Emotion and control

Bernhard Hommel, Department of Psychology, Shandong Normal University, Jinan, China

Key points

- The traditional model of reason and emotion (aka desire or habit) as opponent forces may be misleading.
- Affective states may serve as information about cognitive or response conflict, which may subserve action control and/or trigger dedicated control operations.
- Affective states share mechanisms with information-processing styles (metacontrol).
- Emotion action control may be two sides of the same coin.

Glossary

Cognitive dissonance A state in which mutually contradictory, conflicting information is held active. The conflicting state is assumed to be aversive, motivating the individual to reduce the conflict

Metacontrol Mode of information processing that can vary between extreme persistence and extreme flexibility

Persistence A metacontrol state in which information is strongly focused on currently relevant information

Flexibility A metacontrol state in which information is broadly integrated, considering both relevant and currently irrelevant information

Abstract

The article considers the relationship between emotion and cognitive/action control. Some approaches consider affective signals as important information on which control decisions are made. In particular, information conflict is assumed to be associated with negative affective states, which in turn are signaled to a conflict-monitoring system, which in turn drives the degree of top-down control. Other, not necessarily mutually exclusive approaches consider a role of affective signals in biasing the information-processing mode of the agent (metacontrol) toward more persistence or more flexibility. The connection between emotion and control likely relies on shared dopaminergic mechanisms in the frontal and striatal dopaminergic pathway. The available evidence suggests that emotion and control might be two sides of the same coin.

Introduction

The close connection between affective states and action control is something we witness every day: while we like to do things that are fun, we often ought to do things that are not, so that we often struggle between pleasure and duty, between immediate satisfaction and delayed gratification, between things that we feel we should do but we think we should not. Many of these struggles are nicely captured by Plato's tri-partition of the human soul into reason, passion, and desire (see Hommel, 2019a). According to this concept, reason makes us do the right thing, that is, to do what rational thinking and argumentation suggests to us, passion drives us to fulfill our needs, and desire makes us seek pleasure and avoid pain. Reason was considered the driver that is trying to control the two horses passion and desire. This picture is still with us, as it represents the core of not only psychoanalytic conceptions, where the ego is trying to mediate between the societal super-ego and the desiring id, but also in modern models of human action control. Almost all of these models distinguish between two routes, one intentional, logical, and rational route and another

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that is driven by habits and desires (for overviews and criticism, see Hommel, 2019b; Hommel and Wiers, 2017). Like in Plato's horse scenario, the intentional route is still assumed to be the one that provides control and that makes us to do the right thing, while the other (often called the automatic route) is considered to challenge the other by suggesting action alternatives that are more fun, less effortful, and generating faster reward.

The specific implications of such dual-route thinking for selecting and performing particular actions, I refer the reader to the chapter by Kirschner and Ullsperger. In the following, I will concentrate on more general relationships between affective states and action control. Research on this relationship has been mainly driven by two conceptually different, but not necessarily incompatible lines of reasoning. The first considers the possibility that particular affective states, and especially the hedonic value of the states (i.e., whether particular events make one feel good or bad) provide us with specific information that can be used to make our action control more adaptive and tailor it better to the situation at hand. The second is motivated by neuroscientific insights that suggest a substantial overlap between areas and neurochemical activities in the human brain that underlie affective states on the one hand and control abilities on the other. These insights suggest that emotion and action control may not necessarily be considered entirely independent factors that impact each other but, rather, as two different sides of the same coin, at least to some degree.

Affect as information

According to the theoretical considerations of James (1884), our responses to the events we are facing are an important ingredient of our emotional experience of these events. James assumes that this experience integrates all our bodily reactions, our embodiment of the particular event, so that we, as the famous saying goes, do not flee because we are afraid (of a snake or spider, say), but we are afraid because we flee. This means that action actually provides information that is used to create an emotion. Interestingly, later approaches have also considered the opposite: that emotions or, more specifically, the sensing of affective reactions of our body, might provide important information for regulating our actions.

Cognitive dissonance

Since the 1940s, researchers in the tradition of Gestalt psychology have considered the consistency between cognitive representations a driving force of human action. A particularly influential concept was developed by Festinger (1957). He assumed that all facts an individual is perceiving about herself, including the things she assumed and did, are coded into what Festinger calls "cognitions." Like many consistency theorists (e.g., Heider, 1958), he was interested in the relationship between cognitions, that is, the degree to which cognitions are related to each other and whether their implications do or do not fit. This resulted in the consideration of three kinds of relationship: two or more cognitions could be unrelated and thus have an *irrelevant* relationship, they could fit with each other and thus be *consonant* (e.g., wanting to be healthy and going to the gym), and they might not fit and thus be *dissonant* (e.g., wanting to be healthy and smoking). Dissonance between cognitions were assumed to be a driving force of human behavior. The idea was that dissonance creates a feeling of discomfort, which people are naturally motivated to avoid or reduce. Achieving this aim requires the individual to do something about the dissonance, and Festinger considered various kinds, such as downplaying a dissonance-inducing cognition (e.g., belittling the importance of being healthy), justifying a dissonance-inducing behavior (e.g., assuming that smoking "just a little" is not really unhealthy), ignoring or denying the conflict, or actually changing one or more cognitions.

Evidence for the latter has been gathered by running forced-compliance experiments, in which participants were asked to carry out actions that were assumed to be dissonant with their actual attitudes, and to provide either weak or strong external justifications for this behavior (e.g., Helmreich and Collins, 1968). For instance, students were asked to write a short paragraph explaining why they like an American president the policy of whom was clearly inconsistent with their actual political beliefs, after which they received a very low or a rather high financial reward. If the reward was high, which was assumed to provide a strong external justification of the dissonant behavior, students did not change their political attitude. But if the reward was low, and would thus not provide any external justification for the behavior, students often changed their attitudes, in the sense that they increased their sympathy for the described president's policy.

The cognitive-dissonance account has motivated the use of various kinds of paradigms and applications, including therapeutic interventions (Harmon-Jones and Mills, 1999). Some of the findings turned out to be difficult to replicate and others are open to alternative interpretations (McGrath, 2017). But the general idea that feelings of discomfort related to the degree to which one's thoughts and actions do not fit with each other can inform and guide action control has received strong confirmation (Elliot and Devine, 1994). For instance, participants of an fMRI study were scanned while pretending to enjoy the noisy and actually rather uncomfortable fMRI environment more than they actually did (van Veen et al., 2009). They were told that they were watched by the next participant, who would be extremely nervous and scared about the upcoming scan, and were asked to fake a positive experience to reduce the nervousness of this observer. Hence, the actual participants were asked to pretend being much more positive about the experience than they actually were, which was assumed to create cognitive dissonance. As predicted, participants of the enjoyment-faking group showed significantly more activation in the dorsal anterior cingulate cortex (dACC) and the anterior insula than participants of a suitable control group, who were merely encouraged to perform the task as if they would enjoy the experience. Even more interestingly, in a final test, participants of the enjoyment-faking group reported enjoying the experience significantly more than participants of the control group, and the positivity of the reported experience in the enjoyment-faking group was significantly predicted by the individual degree to which dACC and anterior insula were activated during the experiment. This suggests that both brain structures play an important role in processing cognitive dissonance, an issue that will return in the next section.

Conflict monitoring

The heydays of dissonance theory, and of consistency theories in general, were in the 1960s and 70s, but some more recent observations have revived the interest in these approaches. The key observation that has driven much of this interest comes from conflict tasks. The perhaps most famous conflict task is producing the notorious Stroop effect (named after Stroop, 1935). In this task, participants respond to a less familiar or obvious feature of stimuli (such as the ink in which a word is presented) and ignore a more familiar or obvious feature (the word itself; i.e., its meaning). More specifically, participants are presented with color words in various colors, and the meaning of the word is sometimes consistent with the color it is presented in (such as the word RED presented in red ink), and sometimes inconsistent (such as the word RED presented in green ink). As one would expect, it can be very hard to name the ink of a word if this is inconsistent with its meaning, that is, to say "green" in response to the word RED, and so it takes no wonder that reaction times and error rates are much higher for inconsistent than consistent words. Similar findings can be obtained with other kinds of conflict tasks, such as the flanker task, in which participants report a symbol that is flanked by consistent or inconsistent symbols, or the Simon task (Simon, 1969), in which participants respond to the shape or color of a stimulus by pressing a left and right key, and in which the actually irrelevant location of the stimulus is sometimes consistent with (i.e., on the same side as), and sometimes inconsistent with (i.e., on the opposite side as) the response key.

Of particular interest for our purposes, however, the size of such consistency effects (e.g., the reaction time difference between trials with consistent and inconsistent words, flankers, or stimulus locations) depends on the nature of the previous trial: the consistency effect is substantially larger after a consistent trial than after an inconsistent trial—a pattern that is sometimes called Gratton effect (after the first author of Gratton et al., 1992) or compatibility-sequence effect. From a cognitive-dissonance perspective, these observations could be explained as follows. Facing a relevant stimulus that is inconsistent with a salient but irrelevant stimulus creates conflict. For instance, facing the word RED will often evoke the tendency to say "red," which happens to be the correct response if the ink of the word also happens to be red, but the incorrect response if the ink happens to be green. In other words, inconsistency between aspects of the stimulus or the response they imply can be assumed to create cognitive conflict: cognitive dissonance, that is. If, according to Festinger, people are motivated to reduce this dissonance and the underlying conflict, they could for instance ignore the conflict, which however would be likely to lead to an error, or support the cognition that is likely to lead them to a correct response (Botvinick, 2007). In this case, this would be the instructed stimulus feature, such as the ink of the word in a Stroop task.

Fig. 1 shows how this scenario might work (cf., Cohen et al., 1990). Panel 1A sketches how people might represent the Stroop task. A stimulus like the word RED written in green ink would activate representational maps that code for the different stimulus

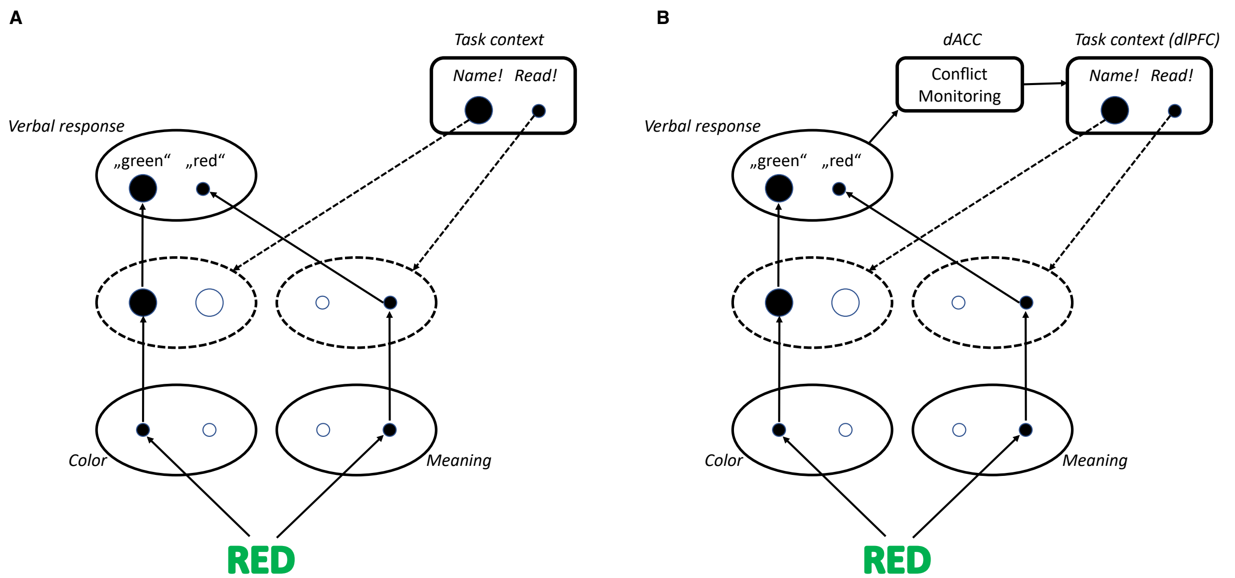

Fig. 1 Panel A sketches information processing in a Stroop task. The stimulus "RED" written in green ink is supposed to be color-named. The information is first processed in feature maps coding for the color and the meaning of the word, and channeled through to the verbal response stage in the uppermost layer. The medium layer is targeted by top-down regulation informed by the task context, boosting task-relevant but not task-irrelevant information. Panel B adds conflict monitoring to the scenario. Conflict at the response stage is picked up by a conflict monitoring assumed to be housed by dACC, which in turn increases the bias toward task relevance in task-context representations, assumed to be housed by dlPFC.

features. The left color map codes the color of the stimulus (green) and passes this information on to the response stage, where the verbal response "green" would be activated. The right word or word-meaning map would code for the word that people normally would have the tendency to read. Accordingly, activation on this map is passed on the response stage, where it would tend to activate the verbal response "red." Given that people are commonly more used to read words than to name their color, there would be a natural tendency to read the word. This is the reason why the meaning is processed at all, even though the instruction of the task renders it irrelevant, and why the corresponding response "red" is activated at least a little bit. Given that no such an overlearned tendency to color-name words exists, giving people no instruction would lead them to always read the word. To prevent that from happening, people are assumed to represent the task context, as defined in the instruction. As the context asked for naming, rather than reading, this task-context representation promotes the left processing route, which eventually leads the correct response "green" to be more strongly represented than the incorrect response "red." Nevertheless, any activation of any other response at the response stage is assumed to slow down response selection, which is why response decisions will be slower with inconsistent than with consistent stimuli.

Panel 1B illustrates how the experience of consistent or inconsistent trials might affect action control. According to the account of Botvinick et al. (2001), an existing conflict between responses or related codes would be picked up by a conflict-monitoring system. If a conflict is picked up, this is signaled to the task-context representation, and the emphasis on task-relevant information is increased. Accordingly, the top-down regulation of the processing streams is refreshed and more biased toward the relevant information. This bias will lead to a relative increase of the activation of the correct response at the expense of the incorrect response. For one, this will reduce the competition and support the selection of the correct response. For another, at a different time scale, the increase of the top-down regulation is also likely to lead to a stronger bias toward relevant information in the next trial. Accordingly, the experience of conflict and, thus, the processing of inconsistent information, reduces the processing of irrelevant information in the near future, which can explain why consistency effects are reduced after inconsistent trials—the Gratton effect.

In principle, this scenario would work without any reference to affective states or emotions, as long as there is some degree of competition or conflict that can be picked up by other neural systems. However, increasing evidence has suggested that affective states are somehow involved in the transfer of information about existing conflict to the assumed conflict-monitoring system (Botvinick, 2007). For instance, the Gratton effect is strongly reduced or even eliminated if participants perform a conflict task after having undergone a positive-mood induction or after having received unexpected reward in the previous trial (van Steenbergen et al., 2009, 2010). This might suggest that positive mood or affective states outcompete or overwrite the negative hedonic signals informing about conflict, which in turn might suggest that the signals refer to the hedonic quality of conflict. This possibility would fit with the already mentioned observation that processing conflict is associated with the activation of the anterior insula. The human insular cortex is known to be tightly connected to the autonomic system and to limbic and frontal regions involved in processing affective information, it is central for human interoception, and it has a long-standing co-evolutionary relationship with the ACC. In other words, the insula would be a perfect communication partner for the dACC, which we have already identified as the other crucial neural system involved in conflict processing. Along these lines, Botvinick et al. (2001) consider the ACC as the conflict monitoring system in the above-sketched scenario. Hence, the insula and/or related neural systems might be involved in generating information about conflict and/or transferring this information to the dACC, which in turn serves as conflict monitor. This monitor would then be expected to strengthen task-relevant information held in the dorsolateral prefrontal cortex (dlPFC), which in turn would increase its top-down impact on the processing of incoming information.

Further evidence for a role of affective states in action control comes from fMRI studies. Some have induced affective state systematically by using cartoons that were either funny or not, assuming that funny cartoons would induce a more positive hedonic state (van Steenbergen et al., 2015). As expected, being exposed to funny cartoons reduced the Gratton effect, suggesting that positive hedonic states overshadow the processing of hedonic signals regarding response conflict. Interestingly, connectivity analyses suggest that the induction of positive hedonic states tends to cut off the ACC from interactions with other brain systems, including striatal structures that are known to code for hedonic information. This suggests that being happy comes with greater tolerance regarding conflict. Given that conflict is necessary to keep processing accurate, this implies that happiness comes with some degree of carelessness.

Metacontrol

Another research line that has been taken to suggest a tight connection between affective states and action control aims to account for what might be called metacontrol (Hommel, 2015; Hommel and Colzato, 2017; see also chapter of Musslick et al.). The original concept of cognitive control or executive functioning was strongly driven by the historical concept of willpower: the keeping and eventual realization of a more or less continuously challenged intention against all odds (e.g., Miller and Cohen, 2001). Many tasks in this research area are modeled according to this concept, like the conflict tasks, in which participants are asked to enforce a not particularly obvious or possible intention, such as to name the color of words, against a much more familiar and more dominant tendency, like reading the words. All of these tasks make sure to remove any fun from the task and to avoid any possible reward that performing it might provide, except for the agreed-on, commonly modest renumeration or credit points. What conventional control tasks are thus tapping into can be considered the process of sticking to a not particularly plausible and attractive goal by carrying out rather demanding cognitive work in the face of more plausible, less demanding alternatives. Optimizing this process is no doubt important in many circumstances: when trying to motivate oneself to perform an unattractive job, to quit smoking, or to fulfill unpleasant social obligations. But there are also many other circumstances that call for a very different mindset. It can sometimes be wise and absolutely rational to give up plans that turned out to be unsuccessful for a while already, to think of alternatives, to follow one's intuitions, and to act spontaneously. The rationality of this, loser side of the control point does not seem to be well-captured by the will-power concept.

Increasing insights into the limits of this view on cognitive control have given way to a more complex concept of cognitive control as a balance between different control states. Some accounts have focused on the fact that cognitive control is often facing dilemmas that can be characterized as "keep sticking" or "focusing" on the one hand and "letting go" or "opening up" on the other. Various kinds of such dilemmas have been discussed (Goschke and Bolte, 2014), and they all share this basic character: the plasticity/stability dilemma, that people face when deciding whether they should use already learned procedures to tackle a problem or engage in creating a new procedure; the maintenance/switching dilemma, very similar to the exploitation/exploration dilemma, as being faced by animals when deciding whether to stay in a particular region to find food or to move to another, remote region with uncertain outcomes; and even the well-known speed/accuracy dilemma, when deciding whether to trust one's quick intuitions or to await further, demanding cognitive analysis.

These functional analyses turned out to fit with increasing insights into the contributions of different brain regions to cognitive control. While the traditional willpower-based approach has focused on the prefrontal cortex, which is known to be a central hub in representing task information, longer-term plans and goals, in logical thinking and general intelligence, there is increasing evidence that evolutionary older structures like the striatal region also play an important role in aspects of cognitive control. Of particular interest, both the prefrontal cortex and the striatum are driven by dopamine, a human neurotransmitter with a particularly broad distribution throughout the brain. However, the prefrontal dopaminergic pathway originates in the ventral tegmental area (VTA) and is dominated by dopaminergic receptors of the D1 family, whereas the striatal pathway originates in the substantia nigra (SN) and is dominated by dopaminergic receptors of the D2 family. There is some evidence for an antagonistic relationship between these two pathways, which has fueled the idea that they (Cools, 2008) and/or the receptor families they are dominated by Durstewitz and Seamans (2008) may underlie equally antagonistic control functions.

Fig. 2 shows how the control of information processing could emerge from the interaction of these two functions. On the one hand, the interaction between the involved control functions might be biased toward persistence, a situation that would be captured by panel A of the figure. It corresponds to the traditional idea of willpower, as information is strongly biased by the present task context and the processing mode is considered to be highly selective, focused, and competitive. This is expressed by a strong degree of competition between alternative representations, like the two response codes in the figure. Conflict tasks like the Stroop task would call for this processing mode, as it provides reward for ignoring task-irrelevant information and reducing conflict. On the other hand, the direction might be biased toward flexibility, a situation that is captured in panel B. Here, top-down moderation by task context is minimal, as is the competition between alternative responses or other codes. This would render information processing integrative, parallel, and very non-selective, which could be considered dysfunctional in a Stroop task but would be extremely useful in brainstorming or other creative activities. Obviously, different situations, tasks, and challenges call for different processing styles, so that cognitive control could be considered to always find the right balance between persistence and flexibility,

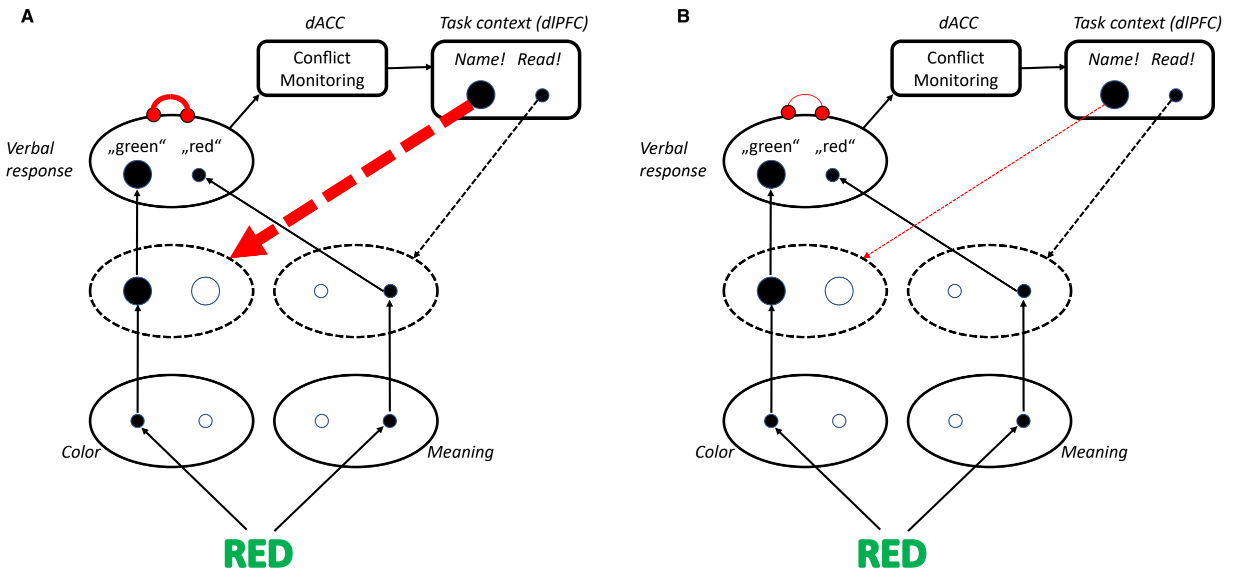

Fig. 2 Hypothetical modulation of information processing through metacontrol. Panel A sketches how processing might be affected by a strong metacontrol bias toward persistence, based on the processing architecture of **Fig. 1**. Strong persistence increases the top-down influence of the task context, as shown by the red downward arrow, and the competition between alternative responses, as indicated by the red inhibitory link between the responses "green" and "red" at the response stage. Panel B sketches a metacontrol state with a strong bias toward flexibility, which is associated by a very weak top-down impact of the task context and a very weak competition between alternative responses.

and the ability to readjust this balance whenever needed. This tailoring of the current processing style to the situation at hand has been called metacontrol.

Numerous neuroscientific and behavioral findings support the idea of (at least) two different, at least partly antagonistic components of a more comprehensive metacontrol system. For instance, the assumed link between the antagonistic control components and particular dopaminergic receptor families suggest that people's control style might be reflected by their genetic predispositions regarding these receptors or the efficiency of dopaminergic processing in different brain areas. For instance, different polymorphisms of the COMT gene (Val^{158}Met) are assumed to affect the efficiency of dopaminergic processing in the frontal lobe, while polymorphisms of the DRD2 C957T gene are assumed to impact the efficiency of striatal dopaminergic processing. If metacontrol persistence relies more on the frontal than on the striatal system, while the opposite holds for flexibility, one would thus predict that individual differences regarding COMT are particularly visible in tasks that rely on persistence, whereas individual differences regarding DRD2 should be associated with performance differences in tasks that rely on flexibility. Several studies have indeed confirmed this prediction (for an overview, see Hommel and Colzato, 2017), so that for instance performance in the Stroop task is related to individual differences regarding COMT, while tasks that call for the integration of information, like the attentional blink task, are associated with individual differences regarding DRD2.

But cultural differences can be as effective as those of hardwired genes. There is systematic evidence that cultures or religious groups with a strong individualistic bias, like citizens of the USA or neo-Calvinists, excel in tasks that rely on persistence, while cultures or religious groups with a strong collectivistic bias, like Asians, Catholics, Buddhists, or Orthodox Jews, excel in tasks that rely on flexibility (for an overview, see Hommel and Colzato, 2017). Given that systematic genetic differences between these investigated populations are highly unlikely, such differences must have been acquired through cultural practices. This suggests that metacontrol biases can emerge through such practices, presumably by repeatedly reminding the developing individual to either focus on herself or on her social or societal context. As the available findings suggest, this practice seems to generalize to laboratory tasks without any recognizable social function, suggesting that cultural practice can train specific metacontrol biases by providing reward and/or punishment for particular metacontrol biases. For instance, a cultural emphasis on the individual might provide selective reward for the consideration of one's personal issues and belongings but disapproval for too much consideration of other people's issues and belongings, so that growing up in this particular culture would systematically promote a rather strongly focused, highly persistent metacontrol state.

Of particular interest for our present purposes, short-term affective states and longer-term moods have also been found to have an impact on metacontrol. A first indication that mood might have an impact on the way people process information comes from studies on creativity. More specifically, positive mood was often found to improve performance in creative thinking, and in particular in verbal problem-solving (Isen, 1999). In the beginning, research on this relationship also revealed many non-replications and failures to find a strong connection. However, more systematic analyses later revealed that this has something to do with the type of creativity tasks being used (Baas et al., 2008). Even though creativity is often considered as a uniform, coherent ability, true creative acts must be considered as consisting of several, maybe even antagonistic components (Wallas, 1926): to solve a problem in a truly creative fashion, one needs to think very broadly about possible solutions, including out-of-the-box options, to identify the best of the solution by thinking through all its implications, to stick with the chosen solution until the problem is resolved, and to evaluate fairly how good the resolution was. Many individuals excel in one or more of these components, but combining them to a sufficient degree is a challenge. Tasks tapping into human creativity often focus on one or a few of these components (Guilford, 1967), but hardly any task captures all of them. In particular, divergent thinking is commonly studied by presenting participants with a vaguely defined problem and allowing for as many responses as possible (e.g., list as many uses of a brick as you can think of in 3 min), whereas convergent thinking is studied by presenting participants with a well-defined problem that has only one solution (e.g., which word can be combined with "man," "glue," and "market"?). Performance in these two classical tasks is often weakly or even negatively correlated (e.g., Akbari Chermahini et al., 2012), suggesting that the tasks tap into different components. As systematic research has shown, divergent thinking does strongly benefit from positive mood, while convergent thinking is hardly affected. From a metacontrol perspective, this would fit with the idea that positive mood is associated with a more flexible metacontrol state.

More recent research has looked into this possible connection more systematically. Indeed, inducing positive mood was found to impair focused attention under Stroop-like conditions that call for the neglect of task-irrelevant information (Dreisbach and Fischer, 2015). At the same time, inducing positive mood can increase performance in tasks that require the integration of information or the switching between different task-related states (e.g., Zhang and Hommel, 2022; Zwosta et al., 2013). Findings of that sort are particularly interesting, as they fit with the already discussed observation that conflict control is impaired by positive-going mood. Another observation that fits with the assumed connection between mood and metacontrol comes from creativity studies showing that engaging in divergent thinking systematically lifts the mood of the participant. Along the same lines, stimuli that create response conflict were reported to effectively function as negative hedonic primes (i.e., have similar effects as pictures with a negative valence).

Conclusions

As we have seen, emotional states seem to be tightly associated with cognitive control, and there seem to be systematic relationships between the hedonic value of the emotional states on the one hand and biases toward a more persistent or more flexible metacontrol bias on the other. It might be tempting to consider the relationship between emotion and control in terms of causality: getting into a particular mood might provide the agent with particular cues that motivate her to change her metacontrol in particular ways.

However, the fact that both emotion and control seem to strongly rely on dopamine, and the frontal and striatal dopaminergic pathways in particular, might also suggest another interpretation. Note that the concepts of emotion and of control are not entirely independent: even the etymological roots of the word "emotion" point to the motivational, "moving" aspect of emotions, which overlaps with the concept of cognitive control. It is thus possible that the labels emotion and control do not refer to completely separable functions but to shared components and mechanisms (Hommel, 2019a). In other words, the concept of emotion might refer to how the operation of particular mechanisms feels like while the concept of control refers to what this operation does for us, how it regulates our actions. Such an interpretation would get back to William James, whose emotion theory was almost indistinguishable in terms of the underlying mechanisms from his (ideo-motor) theory of voluntary action. This interpretation would also fit with recent constructivist ideas regarding the mechanisms of emotion (Barrett, 2017). The mechanisms themselves might not "care" about how particular emotions feel. They would simply exist for maintaining basic bodily functions, but by doing so they would send various signals that we can pick up and sense, and this then in some sense constructs the emotion. Hence, what we call emotion might actually represent how the controlling of our actions feels.

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