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Madan, C. R. (2017). Motivated Cognition: Effects of Reward, Emotion, and Other Motivational Factors Across a Variety of Cognitive Domains. *Collabra: Psychology,* 3(1): 24. DOI: https://doi.org/10.1525/collabra.111

PERSPECTIVE/OPINION

Motivated Cognition: Effects of Reward, Emotion, and Other Motivational Factors Across a Variety of Cognitive Domains

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A growing body of literature has demonstrated that motivation influences cognitive processing. The breadth of these effects is extensive and span influences of reward, emotion, and other motivational processes across all cognitive domains. As examples, this scope includes studies of emotional memory, value-based attentional capture, emotion effects on semantic processing, reward-related biases in decision making, and the role of approach/avoidance motivation on cognitive scope. Additionally, other less common forms of motivation–cognition interactions, such as self-referential and motoric processing can also be considered instances of motivated cognition. Here I outline some of the evidence indicating the generality and pervasiveness of these motivation influences on cognition, and introduce the associated 'research nexus' at *Collabra: Psychology*.

Keywords: motivation; cognitive psychology; goal-oriented behavior; emotion; reward

Considering the scope of motivated cognition

Generally, motivation can be defined as goal-oriented behavior, often with the goal of maximizing pleasure and minimizing pain (Berridge, 2004; Hassin et al., 2009; Hughes & Zaki, 2015; Madan, 2013; see Kleinginna Jr. & Kleinginna, 1981, for an overview of different researchers' definitions). As topics within the scope of of 'motivated cognition' often are considered more directly, I will first briefly describe a facet of this research area as an example. It is well known that emotion can influence how we attend to the world around us, such as in studies of the weapon-focus effect (Fawcett et al., 2013; Loftus et al., 1987; Steblay, 1992) and flash-bulb memories (Bohn & Berntsen, 2007; Brown & Kulik, 1977; Hirst et al., 2009). These findings lay the foundation for theories such as the attentional narrowing hypothesis (Easterbrook, 1959) and arousal-biased competition hypothesis (Mather & Sutherland, 2011) (though there is also evidence of a role of distinctiveness; Dewhurst & Parry, 2000; Pickel, 1998; Talmi & Moscovitch, 2004). However, a broader view would be to consider emotion-cognition interactions as segment of a more extensive literature on goal-oriented behavior and motivation, a domain-general perspective on the influences of motivational factors on cognition. For instance, rewards have been shown to similarly bias attention allocation, even when using considerably different experimental procedures (Anderson, 2013, 2016a; Awh et al., 2012). This broader view is in-line with recent perspectives on the influence of motivation on cognition (Botvinick & Braver, 2015; Braver et al., 2014; Chiew & Braver, 2011; Cunningham & Brosch, 2012; Gable & Harmon-Jones, 2010; Harmon-Jones et al., 2012a, b; Hughes & Zaki, 2015; Madan, 2013; Murty & Dickerson, 2017; Northoff & Hayes, 2011).

Emotion and reward

Considered broadly, emotion and reward processing bare many commonalities in their influence on cognition. For instance, both can preferentially capture attention (Aarts et al., 2008; Anderson, 2005, 2013, 2016a; Arnell et al., 2007; Bocanegra & Zeelenberg, 2009; MacKay et al., 2004; Raymond & O'Brien, 2009; Strange et al., 2003) and lead to impairments in processing of peripheral information information (Anderson, 2013; Anderson & Yantis, 2013; Bucker & Theeuwes, 2017; Dolcos et al., 2011; Kensinger et al., 2007; Talmi, 2013). Moreover, even when allowing for sufficient allocation of attention, both emotion and reward can impair memory for intentionally encoded contextual information (Madan et al., 2012a, 2017a, 2012b; Zimmerman & Kelley, 2010). Emotional arousal is often thought to be the principle dimension (as opposed to valence) (Bradley et al., 2001; Christianson, 1992; Mather & Sutherland, 2011; Talmi, 2013), and there is increasing evidence that 'salience,' an analogous dimension, is important to reward processing (Castel et al., 2016; Kahneman et al., 1993; Litt et al., 2011; Ludvig et al., 2014; Madan et al., 2014; Madan & Spetch, 2012; Tsetsos et al., 2012; Wispinski et al., 2017; Zeigenfuse et al.,

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2014). Providing more mechanistic similarities between emotion and reward, both have been shown to relate to autonomic function (e.g., pupil dilation and heart rate) (Abercrombie et al., 2008; Ariel & Castel, 2014; Bijleveld et al., 2009; Bradley et al., 2001, 2008; Buchanan et al., 2006; Fowles et al., 1982; Hochman & Yechiam, 2011; Manohar et al., 2017). Additionally, there are age-related differences in both emotion and reward processing, where older adults are more biased towards positively valenced and gain experiences, than negative/loss experiences (Barber et al., 2016; Carstensen & Mikels, 2005; Castel et al., 2016; Mikels & Reed, 2009; Mikels et al., 2016; Pachur et al., 2017; Samanez Larkin et al., 2007). This parallel may be somewhat exaggerated, however, as emotion and reward are sometimes experimentally operationalized similarly, and thus would produce similar effects in behavior. Specifically, both emotion and reward are often studied using shocks (Bauch et al., 2014; Bisby & Burgess, 2014; Dunsmoor et al., 2015; Jensen et al., 2007; Murty et al., 2012, 2011; Pessoa, 2009; Phelps & LeDoux, 2005; Redondo et al., 2014; Schmidt et al., 2015; Wang et al., 2013; Weiner & Walker, 1966), food (Beaver et al., 2006; de Water et al., 2017; Isen & Geva, 1987; LaBar et al., 2001; Polanía et al., 2015; Talmi et al., 2013; Wadlinger & Isaacowitz, 2006), emotional face pictures (Bradley et al., 1997; Lin et al., 2012; Tsukiura & Cabeza, 2008; Vrijsen et al., 2013; Vuilleumier & Schwartz, 2001; Woud et al., 2013), or erotic/sexual pictures (Attard-Johnson & Bindemann, 2017; Bradley et al., 2001; Ferrey et al., 2012; Hamann et al., 2004; Iigaya et al., 2016; Most et al., 2007; Sescousse et al., 2013a, 2010). As such, it would be expected that both emotion and reward demonstrate similar effects on cognition, as they can be studied using nearly identical experimental designs.

Despite these similarities between how emotion- and reward- processing are studied, there are also a variety of differences. Providing evidence of distinct roles of emotion and reward, when varied within the same experiment, the two factors can produce additive effects (Shigemune et al., 2010) or have otherwise been shown to separably influence behavior (Bennion et al., 2016; Bowen & Spaniol, 2017; Chiew & Braver, 2014; Isen et al., 1988; Mather & Schoeke, 2011; Otto et al., 2016). Emotion is often studied using stimuli that are inherently emotional–words, pictures, sounds, or videos that themselves semantically connote emotional content (Kensinger et al., 2007; MacKay et al., 2004; Madan et al., 2012a, 2017c; Shafer et al., 2012; Shigemune et al., 2010; Strange et al., 2003). In contrast, reward is often implemented as an instructional cue or feedback outcome (Adcock et al., 2006; Castel et al., 2002; Mason et al., 2017; Murayama & Kitagami, 2014; Murty et al., 2012; Pessiglione et al., 2007; Shigemune et al., 2010; Shohamy & Adcock, 2010; Spaniol et al., 2013). Though this dissociation is often true, there are exceptions—such as emotion studies where emotionally neutral stimuli are associated with emotional responses through a similar training task (Mather & Knight, 2008), emotional stimuli are presented just prior to the stimuli of interest (Qiao-Tasserit et al., 2017; Xie & Zhang, 2016, 2017), or with emotional stimuli are used as a feedback signal (Finn & Roediger, 2011). Similarly, in reward studies, items can be 'trained' to have a reward value before the task-of-interest (Anderson, 2013; Madan et al., 2012b; Madan & Spetch, 2012; Raymond & O'Brien, 2009), While a comparison of instructed vs. learned rewards has not been studied directly, there is a parallel with the literature on decisions from uncertainty. Specifically, studies have found differences in people's risk preferences when decisions are made based on explicitly described odds and outcomes ('decisions from description'), relative to those based on learned experiences ('decisions from experience') (Barron & Erev, 2003; Camilleri & Newell, 2011; Hertwig & Erev, 2009; Jessup et al., 2008; Ludvig et al., 2014; Ludvig & Spetch, 2011; Madan et al., 2017b; Mata et al., 2011; Yoon et al., 2017) (also see Braem et al., 2017).

A particularly interesting consideration when comparing the motivational characteristics of emotion and reward processing is the role of valence—emotional experiences can be either positive or negative (i.e., pleasant or unpleasant), rewards can be either gains or losses (though these could be gains and losses *relative* to expectations, based on either the average outcome or prior experiences). Within their respective literatures, when only one valence is included, it is often the case that only negatively valenced emotional effects are studied, whereas only gain reward outcomes are included. Given the growing literatures demonstrating valence effects in both emotion (Bowen et al., in press; Fredrickson & Branigan, 2005; Gasper & Clore, 2002; Kensinger & Corkin, 2004; Taylor, 1991; Xie & Zhang, 2016) and reward (Jensen et al., 2007; Kahneman & Tversky, 1984; Lejarraga & Hertwig, 2016; Litt et al., 2011; Ludvig et al., 2014; Samanez Larkin et al., 2007) effects on cognition, it is important to be aware of this limitation when only one valence is included in an experimental design. Motivation more generally can also be valenced, as a continuum of approach vs. avoidance motivation (Braver et al., 2014; Gable & Harmon-Jones, 2010; Kaplan et al., 2012; Murty et al., 2011; Vrijsen et al., 2013; Woud et al., 2013). Critically, this valence dimension of motivation does not directly map onto the valence of emotions or rewards. For instance, both anger and determination can be considered an approach motivation, while fear corresponds with avoidance (Carver & Harmon-Jones, 2009; Harmon-Jones et al., 2011, 2013).

Within the domain of rewards, there are a multitude of forms that a reward can take. Monetary rewards are the most common type of incentive; the use of shocks, and thus the avoidance of punishment, is also used often. However, it is important to consider that other rewards may yield different effects on cognition. Rather than examining these different rewards in isolation, a subset of studies have taken the approach of comparing their effects, or putting them in conflict. For instance, some studies have examined the motivational effects of monetary reward alongside another reward-related stimuli type, such as an appetitive juice reinforcer (Beck et al., 2010; Krug & Braver, 2014; Yee et al., 2016) or pain induction (Delgado et al., 2011; Murty et al., 2011; Read & Loewenstein, 1999; Talmi et al., 2009; Vlaev et al., 2014, 2009; Zhou & Gao, 2008). Other studies use what could

be broadly considered a social reward, such as smiling face (Lin et al., 2012), indicator of social status (Izuma et al., 2008; Zink et al., 2008), or erotic pictures (Iigaya et al., 2016; Sescousse et al., 2013a, b). Additionally, some studies have investigated the motivational role of monetary feedback relative to verbal praise (e.g., "Very well done!", "Great job!") (Albrecht et al., 2014; Deci, 1971, 1972; Williams & DeSteno, 2008) though comparisons between reward categories have also been studied (Gross et al., 2014; Roper & Vecera, 2016; Rosati & Hare, 2016).

Other motivational factors

The extent of motivation on cognition is not constrained to emotion and reward. From the current perspective, other factors that lead to selective prioritization of cognitive processes also include the influences of motoric and self-referential processing.

While it is clear that emotion- and reward-related information are preferentially processed and modulate cognitive processes, it is likely less obvious that this may also be true for motor movements. It can be argued that the entire purpose of the brain is to produce movement–the 'motor chauvinist' view (Wolpert et al., 2001), a particularly strong perspective within the scope of embodied cognition. While this is an extreme stance, there is evidence that motor processes–such as enacted actions, gestures, and exercise–are beneficial to cognitive processes (Madan & Singhal, 2012b, c). Here motoric processing can be viewed as a type of goal-oriented behavior and in alignment with an approach motivation. A number of more subtle manipulations have demonstrated that cognitive processes can cue motor representations and influence motor movements, and that motor representations can modulate performance in cognitive tasks. For instance, in a simple task involving reaching for blocks and picking them up, grasping kinematics are influenced by text printed on the blocks, such as 'long' or 'short', as well as by words representing relative large or small objects (e.g., 'apple' or 'grape') (Gentilucci et al., 2000; Gentilucci & Gangitano, 1998; Glover et al., 2004). In the opposite direction, motor congruency of objects and pictures of objects, such as the side of a handle can influence response time and other measures in cognitive tasks (Brouillet et al., 2015; Buccino et al., 2009; Chum et al., 2007; Handy et al., 2003; Marino et al., 2014; Oakes & Onyper, 2017; Tucker & Ellis, 1998). Even more broadly, words and pictures representing objects varying in functionality can influence attention, semantic processing, and memory (Hauk et al., 2004; Madan et al., 2016; Madan & Singhal, 2012a; Montefinese et al., 2013; Pulvermüller, 2005; Shebani & Pulvermüller, 2013; Tousignant & Pexman, 2012; Witt et al., 2010). These effects are particularly interesting given debates regarding the role of evoked motor functionality information in response to pictures and words, as opposed to physical objects (Skiba & Snow, 2016; Snow et al., 2011, 2014; Squires et al., 2016; Wilson & Golonka, 2013). Taken together, functional objects can also capture attention, interfere with concurrent processes, and elicit approach motivation responses in ways that share commonalities with emotion and reward processes.

Self-referential processing can also be considered subset of motivated cognition. Unlike emotion-, reward-, and motor-processing, which are properties of the stimuli or how they are attended to, self-relevance is a property of the stimuli's congruence with the participant. Often self relevance is studied using words that relate to the participant, such as personality trait adjectives (e.g., 'curious', 'stingy') (Fujiwara et al., 2008; Gutchess et al., 2007; Rogers et al., 1977; Symons & Johnson, 1997; Wentura et al., 2000) or autobiographical words (e.g., hometown, high school) (Gray et al., 2004; Yamawaki et al., in press). In other studies, self relevance is experimentally assigned, such as using sentences that refer to either 'you' or another person (Fields & Kuperberg, 2012) or by assigning the ownership of presented objects to the participant or 'other' (Cunningham et al., 2008; DeScioli et al., 2015; Truong et al., 2016, 2017). (See Northoff et al., 2006, for a review.) In some ways these two approaches align with the distinction outlined with emotion and reward studies, where the property can either be congruence between self and the stimuli (personality trait adjectives) or implemented as part of the task instructions (assigned ownership). Similar to both emotion and reward, self-referential stimuli can also elicit attentional capture (Alexopoulos et al., 2012; Arnell et al., 1999; Bargh, 1982; Tacikowski & Nowicka, 2010). This is particularly well exemplified by the 'cocktail party effect,' where people are able to focus on a particular conversation amidst a variety of concurrent sounds, but can readily and automatically attend to a different conversation if their name is mentioned (Conway et al., 2001; Moray, 1959; Wood & Cowan, 1995). Nonetheless, prior work has demonstrated that the effects of self-referential processing can be dissociated from reward (Northoff & Hayes, 2011) and emotion (Fields & Kuperberg, 2012, 2016; Grilli et al., in press; Kensinger & Gutchess, 2016) processes. In some studies, social cues have been used analogously to rewards, such as trial feedback (Anderson, 2016b, 2017) or in association with other stimuli, such as faces, as a signal for importance (Hargis & Castel, in press). More broadly, it has been shown that people exhibit a bias to pay more attention to pictures of their enemies and incidentally remembered more information about their enemies (Li et al., in press). Along this social dimension, people have also been found to have an 'own-race bias,' where people remembered faces of individuals of the same racial background better than those of another race (DeLozier & Rhodes, 2015). To some degree, cultural differences in attention and memory may also be influenced by collective self-referential effects, where cultural background leads to inter-individual differences in how contextual information is prioritized and attended to (Lin & Han, 2009; Masuda & Nisbett, 2001; Millar et al., 2013). In sum, studies of self-referential processing have demonstrated that we have a bias towards stimuli that correspond to ownership or our identity. The design of these self-referential studies share many commonalities with emotion and reward, in operationalization and in their observed influence on

cognitive processing, providing additional support for a domain-general view of motivation-cognition interactions and goal-oriented behavior.

Importantly, the factors discussed thus far are not intended to be an exhaustive list of motivational factors known to influence cognitive processes. Beyond motoric and self-referential processing, numerous other distinct factors can also be construed as being instances of motivated cognition. For instance, people have also been shown to be able to prioritize memory for words representing allergens and medication side-effects that were instructed to be more severe (Friedman et al., 2015; Middlebrooks et al., 2016), similar to prior prioritization studies that used reward values (Castel et al., 2002). It has also been shown in a number of studies that words processed with their survival relevance in-mind are remembered better than in the context of several other instructions (Kang et al., 2008; Nairne & Pandeirada, 2008; Nairne et al., 2008, 2007; Soderstrom & McCabe, 2011; Weinstein et al., 2008). Food stimuli, briefly discussed as being used in both studies of emotion and reward, have also been studied in their own right as a means of probing motivational processes, particularly with interest in time-varying differences in motivation through satiation (Radel & Clément-Guillotin, 2012; Skrynka & Vincent, 2017; Wagner et al., 2012) and other measures of physiological homeostasis (Padulo et al., 2017; Tiedemann et al., 2017).

Conclusion

In sum, it is clear that motivation can guide cognition. These motivational factors–including, but not limited to, emotion and reward processes—modulate behavior across a variety of cognitive domains, often resulting in the prioritized processing of some stimuli. Nonetheless, many of the nuances of these motivation-cognition interactions have yet to be sufficiently understood. One general question is the specificity of these different motivational factors in modulating cognition. For instance, how much of what is known about the effects of emotion on memory can be considered domain-general characteristics of motivational salience and valence, rather than domain-specific effects of emotion? Along these lines, it is clear that emotion and reward, among other factors, necessitate unique research approaches (Gershman & Daw, 2017; Mattek et al., 2017; Panksepp et al., 2017; Schultz, 2015), but it is an open question where the boundaries lie between these different facets of motivation. More broadly, while the position of this perspective paper is that these factors can be summarized as 'motivational factors' despite a variety of differences–this is far from conclusive. It is well-established that there are different mechanisms and brain structures associated with these factors, but there nonetheless is a substantiative number of commonalities between them as well. My hope is that this perspective article will provide a new lens evaluate existing research and help to inspire further research to better understand how these constructs relate to each other.

Associated with this Perspective article is a new 'research nexus' at *Collabra: Psychology*, focused on fostering future research into motivated cognition. Briefly, a research nexus is similar to a special issue/collection in a journal, but in addition to invited authors and articles, the nexus will remain open for submissions, in order to create a growing collection of articles around the topic. In this newly launched research nexus, we welcome research into any individual motivational factor and their influence on cognition, as well as studies that compare or otherwise investigate the interactions between different motivational factors. While the perspective outlined here is suggestive that nearly all of cognition is motivated, manuscripts submitted to this research nexus must explicitly discuss how their research question and findings inform our understanding of the influence of motivation on cognition. Studies comparing different motivational factors are of particular interest, as this work is ultimately necessary to address open questions regarding the overlap or diversity in how different factors influence cognition.

Acknowledgements

I would like to thank Ryan Daley, Elizabeth, Kensinger, John Ksander, and Debbie Yee for feedback on an earlier draft of the manuscript.

Competing Interests

Christopher Madan is an Editor at Collabra: Psychology. He was not involved in the peer review of the article.

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Peer review comments
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How to cite this article: Madan, C. R. (2017). Motivated Cognition: Effects of Reward, Emotion, and Other Motivational Factors Across a Variety of Cognitive Domains. *Collabra: Psychology,* 3(1): 24. DOI: https://doi.org/10.1525/collabra.111

Senior Editor: Rolf Zwaan

Part of Research Nexus: Motivated cognition: Effects of reward, emotion, and motivational processes across a variety of cognitive domains

Submitted: 08 September 2017 **Accepted:** 29 September 2017 **Published:** 19 October 2017

UNIVERSITY of CALIFORNIA PRESS | Collabra

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