the anterior cingulate cortex (which is involved in executive control over behavior, among other functions), and the dorsal prefrontal cortex (which is involved in actively maintaining reward information over time; Haber & Knutson, 2009). Thus, the structure and function of the brain suggests that both rudimentary and higher-level functions are successively engaged in reward processing, but only the latter are associated with conscious awareness of the reward at stake (Berridge, 2003).

The engagement of the cortex in the service of reward pursuit likely has important implications for behavior. The higher-level functions associated with full reward processing are known to be involved in controlling and coordinating brain processes that would otherwise operate independently (Dehaene et al., 2006); thus, although initial reward processing may prompt the recruitment of effort, full reward processing allows people to initiate a more advanced mode of reward pursuit (Wallis & Kennerley, 2010). This idea is consistent with theories of reward pursuit that propose that people consciously reflect on a reward's expectancy, its value, and any information they have about task demands before they make a strategic decision about how to attain it (e.g., Brehm & Self, 1989; Eccles & Wigfield, 2002). Building on this work, we propose that the full processing of a reward allows people to make strategic decisions about attaining it that go beyond the mere recruitment of effort (Dehaene et al., 2006). Moreover, full processing allows people to reflect on the reward at stake (Schooler, 2002). In the next section, we address how these specific features of full reward processing can cause its outcomes to diverge from those of initial reward processing.

When Consequences of Initial and Full Reward Processing Diverge

In many tasks (e.g., squeezing a handgrip), the quality of performance is mainly determined by the recruitment of effort. Because strategic considerations play only a minor role in such tasks, the specific processes instigated by full reward processing do not necessarily affect performance. This idea is corroborated by the research reviewed above, in which rewards led to similar outcomes regardless of whether they were processed fully or only initially (see also Capa, Bustin, Cleeremans, & Hansenne, 2011). In other tasks or circumstances, however, people may choose between multiple strategies that might increase their chance of attaining a reward (e.g., people may choose an eager or a cautious strategy). Given that full reward processing may enable people to make such strategic choices, such task situations may foster differences between the outcomes of initial and full reward processing.

In a study designed to test this idea (Bijleveld, Custers, & Aarts, 2010), participants could earn money by quickly and accurately solving a mathematical equation. In their performance of this demanding task, participants could focus on either their speed or their accuracy—in other words, they could choose between using an eager strategy or a cautious one. When rewards were processed only initially, participants did not change their strategies (i.e., although participants' performance was faster for higher rewards, this did not affect their accuracy). When rewards were fully processed, however, people strategically prioritized accuracy over speed in order to ensure their attainment of the reward. Full reward processing thus permitted participants to make strategic choices in the service of reward attainment.

People do not always make the right choice, though. Some task situations are known to prompt people to use strategies that *hurt*, rather than help, performance. For example, people often feel that concentrating on a task that requires attention helps them to perform well, but this strategy may backfire on tasks such as the attentional blink task (Olivers & Nieuwenhuis, 2006), in which participants must detect two target stimuli embedded in a quickly changing stream of distracters. In one study, people were rewarded for accurately detecting the targets in this task, which is challenging. Although initial processing of rewards boosted performance, this performance increment disappeared when the same rewards were fully processed (Bijleveld, Custers, & Aarts, 2011a). This finding supports the idea that full reward processing leads people to consciously choose a strategy—in this case, concentrating on the task—but that this strategic choice may backfire and worsen performance. Thus, although full reward processing may lead to the engagement of higher-level functions, it does not necessarily enhance the effectiveness of reward pursuit.

Aside from enabling the selection of specific task strategies in the service of reward attainment, full reward processing is associated with conscious awareness of the reward that is at stake. Accordingly, full reward processing may cause people to reflect on the meaning and the importance of a given reward (Schooler, 2002). Importantly, recent research has suggested that such reflections can affect performance as well. In one study, the performance of participants who fully processed rewards while they carried out a demanding working memory task declined, whereas the same rewards boosted performance when they were processed only initially (Zedelius, Veling, & Aarts, 2011). This finding is in line with the idea that thinking about desired outcomes (e.g., attaining money) may distract attention from the current task and thus hamper performance (Beilock, 2010; Bijleveld, Custers, & Aarts, 2011b).

The notion that fully (but not initially) processed rewards distract attention may be explained by the idea that the full processing of rewards can put people in a conscious state of mind in which they deliberate or ruminate about how to deal with the present situation (e.g., "Is it worth the effort?"; "Can I really do it?")—which can impede ongoing performance on demanding tasks (Gollwitzer, 1990; Kuhl, 1984). This theoretical perspective may be employed to further understand and examine the conditions under which full reward processing worsens performance. For example, some task contexts more than others have the potential to be interpreted in terms of reward pursuit (e.g., because of task instructions) and may thus be more likely to be influenced by full reward processing (Koole & Jostmann, 2004; Richter, 2010). Furthermore, some people may be more likely than others to ruminate about desired outcomes (e.g., rewards) and may therefore be more vulnerable to the adverse effects of full reward processing (e.g., Kuhl, 1984). On the basis of this work, new predictions may be formulated about when and for whom the effects of full reward processing are most pronounced.

Conclusion and Implications

The current framework suggests a new, more precise way of understanding how people act when they pursue rewards. The research we have reviewed in this article converges on the idea that reward pursuit is shaped by the successive employment of rudimentary and higher-level functions, which have distinct effects on behavior (Table 1). We suggest that initial reward processing may facilitate performance by prompting the recruitment of effort. Accordingly, when the quality of task performance is mainly determined by effort, initial and full reward processing may have the same outcomes. However, in specific circumstances—for instance, when task strategies or conscious reflection on the reward affect performance—the outcomes of initial and full reward processing may diverge. As it turns out, full reward processing does not necessarily lead to better outcomes.

A key implication of our framework is that it is not always necessary, or even desirable, for people to make conscious assessments about expectancy and value when they pursue rewards (Camerer et al., 2005; Custers & Aarts, 2010). Instead, our analysis indicates that the rudimentary functions that underpin these assessments can also affect performance directly. Although the studies described in this article mainly addressed decisions related to effort and performance, their findings in principle may generalize to other types of decisions as well—such as decisions in negotiations and under risk. For example, initial processing of valuable rewards may increase choices in line with risk-seeking behavior (Knutson, Wimmer, Kuhnen, & Winkielman, 2008), whereas full processing may instead lead to choices reflecting risk aversion (Bijleveld et al., 2010). The present framework thus generates new and specific hypotheses about when rudimentary and higher-level functions have similar or different consequences in decision making.

More broadly, the present framework may prove interesting to fields of research that have identified and studied the effects of using rewards to increase people's motivation and performance. For example, when rewards can be earned on a task, motivation is often undermined because of decreases in participants' task enjoyment (Deci, Koestner, & Ryan, 1999; Murayama, Matsumoto, Izuma, & Matsumoto, 2010), a finding that has important implications for educational and organizational practices. Given that these effects stem from people's reflections on what is at stake (Deci et al., 1999), they are likely due to full reward processing. Accordingly, the present framework raises the possibility that initial and full reward processing have different consequences for people's experience of tasks that they carry out in pursuit of rewards. Perhaps by processing extrinsic rewards only initially, people may boost their performance *without* compromising their task enjoyment. Taken together, our review of the literature and the present framework provide a new way of looking at important psychological phenomena, contributing to a precise but broadly applicable science of the effects of rewards on human motivation and performance.

Recommended Reading

Bargh, J. A., & Morsella, E. (2008). The unconscious mind. *Perspectives on Psychological Science, 3*, 73–79. An article that provides a perspective on the role of unconscious processes in behavior, in line with the present framework.

Bijleveld, E., Custers, R., & Aarts, H. (2010). (See References). Two studies that provide insight into how initial and full reward processing may lead to different strategic choices.

Cohen, M. A., & Dennett, D. C. (2011). Consciousness cannot be separated from function. *Trends in Cognitive Sciences, 15*, 358–364. An article that presents a perspective on the study of the functions and neural underpinnings of consciousness.

Gendolla, G. H. E., Wright, R. A., & Richter, M. (2011). (See References). A review of how the recruitment of effort is (consciously) constrained by effort requirements and reward value.

Haber, S. N., & Knutson, B. (2009). (See References). A review of how reward information travels through the brain.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding

The work in this paper was supported by Netherlands Organization for Scientific Research Grants VENI 451-06-014 (to Ruud Custers) and VICI 453-06-002 (to Henk Aarts).

References

Bargh, J. A. (2006). What have we been priming all these years? On the development, mechanisms, and ecology of nonconscious social behavior. *European Journal of Social Psychology, 36*, 147–168. doi:10.1002/ejsp.336

Beilock, S. L. (2010). *Choke: What the secrets of the brain reveal about getting it right when you have to*. New York, NY: Simon & Schuster.

Berridge, K. C. (2003). Irrational pursuits: Hyper-incentives from a visceral brain. In I. Brocas & J. Carillo (Eds.), *The psychology of economic decisions* (Vol. 1, pp. 17–40). New York, NY: Oxford University Press.

Bijleveld, E., Custers, R., & Aarts, H. (2009). The unconscious eye-opener: Pupil size reveals strategic recruitment of resources upon presentation of subliminal reward cues. *Psychological Science, 20*, 1313–1315. doi:10.1111/j.1467-9280.2009.02443.x

Bijleveld, E., Custers, R., & Aarts, H. (2010). Unconscious reward cues increase invested effort, but do not change speed-accuracy tradeoffs. *Cognition, 115*, 330–335. doi:10.1016/j.cognition.2009.12.012.

Bijleveld, E., Custers, R., & Aarts, H. (2011a). Once the money is in sight: Distinctive effects of conscious and unconscious rewards on task performance. *Journal of Experimental Social Psychology,* 865–869. doi:10.1016/j.jesp.2011.03.002

Bijleveld, E., Custers, R., & Aarts, H. (2011b). When favourites fail: Tournament trophies as reward cues in tennis finals. *Journal of Sports Sciences, 29*, 1464–1470. doi: 10.1080/02640414.2011.604679

Bijleveld, E., Custers, R., & Aarts, H. (in press). Adaptive reward pursuit: How effort requirements affect unconscious reward responses and conscious reward decisions. *Journal of Experimental Psychology: General.*

Brehm, J. W., & Self, E. A. (1989). The intensity of motivation. *Annual Review of Psychology, 40*, 109–131. doi:10.1146/annurev.ps.40.020189.000545

Camerer, C., Loewenstein, G., & Prelec, D. (2005). Neuroeconomics: How neuroscience can inform economics. *Journal of Economic Literature, 43*, 9–64.

Capa, R. L., Bustin, G. M., Cleeremans, A., & Hansenne, M. (2011). Conscious and unconscious reward cues can affect a critical component of executive control: (Un)conscious updating? *Experimental Psychology, 58*, 370–375.

Childress, A. R., Ehrman, R. N., Wang, Z., Li, Y., Sciortino, N., Hakun, J., . . . O'Brien, C. P. (2008). Prelude to passion: Limbic activation by "unseen" drug and sexual cues. *PLoS ONE, 3*, e1506. doi: 10.1371/journal.pone.0001506

Custers, R., & Aarts, H. (2010). The unconscious will: How the pursuit of goals operates outside of conscious awareness. *Science, 329*, 47–50. doi:10.1126/science.1188595

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*, 627–668. doi:10.1037/0033-2909.125.6.627

Dehaene, S., Changeux, J.-P., Naccache, L., Sackur, J., & Sergent, C. (2006). Conscious, preconscious, and subliminal processing: A testable taxonomy. *Trends in Cognitive Sciences, 10*, 204–211. doi:10.1016/j.tics.2006.03.007

Delgado, M. R. (2007). Reward-related responses in the human striatum. *Annals of the New York Academy of Sciences, 1104*, 70–88. doi:10.1196/annals.1390.002

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109–132. doi:10.1146/annurev.psych.53.100901.135153

Feather, N. T. (Ed.). (1982). *Expectations and actions: Expectancy-value models in psychology*. Hillsdale, NJ: Erlbaum.

Gendolla, G. H. E., Wright, R. A., & Richter, M. (2011). Effort intensity: Some insights from the cardiovascular system. In R. Ryan (Ed.), *The Oxford handbook of motivation* (pp. 420–440). New York, NY: Oxford University Press.

Gollwitzer, P. M. (1990). Action phases and mind-sets. In E. T. Higgins & R. M. Sorrentino (Eds.), *Handbook of motivation and cognition* (Vol. 2, pp. 53–92). New York, NY: Guilford.

Haber, S. N., & Knutson, B. (2009). The reward circuit: Linking primate anatomy and human imaging. *Neuropsychopharmacology, 35*, 4–26.

Hassin, R. R., Bargh, J. A., Engell, A. D., & McCulloch, K. C. (2009). Implicit working memory. *Consciousness and Cognition, 18*, 665–678. doi:10.1016/j.concog.2009.04.003

Hull, C. L. (1943). *Principles of behavior*. New York, NY: Appleton-Century-Crofts.

Knutson, B., Wimmer, G. E., Kuhnen, C. M., & Winkielman, P. (2008). Nucleus accumbens activation mediates the influence of reward cues on financial risk taking. *NeuroReport, 19*, 509–513. doi:10.1097/WNR.0b013e3282f85c01

Kool, W., McGuire, J. T., Rosen, Z. B., & Botvinick, M. M. (2010). Decision making and the avoidance of cognitive demand. *Journal of Experimental Psychology: General, 139*, 665–682. doi:10.1037/a0020198

Koole, S. L., & Jostmann, N. B. (2004). Getting a grip on your feelings: Effects of action orientation and external demands on intuitive affect regulation. *Journal of Personality and Social Psychology, 87*, 974–990. doi:10.1037/0022-3514.87.6.974

Kuhl, J. (1984). Volitional aspects of achievement motivation and learned helplessness: Toward a comprehensive theory of action control. In B. Maher & W. Maher (Eds.), *Progress in experimental personality research* (Vol. 13, pp. 99–171). New York, NY: Academic Press.

LeDoux, J. (1996). *The emotional brain: The mysterious underpinnings of emotional life.* New York, NY: Simon & Schuster.

Merker, B. (2007). Consciousness without a cerebral cortex: A challenge for neuroscience and medicine. *Behavioral and Brain Sciences, 30*, 63–134. doi:10.1017/S0140525X07000891

Murayama, K., Matsumoto, M., Izuma, K., & Matsumoto, K. (2010). Neural basis of the undermining effect of monetary reward on intrinsic motivation. *Proceedings of the National Academy of Sciences, USA, 107*, 20911–20916. doi:10.1073/pnas.1013305107

Olivers, C. N. L., & Nieuwenhuis, S. (2006). The beneficial effects of additional task load, positive affect, and instruction on the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 364–379. doi:10.1037/0096-1523.32.2.364

Olson, M. A., & Fazio, R. H. (2001). Implicit attitude formation through classical conditioning. *Psychological Science, 12*, 413–417. doi:10.1111/1467-9280.00376

Pessiglione, M., Schmidt, L., Draganski, B., Kalisch, R., Lau, H., Dolan, R. J., & Frith, C. D. (2007). How the brain translates money into force: A neuroimaging study of subliminal motivation. *Science, 316*, 904–906. doi:10.1126/science.1140459

Phillips, P. E., Walton, M. E., & Jhou, T. J. (2007). Calculating utility: Preclinical evidence for cost-benefit analysis by mesolimbic dopamine. *Psychopharmacology, 191*, 483–495.

Richter, M. (2010). Pay attention to your manipulation checks! Reward impact on cardiac reactivity is moderated by task context. *Biological Psychology, 84*, 279–289. doi:10.1016/j.biopsycho.2010.02.014

Schooler, J. W. (2002). Re-representing consciousness: Dissociations between experience and meta-consciousness. *Trends in Cognitive Sciences, 6*, 339–344. doi:16/S1364-6613(02)01949-6

Wallis, J. D., & Kennerley, S. W. (2010). Heterogeneous reward signals in prefrontal cortex. *Current Opinion in Neurobiology, 20*, 191–198. doi:10.1016/j.conb.2010.02.009

Zedelius, C. M., Veling, H., & Aarts, H. (2011). Boosting or choking—How conscious and unconscious reward processing modulate the active maintenance of goal-relevant information. *Consciousness and Cognition, 20*, 355–362. doi:10.1016/j.concog.2010.05.001

Current Directions in Psychological Science

http://cdp.sagepub.com/

Erratum

Current Directions in Psychological Science 2012 21: 273
DOI: 10.1177/0963721412452845

ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Erratum

Current Directions in Psychological Science
21(4) 273

DOI: 10.1177/0963721412452845
http://cdps.sagepub.com
SAGE

Bijleveld, E., Custers, R., & Aarts, H. (2012). Human reward pursuit: From rudimentary to higher-level functions. *Current Directions in Psychological Science, 21*, 194–199.

Table 1 of the above article had a table heading that read "Required intensity of effort." It should have read "Required intensity of reward." The corrected Table 1 is printed below.

Table 1. Framework for Understanding Human Reward Processing and Its Effects on Task Performance

Type of reward processing	Required intensity of reward	Phenomenological experience of reward	Functionality and potentially involved brain structures	Behavioral outcomes
Initial	Low	Reward is not consciously experienced	Rudimentary: VS and its immediate outputs	Facilitation of performance
Full	High	Reward is consciously experienced	Rudimentary: VS and its immediate outputs; higher-level: MPFC, ACC, DLPFC	Facilitation of performance; strategic decision making and reflections on rewards

Note: VS = ventral striatum; MPFC = medial prefrontal cortex; ACC = anterior cingulate cortex; DLPFC = dorsolateral prefrontal cortex.