The drive to control : how affect and motivation regulate cognitive control

Steenbergen, H. van

Citation

Steenbergen, H. van. (2012, January 17). *The drive to control : how affect and motivation regulate cognitive control*. Retrieved from https://hdl.handle.net/1887/18365

10

Discussion

"To every thing there is a season, and a time to every purpose under the heaven: A time to weep, and a time to laugh; a time to mourn, and a time to dance."

Ecclesiastes 3: 1 and 4, King James translation

The studies described in this thesis aimed to investigate how affect and motivation impact cognitive control. As summarized in Table 1 of Chapter 1, six out of the eight empirical studies found support for indirect effects on cognitive control, as measured with sequential trial-to-trial adaptations in cognitive control tasks. Only two studies resulted in evidence for a direct modulation of cognitive control. The implications of these results are discussed below. This chapter begins with a discussion of the sparse evidence found in our experimental work for direct effects of emotion on cognitive control, and of the question how the effects observed relate to earlier theorizing and empirical work in the field. This is followed by a summary of the abundant evidence for indirect effects on cognitive control, and a discussion of their implications. Next, on the basis of the neuroimaging data obtained, a theory about the neural mechanism that might be responsible for the indirect effects on behavior is proposed. A comment on the adaptive value of emotions concludes this chapter.

Direct effects of emotions

One important aim of this thesis was to investigate how emotions, as manipulated by short-term affect inductions, may directly improve or impair cognitive control. In Chapters 2 and 3 we reported that we did not find any evidence for a direct effect of positive and negative feedback on cognitive control in a flanker task. That is, contrary to existing theories (Fredrickson, 2001; Schwarz, 1990), we did not observe valence effects on attentional scope. The role of arousal was further investigated in the study described in Chapter 4. Here, we showed that in comparison to neutral pictures, negative high-arousing pictures with threatening content led to improved subsequent anti-saccade task performance, whereas positive high-arousing pictures did not produce this effect. Importantly, pupil dilation data confirmed that both positive and negative pictures successfully induced a state of increased sympathetic activation, so that the null-effect for positive pictures could not be attributed to an unsuccessful manipulation of emotional arousal.

Taken together, these studies using short-term affect manipulations confirm Derryberry and Tucker's (1994) interpretation of Easterbrook's (1959) hypothesis that high-arousal negative emotional states improve selective attention (Chapter 4). On the other hand, negative valence alone, as manipulated by feedback (Chapters 2 and 3), appears insufficient to modulate cognitive control directly, and hence contradicts theories by Schwarz (1990) and Fredrickson (2001) predicting valence-only effects. Interestingly, we did not observe that positive emotions led to reduced selective attention – even when these emotions induced physiological arousal – which supported neither valence-only theories (Fredrickson, 2001; Schwarz, 1990), nor the theory that positive arousal causes attentional broadening (Derryberry & Tucker, 1994).

It is interesting to note that recent findings from other studies also have consequences for earlier theorizing. Experimental work by Gable and Harmon-Jones (for a review, see Gable & Harmon-Jones, 2010b), has shown that positive emotions broaden attention only when they are accompanied by a low approach motivation (e.g., contentment), but that they will narrow attention when accompanied by a high approach motivation (e.g., desire). Similar effects have been observed for negative emotions: sadness, a negative emotion with low withdrawal motivation, broadens attention, whereas disgust, a negative emotion with high withdrawal motivation, narrows attention. Taken collectively these findings indicate that it is the motivational intensity as such, i.e., the strength of the drive to approach or avoid an object or goal, that determines one's attentional scope. Hence, as described by the motivational dimensional model (Gable & Harmon-Jones, 2010b) the degree of motivational intensity can be orthogonal to the dimension of motivational direction or affective valence. However, as motivationally intense states have been associated with greater sympathetic nervous system activation, they may often be reflected in arousal effects. Nonetheless, as has been carefully pointed out in earlier work (e.g., Kahneman, 1973), arousal is determined by several factors and does not necessarily constitute an index of motivational intensity. For example, amusement is a positive high-activating emotion, but unlikely to urge one to approach something in the environment (Gable & Harmon-Jones, 2010b). Indeed, our findings do not support the notion either that high-arousal positive emotions by themselves narrow attention.

If motivational intensity is indeed a better predictor of attentional narrowing than arousal or valence, the core affect model we used as a heuristic in our research needs to be replaced. Future studies, then, should make use of new dimensional frameworks that are better able to capture the fundamental affective processes driving focused attention, preferably those that have been shown to have a sound empirical basis. A recent study by Fontaine, Scherer, Roesch, & Ellsworth (2007) provides an excellent example of such an approach. These authors have shown that, besides the dimensions of valence and arousal, at least two other emotional dimensions can be identified, namely 'unpredictability' and 'potency / control'. Together, these four dimensions were shown to provide a very adequate description of emotional states across three different languages. The ‘potency / control’ factor may be of particular relevance for effects on attentional scope. This factor is characterized by action tendencies, such as wanting to take an initiative versus being apathetic. The description of this dimension actually comes close to the motivational intensity factor proposed by Harmon-Jones and Gable (2010b). Interestingly, this factor also captures parasympathetic forms of activation, and it might be argued that these effects are more important for motivation than the sympathetic activation usually associated with arousal (Fontaine et al., 2007).

The use of stimulus sets such as those validated by Fontaine et al. (2007) may also overcome another major shortcoming of previous studies. Some of the studies by Harmon-Jones and Gable apparently involved an ad-hoc inclusion of stimulus material, and it might be argued that the level of motivational intensity induced by these stimuli depends more on the introspective qualities of the researcher than on objectively measurable standards (cf. Friedman & Forster, 2011). For example, Gable & Harmon-Jones (2008) attribute different attentional focus effects induced by film clips showing scrumptious desserts versus clips presenting cats in humorous situations to differences in approach motivation. However, it has been argued that these obviously cute animals may induce a similar drive to approach them and hug, pet, or play with them, as the drive induced by the desserts to approach and eat them (as discussed by Friedman & Forster, 2011). For this reason, future studies should provide proper independent indices of motivational intensity. This is also important to ensure that the motivation intensity theory is falsifiable, and to prevent circular argumentation (e.g., observation: a stimulus narrows the attentional scope; conclusion: it apparently had motivational intensity).

Direct effects of mood?

In contrast to theories predicting that emotions and moods do not differ in the way they impact behavior (Derryberry & Tucker, 1994; Fredrickson, 2001; Schwarz, 1990), the Mood-Behavior-Model (MBM; Gendolla, 2000) states that moods do not have direct effects on cognitive effort. According to the MBM, moods, unlike emotions, are usually not related to any particular goal or object. Because of this, moods may lack the specific action tendencies and stable motivational implications that emotions have. Accordingly, mood may not have a direct effect on cognitive control, but may affect behavior in a context-sensitive, indirect way only. That is, the recruitment of effort depends on how a particular situational demand is evaluated, and affect regulates this appraisal. Our data are entirely consistent with this suggestion, as mood was found to have an indirect effect (see next section), but lacked a direct effect on cognitive control. This was repeatedly shown in our experiments. First, using a standard mood induction procedure that combined imagination with music, we found (Chapter 5) that neither mood valence nor arousal directly impacted cognitive control as measured in a flanker and Stroop task. In addition, we did not observe an interactive effect of valence and arousal, as would have been predicted by Derryberry and Tucker's framework. Similarly, we found (Chapter 6) that sustained positive affect induced by funny cartoons did not directly reduce cognitive control. Finally, depressive symptoms after ATD, a pharmacological manipulation known to induce depressed mood in this population of remitted depressive patients, were not associated with cognitive control deficits or improvements either, as described in Chapter 7.

Altogether, our null findings regarding direct mood effects suggest that the influence of mood on sustained effortful processing as measured in standard cognitive control tasks is limited. Thus, although under certain conditions (cf. Forgas, 1995) moods may have an effect on the way visual stimuli are judged on global versus local features, as measured in Navon tasks (e.g., Gasper & Clore, 2002; Gasper, 2004), this effect might be unrelated to effects on mental effort and cognitive control. This conclusion is also supported by studies showing that moods do not have direct effects on effort-related cardiovascular measures. Moreover, cumulative findings from other labs also show the lack of impact of mood states on direct measures of cognitive control (e.g., Finucane, Whiteman, & Power, 2010; Martin & Kerns, 2011; but see Mitchell & Phillips, 2007; Rowe et al., 2007).

It is important to note that affective states may still impair cognitive control via other, more cognitive, mechanisms. As has long been recognized, processing the emotion-inducing stimulus or problem and the elaborated task-irrelevant thoughts triggered by this stimulus, may deplete resources needed for cognitive control (Mitchell & Phillips, 2007; Schwarz, 1990). This effect may also explain the observation in Chapter 9 concerning passionate lovers who had only recently fallen in love. Participants reporting very high levels of passionate love showed worse performance on a Stroop and flanker task than participants reporting lower levels of infatuation. The extreme, almost obsessive, attention for the other characteristic for these high levels of infatuation may simply have depleted resources needed for cognitive control. However, mood scores in this study were not related to control impairment, which reinforces our conclusion that mood in itself seems not to have direct effects on cognitive control.

Indirect effects: a matter of valence

In contrast to the scant evidence for direct effects on cognitive control, our findings provide a great deal of support for indirect effects of emotional states on cognitive control. These effects occurred on trial-to-trial adaptation in cognitive control tasks involving a random presentation of compatible and incompatible trials. We found that conflict adaptation, the transient improvement of behavioral control after incompatible in comparison to compatible trials (Botvinick et al., 2001), was subject to affective regulation. We found that after incompatible trials, positive emotional states reduced and negative emotional states increased adaptation. These effects occurred for both short-term (Chapters 2 and 3) and long-term affect manipulations (Chapters 5, 6, and 7).

As shown in Chapter 2, short-term positive emotions were found to undo the adaptation triggered by previous conflict. This effect was observed in an arrow flanker task with monetary gain or loss as arbitrary feedback between trials. Unlike monetary loss, gain was shown to counteract conflict adaptation. This finding was replicated in the study described in Chapter 3. Consistent with the notion that effortful situations are aversive (Botvinick, 2007), our findings suggest that incompatible trials evoke a negative emotional state that, unless neutralized by a positive event such as a monetary reward, increases attentional focus. These data provide important initial evidence for the notion that affective valence may play a functional role in the transient adaptation of cognitive control, as measured in sequential effects of reaction time (Cabanac, 1992). They are in line with earlier findings that positive emotions can undo the aftereffects of stressful events (Fredrickson et al., 2000).

As described in the previous section, the MBM (Gendolla, 2000) expects that hedonic tone in sustained affective states predicts demand-driven adaptation. That is, conflict-driven adaptation of control may be improved by negative moods and reduced by positive moods. Several of our studies confirmed this prediction. In Chapter 5 this effect is illustrated in a study involving a flanker task, in which mood was induced using a standard induction procedure that manipulated not only affective valence but also arousal levels. We found that conflict-driven control was regulated only by affective valence. Using both funny and neutral cartoons, the study described in Chapter 6 replicated the effect that hedonic tone reduces conflict adaptation. Moreover, in the next study (Chapter 7) we demonstrated that depressive symptoms, induced by ATD in remitted depressive patients, were correlated with increased conflict adaptation. Taken together, these results strongly imply that hedonic tone regulates conflict adaptation: unpleasant states result in stronger adaptation, and pleasant states result in weaker adaptation.

According to the MBM, hedonic tone effects on demand-driven adaptation are impelled by the informational effect mood has on demand-related judgments. Thus, demands, as triggered by incompatible trials in our studies, are experienced as being more unpleasant and difficult when pleasure levels are low, and this evaluation may in turn drive improved effort mobilization. Although other studies have already found evidence for mood effects on subjective evaluation and effort-related cardiovascular measures (e.g., Gendolla, 2000; de Burgo & Gendolla, 2009), it remains an important aim for future research to integrate such measures with sequential analyses of performance on cognitive control tasks. Such an integrative approach may also enhance our understanding of situations in which adaptation to cognitive demands fails, for example with extremely difficult tasks. As illustrated in Chapter 8, conflict-adaptation effects are eliminated or reversed when task demands are extremely high. Pupil dilation also declined under high task demands, suggesting that demand-driven effort mobilization may drop under conditions of mental overload. How the assumed non-linearity between task demands and the mobilization of effort (Brehm & Self, 1989; Kahneman, 1973; Kukla, 1972) is related to conflict adaptation remains an important issue for further research. Future research into the question how the evaluation of demands influences physiological and neural responses associated with emotions, conflict monitoring, and effort may provide important insights into how these concepts are related.

Another topic for future research is the question how affective modulation of conflict adaptation is related to other measures of adaptation in cognitive psychology paradigms. For example, the conflict monitoring theory suggests that adaptation to demanding events has much in common with another type of adaptation, usually referred to as post-error adaptation (Botvinick et al., 2001): behavioral performance after an error is usually slower than after correct trials. Because post-error slowing may reflect cautious processing in response to the error, it has been taken as an index of cognitive control. Given that both errors and demands are generally thought to be registered in the brain as aversive events, affective regulation may involve a similar mechanism, probably involving the ACC (Botvinick, 2007). Indeed, several studies have shown that negative affect amplifies the neural processing of errors, although this increased neural activation does not always modulate post-error slowing (e.g., Hajcak, McDonald, & Simons, 2004; Luu et al., 2000). However, whether effects on post-error slowing reflect an adaptive increase of cognitive control, as conflict adaptation does, has been the subject of serious debate. On the contrary, recent evidence suggests that it is more likely that post-error slowing reflects attentional capture which hinders subsequent performance (Notebaert et al., 2009). Consistent with the suggestion that post-error adjustments are maladaptive, post-error slowing is associated with steeper increases in negative affect and reduced task-focused coping in response to stressors in daily life (Compton et al., 2011).

Recent findings suggest that demand-driven adaptation occurs at a local level. That is, conflict adaptation improves cognitive control in similar tasks, but impairs flexible switching to other task sets (e.g., Notebaert & Verguts, 2008). Since we found that increased pleasure levels left sustained cognitive control unaffected while at the same time reducing conflict adaptation, we might suppose that this effect is adaptive when people have to flexibly switch between other tasks. Although future research will have to address this speculation, a link between positive affect and shifts toward more flexible behavior has indeed been documented earlier (Dreisbach & Goschke, 2004). Interestingly, the combination of the ability to sustain long-term goals with flexibility in the short-term implementation and adjustment of goals has been seen as characteristic of good self-management and self-regulation skills (Baumeister, Heatherton, & Tice, 1994). Thus, positive affect, reduced conflict adaptation, and self-regulation skills may be closely related. Future studies could investigate this possibility. Experience-sampling methods may for instance be used to understand the association between demand-driven adaptation as measured in the lab on the one hand, and the daily-life impact of stressors on motivation, negative emotions, and behavioral control on the other (cf. Compton et al., 2011). Investigating emotion effects on behavior in driving simulators is another way to further investigate the practical applications of our findings (cf. Pecher, Lemercier, & Cellier, 2009).

Neural mechanisms

Direct and indirect effects on cognitive control may reflect different modulatory mechanisms in the prefrontal cortex. On the one hand, direct improvement of cognitive control by emotional or motivational states may directly modulate the more lateral parts of prefrontal cortex, probably via subcortical regions that code the motivational intensity of such states. However, we did not study the neural mechanism of direct effects in this research project, so that this is left for future researchers to investigate. On the other hand, indirect effects may involve not only the lateral but also the more medial parts of the PFC, including the ACC (cf. Figure 1). As summarized below, two of the studies in our project provided direct insight into this neural mechanism.

In Chapter 3 we described evidence for a reward-related inhibition of conflict-related fronto-central theta activity in a flanker task. This neural response observed in the EEG accompanied the reward-driven reduction of conflict adaptation observed in the behavioral data. Consistent with intracranial recordings, this effect in theta power is likely to originate from the ACC and the surrounding medial frontal wall (Cohen et al., 2008). As predicted by the conflict monitoring theory (Botvinick et al., 2001), these data suggest that the ACC represents a signal that indicates the need for more cognitive control. Inhibition of this signal by reward may have counteracted subsequent behavioral adaptation. It seems possible that the opposing influences of conflict and reward that we observed reflect

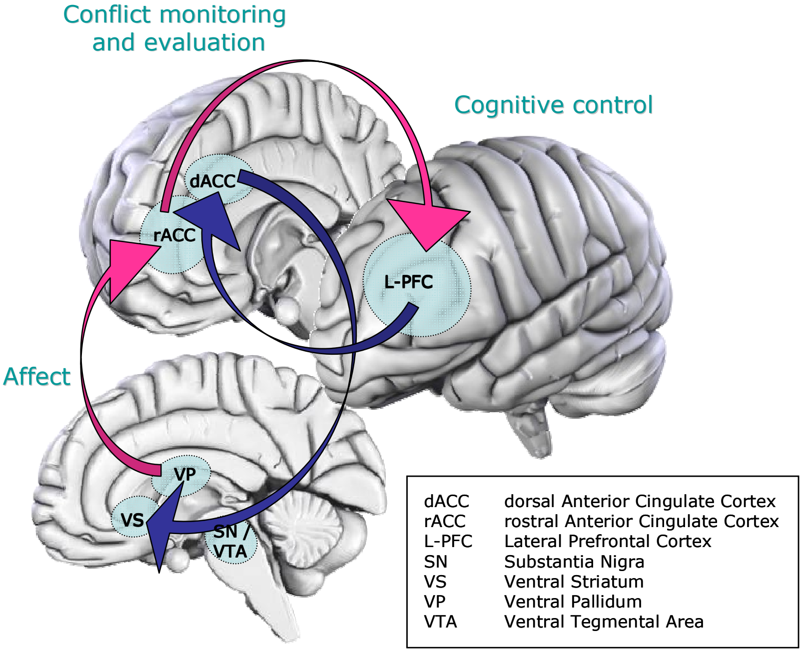

Figure 1. *Neural interactions involved in the indirect affective regulation of cognitive control*

some compensatory effects between conflict and reward at a neurotransmitter level. Consistent with this possibility, Holroyd and colleagues (Holroyd et al., 2008; Holroyd & Coles, 2002) have suggested that negative and positive events interact via dopamine modulation, which drives ACC activity. Conversely, there is also evidence suggesting that the ACC sends feedback signals down to the midbrain, via the striatum, to inhibits dopamine neurons (Frank, 2005).

The role of affective modulation in fronto-striatal interactions was investigated in an fMRI experiment, described in Chapter 6. As summarized in Figure 1, we found that funny cartoons increased neural activity usually associated with the processing of rewards, particularly in the ventral striatum (VS) and ventral pallidum (VP). Animal studies have shown that these basal ganglia (BG) regions include hedonic hotspots that may play a causal role in hedonic states. Reward-related BG activation, in turn, appeared to inhibit the neural response to conflict in a rostral ACC (rACC) region. Because activation in this region proved predictive of conflict-driven control improvement in the emotionally neutral context, it might play an important role in the affective appraisal of demands. Conflict monitoring activity in the dorsal ACC was co-modulated with this behavioral adaptation. Psycho-physiological interaction analyses confirmed functional interactions that were consistent with well-known anatomical connections looping between the VS and ACC through the VP (Alexander et al., 1986). On the basis of these findings we may hypothesize that the VP modulates rostral ACC activation, which in turn drives conflict-driven control. The resulting adaptation is subsequently registered in the dorsal ACC, which then sends feedback signals back to the VS. Within the striatum this feedback signal may become integrated with information concerning the current affective state. One might speculate that the reciprocal loops between the BG and ACC involve different neurotransmitter systems. More specifically, the feedback loop via the dACC and VS is likely to involve dopaminergic mediation, whereas the pleasure-related modulation in the VP and rACC may also involve endogenous opioid modulation (cf. Kringelbach & Berridge, 2009).

An important challenge for future research is to understand the different time scales at which reciprocal interactions between regions identified in this BG-PFC network occur. For example, neural regions coding the hedonic state of an organism may involve tonic signaling, whereas the more short-lived evaluation of incoming events and the associated emotions require faster signaling. Moreover, to ensure constant optimization of the internal homeostatic balance, these signals need to become integrated. However, given the temporal and spatial limitations of neuroimaging techniques a better understanding of these temporal dynamics requires other techniques. Studies using intracranial recordings may be an important tool to gain a better understanding of the temporal dynamics of these networks (cf. for instance Pourtois et al., 2010).

Because neither fMRI nor EEG are able to provide information about the particular neurotransmitters involved, the exact neurochemical basis of affective and motivational regulation requires further investigation. As indicated above, the neural circuitry indentified may involve dopamine and opioid modulation. Nonetheless, the exact role these systems play is not clear. Results from animal studies, for example, have suggested that dopamine is primarily related to motivational aspects, whereas the opioid system is involved in the hedonic aspects of emotions (Barbano & Cador, 2007; Kringelbach & Berridge, 2009). On the basis of this distinction one might propose that direct effects on cognitive control – possibly reflecting motivation – primarily involve dopamine, whereas indirect effects – sensitive to hedonic value – may reflect opioid modulation. To be sure, this is an oversimplified picture. Even within the same neural region or system different neurons have been shown to play different roles. For example, some midbrain dopamine neurons encode motivational values, while others encode motivational salience. These different sets of neurons are assumed to be connected with distinct brain networks, each with its own role in motivational control (Bromberg-Martin, Matsumoto, & Hikosaka, 2010). Similarly, pain and pleasure hotspots have been found in closely adjacent regions in the VS and VP, and release of endogenous μ-opioids is not limited to pleasant events, but can also be observed for painful stimuli. Moreover, the different time courses of neurotransmitter systems cannot be measured by the same technique, making it difficult to compare findings and pin down the actual mechanisms involved. Lastly, the opioid and dopamine systems do not work in isolation but interact with each other in complex, yet ill-understood ways (Leknes & Tracey, 2008).

Taken together, our neuroimaging findings are in line with predictions from the conflict-monitoring theory suggesting that the ACC plays an important role in the online evaluation of demands, which may subsequently drive extra cognitive control. Indirect effects of emotions on cognitive control probably involve the modulation of ACC activity via reward-related processing in the BG. However, the exact temporal dynamics and neurochemical basis of this neural circuitry needs further study.

Outlook: the adaptive role of emotions

One of our main conclusions in this dissertation is that hedonic tone helps to counteract the impact of adverse events on the brain and on our behavior. Consequently, positive emotions may help to reduce the impact of stressors and daily hassles, and play an adaptive role in our daily life. From this perspective we may say that our work contributes to the rapidly growing body of psychological literature stressing the beneficial effects of positive feelings. In line with predictions from the broaden-and-build theory (Fredrickson, 2001), numerous studies have shown that positive affect broadens people's thought-action repertoires, and allows individuals to build vital social, physical, and cognitive resources. This line of research follows numerous self-help books, courses, and magazines reflecting the current *Zeitgeist*, which assumes happiness is essential to human flourishing (cf. Seligman & Csikszentmihalyi, 2000).

However, it is important to note that one cannot say that positive affect is always a good thing, whereas negative affect is always a bad thing (Gruber, Mauss, & Tamir, 2011). On the contrary, emotions typically arise as an adaptive response to a particular situation, and as shown in this dissertation negative emotions may also play an important role in improving cognitive control. Thus, hedonic tone may become dysfunctional when a quick adaptation to a dangerous or difficult situation is needed, whereas it can be adaptive in safe situations in which such adaptation is useless. For example, a positive mood might actually impair driving behavior when a maneuver of a vehicle in front of you calls for enhanced control, whereas it may help you to stop being obsessed by a small but annoying computer error when you are on holiday. Likewise, a depressive episode may initially help to prioritize solving the problem that triggered it (Andrews & Thomson, 2009), but after the situation has taken a favorable turn sustained depression will become maladaptive. Thus, the adaptive value of emotions simply depends on their context and their extent. When things are going well, positive emotions can help people to be flexible, increasing resources and form or strengthen social bonds. However, in problematic situations the experience of negative emotions may offer important benefits that positive emotions do not (Gruber et al., 2011).

In conclusion, although the pursuit of happiness is an important component of the good life, there are times when it is better to accept our negative emotions or even let them help guide our behavior. Beneficial emotion effects are not limited to cognitive control, but may also facilitate more complex functions such as those needed in social situations. For example, it has been suggested that expressing negative emotions, such as anger, can be instrumental in social situations involving negotiation (Gruber et al., 2011; Tamir, Mitchell, & Gross, 2008). Moreover, emotions are not “passions”, i.e., “most of our emotions, most of the time, are not entirely beyond our control” (Solomon, 2007, p. 190). On the contrary, people can actively regulate their emotions (Cornelius, 2006; Ochsner & Gross, 2005) and may even make strategic use of them (Tamir, Chiu, & Gross, 2007). Finally, as already indicated long ago by the Greek philosopher Aristotle (Aristotle, 2009), happiness is more than pleasure: life satisfaction and meaning, too, are important ingredients of the good life (Leknes & Tracey, 2008; Waterman, 1993). Notably, when experienced as meaningful, even the most painful events may become rewarding (Leknes & Tracey, 2008). How exactly people find meaning in the pain and pleasures of everyday life is an essential question that only recently has started to be investigated scientifically (Flanagan, 2007; Kesebir & Diener, 2008; Seligman & Csikszentmihalyi, 2000). Formulating answers to this question is crucial to gaining a rich and deep understanding of the intricate link between emotions, well-being, and goal-directed behavior.