Chapter 7

Levels of cognitive understanding: Reflective and impulsive cognition in alcohol use and misuse

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The influences that guide a person to use and misuse alcohol are complex and involve a number of different facets including social, situational, and environmental aspects (see Borsari, Murphy, Barnett, 2007; Clapper, Martin, & Clifford, 1994; Melotti et al., 2011; Simons, 2003). Whilst these factors can play a large part in guiding one to consume, or even avoid, alcohol, fundamentally it is the cognitive processing of these situational, environmental, and societal factors that leads to specific behavioral responses and decisions to engage with, or avoid, alcohol or alcohol-related situations (see Tiffany & Conklin, 2000). Some of these cognitive processes we can be aware of, and involve us appraising situations or making, and reflecting on, explicit decisions to engage with alcohol or alcohol-related situations, however others are impulsive, or automatic, and can occur without conscious awareness and these can relate to our goals, motivations or previous experiences with alcohol. In this chapter, we will explore and discuss the interaction between these different cognitive processes and specifically focus on the interplay between reflective and impulsive processing of alcohol-related situations, objects and environments and related emotions and how processing of these factors may lead to different behavioral outcomes. We will also explore how researchers have explored these underlying cognitive processes and the research that has helped guide our understanding of the cognitive processing of alcohol-related situations.

Ostensibly all human behavior involves some form of interaction between attention, memory, and decision processes. In relation to alcohol, specific alcohol responses based on our previous experiences with alcohol and in

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alcohol-related situations are stored in our memory, and are thought to develop through positive or negative reinforcement mechanisms (see Cooper, Frone, Russell, & Mudar, 1995; Farber, Khavari, & Douglass, 1980). Evidence suggests that associations and knowledge structures created through these conditioning processes subsequently guide our attention towards or away from alcohol-related situations or objects, these may in-turn lead to impulsive behavioral responses, but we may also be able to make reflective decisions to interact, or not, with the environment, social situation, or specific alcohol-related objects based on the feelings and thoughts that manifest from these underlying cognitive processes. Evidence of such cognitive processing comes from empirical studies showing that those who have higher levels of alcohol consumption have a greater predisposition of attention towards alcohol-related objects – that is, there is some form of attentional orientation to, or attentional capture of, alcohol-related objects over objects unrelated to alcohol (see Cox, Fadardi, & Pothos, 2006; Hallgren & McCrady, 2013; Hobson, Bruce, & Butler, 2013). Commonly termed *attentional bias* this attention-related phenomenon is reported to be stronger in those with a history of alcohol abuse compared to heavy, light or social drinkers (see Cox et al., 2006). Furthermore, alcohol attentional biases have also been shown to be a predictor of treatment outcome, with those who show greater levels of attentional distraction from alcohol-related stimuli having poorer treatment outcomes (i.e. relapsed during treatment, did not maintain outpatient contact, or failed to complete a treatment program; see Cox, Hogan, Kristian, & Race, 2002).

Empirical studies have employed a variety of methods to explore attentional bias in relation to alcohol. The most common method being an adapted version of the emotional Stroop task (Williams, Matthews, & MacLeod, 1996) often called the addiction-Stroop task (see Cane, Sharma, & Albery, 2009). In this task, alcohol-related words (e.g. beer, alcohol, vodka) and words unrelated to alcohol (e.g. mouse, bike, phone) are presented in different colored inks. Participants in these tasks have to identify the color of the ink of the words as quickly and accurately as possible, whilst trying to ignore the words, or the context of the words, themselves. Rooted in the assumptions of classic Stroop task effects (see MacLeod, 1991; Stroop, 1935) whereby color-words conflict with color-naming, it is assumed that *if* the alcohol-related words distract or 'grab' attention then this should lead to slower color-naming of those words. Thus, an *attentional bias* for addiction-related words is thought to be denoted when the color-naming of addiction-related words is slower than the color-naming of neutral words. Such effects have been shown across a number of alcohol-related studies providing evidence of effects indicative of attentional bias for alcohol-related stimuli (e.g. Duka & Townshend, 2004; Field, Duka et al., 2007; Sharma, Albery, & Cook, 2001; see Cox et al., 2006 for a review). The modified Stroop task has proved beneficial in identifying differences in attentional bias for alcohol stimuli between in-treatment abstaining drinkers and those who have high alcohol drinking consumption and those with low alcohol drinking consumption, where those who are currently undergoing treatment show the greatest distractability from alcohol related words over neutral words (see Lusher, Chandler, & Ball, 2004; Sharma, Albery, & Cook, 2001). Similarly, in a study relating to college drinkers, the modified Strop task has highlighted differences in alcohol attentional bias in relation to drinking *intensity* rather than drinking frequency or drinking-related problems, with those who had a recent binge-drinking episode showing greater attentional bias for alcohol stimuli (Hallgren & McCrady, 2013). Thus, the modified Stroop task has proved effective in not only identifying attentional bias in relation to alcohol, but has also proved effective in differentiating between the attentional bias shown in different groups, either who are currently consuming alcohol, or those with a history of alcohol use and abuse.

A further development of the modified version of the addiction Stroop task by McKenna and Sharma (2004) has proved effective in identifying immediate effects on attention which happen during stimulus presentation and 'lingering' effects on attention which occur on trials following the critical stimulus presentation. Measured using a sequence involving a single addiction-related word followed by a number of counterbalanced neutral words, the attention-grabbing effects of stimuli are characterized by slower color-naming during the presentation of the alcohol-related word (also called the 'fast effect'). In contrast, attentional-holding effects are characterized by slower color-naming on neutral stimuli that immediately follow the alcohol-related word – often referred to as the 'slow effect' or 'carryover' effect. These slow effects are thought to represent the difficulty to disengage attention from the stimuli or rumination over the concepts relating to the stimuli (see Cane et al., 2009; Sharma & Money, 2010; Waters, Sayette, & Wertz, 2003; Waters, Sayette, Franken, & Schwartz, 2005). It has been proposed that the fast effects represent impulsive bottom-up stimulus responses stemming from the salience and low-level properties of the stimuli grabbing ones attention and the slow effects represent the more reflective top-down response regulation or disruption of inhibitory regulation and failure to disengage attention from the stimulus or concepts relating to the stimulus (see Cane, Sharma, & Albery, 2009). Through these changes to the modified Stroop task, the task has been further developed to distinguish between different aspects of cognition and attention in relation to alcohol use and misuse. Indeed, research has shown that both fast, immediate attention-grabbing effects, and slow effects, can be present in relation to substance use (see Cane, Sharma, & Albery, 2009), and in relation to alcohol both fast and slow effects of alcohol have been shown to be evident using this modified task (Clarke, Sharma, & Salter, 2015). Furthermore, Clarke et al. (2015) found that the slow effects, but not fast effects, were positively correlated with increased drinking levels in both social drinkers and in-treatment drinkers. Thus, there is emerging evidence that differentiating between these fast and slow effects of attention, may be theoretically, and potentially, practically important.

Dual-task paradigms are conceptually similar to Stroop task paradigms, in that slowing down on one task is a product of reactions to specific stimuli. However, Waters and Green (2003) suggest that the dual-task procedure they used provides stronger evidence for attentional bias effects than the Stroop task and the visual probe task (see below) because, unlike the Stroop task, responses are more likely to represent active shifts in visuo-spatial attention towards addiction-related stimuli. Dual-task paradigms, as the name suggests, involve two concurrent tasks. In one task the user is presented with alcohol-related or neutral stimuli, and in a second task participants complete a reaction time task which is cognitively demanding. As with the Stroop task, slowing down on the reaction time task indicates that attention is being captured by the alcohol-related stimulus. For instance, Waters and Green (2003) adopted a dual-task paradigm in a group of abstinent alcoholics and a group of control subjects. For their dual-task procedure, the reaction time task required participants to respond to odd and even numbers shown centrally on a screen and for the secondary addiction-related task they asked participants to respond to words (alcohol and neutral words) and non-words 'out of the corner of their eye'. Using this task, they found that abstaining alcoholics were slowed on the odd-even task when the peripheral cues were alcohol-related words compared to when the peripheral words were neutral, thus indicating that attention was allocated to alcohol stimuli to a greater extent than neutral stimuli.

Whilst the Stroop task and dual-task paradigms has proved effective in identify effects of attentional orientation or capture in relation to alcohol, they only provide an indication of covert attention processes, other tasks are thought to be a better direct measure visuo-spatial attention as they monitor where visual attention is allocated at particular points in time (i.e. overt attention) – these tasks include tasks such as the visual-probe (or dot-probe) task, and eye-tracking methodology. In the visual-probe task, two stimuli (images or words) are displayed simultaneously adjacent to each other for a short period of time on a screen (commonly below 1 s). One of the stimuli is alcohol-related (e.g. the word 'beer' or an image of a glass of wine) and the other is neutral (e.g. the word 'brick' or the image of a shoe). After the stimuli presentation a probe (usually either one dot or two dots, or an arrow in certain orientation) replaces the position of one of the stimuli. The participants' task is to respond as quickly and as accurately as possible to the nature of probe shown (e.g. the direction of the arrow or the number of dots). It is expected that respondents would be quicker to respond to probes that are presented in the area where their attention has been directed than areas to which attention has been drawn away from. For instance, if respondents' attention is grabbed by an alcohol-related stimuli they should be quicker to respond to probes which replace those alcohol-related stimuli. Thus, an alcohol-related attentional bias in the visual probe task is indicated by faster response times when probes replace alcohol-related stimuli, compared with response times when probes replace neutral stimuli. It has been argued that the visual probe task is a fairly direct measurement of visuo-spatial attention as visual attention has to be given to the area of the stimulus before the probe can be correctly and readily detected (Field, 2006). Furthermore, the task has been consistent in revealing effects which are indicative of attentional bias for alcohol-related stimuli across a number of studies (e.g. Duka & Townshend, 2004; Field, Mogg, Zetteler, & Bradley, 2004; Miller & Fillmore, 2010). Furthermore, recent studies have shown evidence that visuo-spatial orientation to alcohol stimuli using the visual probe task is positively correlated with increased craving (Field, Mogg, & Bradley, 2005).

Research using the visual probe task has also provided interesting findings that suggest a differentiation between impulsive and reflective processes. By varying the duration to which pairs of stimuli are presented it is possible to disentangle between immediate shifts in attention to stimuli and later shifts in attention that occur once the stimuli have been further processed, these are thought to represent impulsive and reflexive responses respectively. Responses to probes after short stimulus durations (commonly <500 ms) are thought to represent immediate 'attention grabbing' effects, whilst responses to probes after longer stimulus durations (commonly >2000 ms) are thought to represent the maintenance of attention on, or inability to disengage from, a stimulus (Bradley, Mogg, Wright, & Field, 2003). Shorter stimulus durations thus correspond to bottom-up stimulus salience responses and longer stimulus durations correspond to the engagement of, or interruption of, top-down regulation of control. These are comparable with the fast and slow effects shown in the Stroop task described previously. Thus, the visual probe task, like the addiction Stroop task, is not only an effective measure of attentional bias but has the potential to distinguish between fast and slow, 'lingering' effects of attentional bias.

Eye-Movement technology has also been used to examine whether visuo-spatial attention is directly given to alcohol-related objects. Some studies have employed this in conjunction with versions of the visual probe task (see above) to corroborate that attention is directed to particular stimuli before responding to the probe (see Miller & Fillmore, 2010) and others have employed eye-tracking with natural scenes containing alcohol-related stimuli. One such study was conducted by Roy-Charland et al., 2017 who across two experiments recorded eye-movement patterns across natural scenes containing either alcohol objects or being absent of alcohol-related objects. In one experiment, participants self-determined the time the images were presented for and were given no direction on the reasons for viewing the images, and in a second experiment the available time for viewing the scenes was limited and participants were specifically asked to memorize aspects of the image for a future recall task. In Experiment 1 there was no evidence of a link between alcohol-related attentional bias and levels of alcohol consumption, even amongst those who reported high levels of drinking. However, in Experiment 2 a positive correlation was identified between the number of shifts into and out of alcohol-related areas of interest and levels of annual alcohol consumption, with greater shifts of attention to these areas being associated with higher levels of consumption. The authors posit that the attentional biases to alcohol-related objects can occur where there is certainty of attentional focus in a particular environment. These findings build on earlier findings that have generally shown evidence of greater attention being given to alcohol objects in natural scenes in those who have a heavy versus light drinking patterns, especially where there are high levels of craving alcohol (see Hobson, Bruce, & Butler, 2013).

In contrast to paradigms purporting to measure visuo-spatial attention, the Go/No-Go task is believed to specifically tap inhibitory-control mechanisms (see Eaglem, Barry, & Robbins, 2008). The measurement of inhibitory control is believed to be important as it is thought to play a role in the development and maintenance of drug use and misuse behaviors (see de Wit, 2009; Fillmore, 2003; Goldstein & Volkow, 2002). The task requires that participants press a designated key when a 'go' symbol is presented as rapidly as possible but withhold their response when a 'no-go' symbol is presented. In alcohol-related studies, participants are typically required to initiate responses to non-alcohol related images of drinks (e.g. a water bottle, bottle of cola) and withhold responses to images of alcohol-related drinks (e.g. a bottle of beer, a bottle of wine). The number of initiated responses to alcohol-related objects (false alarms) is thought to represent problems in inhibitory control. Studies adopting this task have identified poorer inhibitory control in those who have high levels of drinking compared to those with lower levels of drinking (see Ahmadi et al., 2013; Easdon et al., 2005) and furthermore that these indications of poorer performance on the Go/NoGo are related to dysfunction in specific brain regions related to response inhibition (see Ahmadi et al., 2013),

Using these tasks has highlighted the potential underlying cognitive processes that drive behavioral responses in relation to alcohol and alcohol-related situations and environments. Largely, these cognitive processes, once developed, are deemed to be implicit in their nature and impulsive—that is out of our explicit control (see Tiffany, 1990). This is in contrast to cognitive processes which are explicit in their nature, including short and long-terms goals, explicit views and reasoning about alcohol, alcohol use, and alcohol-related situations. In the following section we will discuss how the implicit/impulsive responses to alcohol and alcohol-related situations and environments have been modeled using dual-process models and how these models help us to understand how these cognitive components relate to behaviors, thoughts and feelings that often accompany repeated substance use and misuse.

Dual-process models

Dual-process models have been developed to explain the activation of behavioral representations and influences on behavioral outcomes across different areas of psychology (see Bargh & Chartrand, 1999; Strack & Deutsch, 2004). In general, these models have attempted to describe the interaction between impulsive and reflective processes, where the former are based on associations and representations that are triggered by stimuli (i.e. as a 'bottom-up' process) and are thought to be fast, and the latter reflective processes are processes that are goal-directed, propositional and rule-based and involve reasoning processes (i.e. involving top-down processes; see Barrett, Tugade, & Engle, 2004) and are thought to be slow in nature. In these models, behavior is explained by the interaction of these processes and the moment-to-moment balance of these stimulus-driven and propositional/rule-based components (see Barrett et al., 2004; Palfai, 2006). In everyday terms, the stimulus-driven aspects relate to associations triggered by specific objects or situations, for instance seeing an off-licence on a high street might trigger pleasurable feelings relating to previous drinking experiences. In contrast, the reflective processes guide behaviors in line with propositional reasoning, for instance a person might have the intention to abstain from drinking and will likely reason about the benefits or costs of walking into the off-licence to buy a drink, potentially concluding that this would be a bad idea. Thus, these two distinct processes can be congruous (e.g. the triggering positive feelings about drinking, and reasoning that drinking is good), or they can be incongruous (e.g. the triggering of positive feelings about drinking, but reasoning that drinking would be a bad idea). These dual-process models seek to explain some of the phenomena that have been identified in empirical studies relating to the impulsive responses to stimuli versus the reflective aspects of cognition. These models commonly specify that the attention to, and subsequent perception of, stimuli can trigger automatic internal representations of knowledge structures and internal-goal states. The knowledge structures can be anything that one might already have knowledge about relating to the stimuli-specific context. For instance, knowledge structures can relate to simple memories (e.g. recalling a time when you had a good time with friends when drinking, or when you had a really bad hangover after drinking), or associations derived through, often repeated, logical thinking or assumptions, even if there is no direct experience of those events (e.g. repeatedly being told by a friend that drinking makes them feel good). The propositional route can comprise of reasoning relating to specific goals to which a person is driven to achieve. For instance, one might have the intention to give up drinking and so would have the goal to avoid alcohol-related situations or the consumption of alcohol. In contrast, a person might have the goal to increase their sociability at a party, and therefore may aim to drink alcohol to achieve this goal. It is believed that environmental cues can trigger both the associations and propositional reasoning that can ultimately lead to related thoughts and feelings, and behavioral responses (see Bargh & Chartrand, 1999; Barrett et al., 2004). For instance, the smell of alcohol might trigger memories of previous drinking situations and increase the propensity to drink.

One of the earliest dual-process models specifically developed to explain drug use behavior and that incorporates the idea of an interaction between impulsive and reflective cognitive components is the Cognitive Model of Drug Urges and Drug-Use Behavior proposed by Tiffany (1990). In this model drug use is primarily controlled by automatic processes, which are fast and of which we are not consciously aware of, but is accompanied with non-automatic aspects, such as drug-related urges, which we are consciously aware of and take effort to control. One important aspect of Tiffany's model is that drug-use behaviors that have become automatic will have little influence on the processing of other behaviors or cognitions, and have little or no influence on processes relating to executive function. These responses are therefore reflexive rather than reflective. Such automatic processes are developed through consistent pairings between the drug-stimulus and a response, but can be mediated by the effects of the drug itself, (e.g. alcohol). Tiffany suggests five key properties of these automatic processes:

1. There is little conscious awareness of these processes directly.
2. They become less variable and faster the more they are repeated.
3. The stimulus alone can elicit the response—i.e they are "*stimulus bound*".
4. They require minimal effort or attention.
5. They are not under our explicit control.

Because of their automatic nature on other aspects of cognition, these processes have very little impact on working memory, or on working memory capacity, which can be used for the processing of other stimuli, cognitive inputs or behaviors. Furthermore, when automatic processes are interrupted (e.g. when drinking alcohol is not possible), the non-automatic processes relating to drug-use are likely to be more prominent, i.e. there may be greater craving or explicit thoughts about the drug itself (see Tiffany, 1990).

Wiers et al. (2007) developed a similar dual-process model that specifies how the reflective processes might inhibit the automatic associative processes involved in alcohol use, and how this might change at different life stages (e.g. during adolescence versus adulthood). Through their model, Wiers et al. (2007) that addictive behaviors result from an imbalance between implicit appetite responses towards the consumption of a substance and the self-regulatory control mechanisms available to inhibit these implicit appetitive responses. In their model they specified three particular components: the explicit attitude related to the consumption of a particular substance; the implicit appetitive response tendency for consuming the substance; and the inhibitory control that one can exert over implicit appetitive responses. The latter inhibitory control has the possibility of influencing the implicit appetitive responses, as a form of self-regulation, however this is reliant on their being sufficient motivation to engage those mechanisms and fundamentally the ability to put those processes into play. Wiers et al. highlight evidence that shows that motivational influences to control drinking behavior are often weak during adolescence, where there is little consideration of any issues with their drinking behavior. In contrast, later life comes with the increased probability of the experience of problematic outcomes as a result of drinking, and so the motivation to regulate drinking becomes stronger later in adult life. Furthermore, given that one would need the ability to engage in self-regulation, and this can sometimes be tempered as a results of previous problematic drinking, especially in cases where this has resulted in neurological adaptations or damage affecting inhibitory control mechanisms. This model is therefore important in highlighting the variation in control that the reflective self-regulatory processes have on the implicit, impulsive processes at different stages in the face of non-problematic, and problematic drinking.

More recently, Moss and Albery (2009) proposed an alternative dual-process model drawing from both (i) myopia theory (Steele & Josephs, 1990), which suggests diminished processing capacity after alcohol consumption leading to the processing of only the most salient cues in a situation, and (ii) alcohol-expectancy theory, which posits that expectations of alcohol effects predict behavioral outcomes even in the absence of alcohol (i.e. when a placebo is consumed or when primed with alcohol cues; see Friedman, McCarthy, Förster, Markus, 2005 for an example). Building on previous models, Moss and Albery suggest that mental representations and alcohol expectancies, are triggered by drug-related cues, however the influence that these cues have on behavior is controlled by propositional reasoning, the controlled goal-directed reflective processes. Importantly, their model suggests two particular stages, a pre-consumption stage and a post-consumption stage. In the pre-consumption stage, whilst the associations that are triggered may be many (especially in the case of heavy-drinkers) the propositional reasoning component is able to control the representations that may lead to behavioral outcomes. However, in the post-consumption stage the effortful cognitive processing of other stimuli is disrupted and control processes become disrupted, and therefore these automatically derived mental representations are more likely to influence behaviors. Indeed, evidence from studies has indeed shown that alcohol consumption can lead to impairment of cognitive function, including aspects involved in reasoning (see Dawson & Reid, 1997; Moss & Albery, 2009). Therefore, Moss and Albery's model allows us to understand specifically how alcohol influences the determination of a behavioral outcomes in those who drink alcohol.

A neural network approach to dual-process models

Theoretical models of addiction suggest that attentional bias is a contributor to the development and maintenance of substance abuse. Dual process models suggest that behavior is guided by both impulsive and reflective processes. Such models also indicate that alcohol consumption results in a reduced influence from propositional processes (e.g. Moss & Albery, 2009).

It is clear from the above discussion that dual process models provide a general framework for understanding substance abuse. One drawback of such models is that they do not provide an explicitly computational model. This is important to enable the field to work with complex interacting mechanisms that not only reproduce behavioral outcomes but also are clear about the underlying assumptions. Here we try to make such links with the cognitive literature where these models are more common. The underlying mechanisms described in dual process models have parallels in neural network models. Here we draw attention to the processing of information in a bottom-up (automatic or reflexive) or top-down (proactive or reflective) manner. Such network models have not been described in the addiction literature, however, it is possible to do so. Here we provide a brief description largely to draw parallels with how negative salient stimuli are implemented in neural network models particularly as there is evidence that part of the effects of addictive substances is related to their negative affect. In this literature the general framework for impulsive and reflexive systems is often described as involving cognitive control (Braver, 2012). Cognitive control is the ability to flexibly guide behavior in line with our goals or intentions and in particular to help in situations of otherwise compelling response tendencies or what is also called prepotent tendency. Such a definition has been used in the general cognitive literature to describe behaviors as simple as saying a word to more complex behaviors as crossing the road or stopping at a traffic light.

Cognitive control is fundamental to all forms of higher cognitive function (also known as executive functions) including language planning, problem solving, and decision making. However, to study this scientifically it helps to have a simple example that can be used in the laboratory. The most popular task used to study cognitive control is the original Stroop task which is probably the most robust phenomena in psychology. As described earlier, the Stroop task has also been modified to study salient stimuli that includes emotional and alcohol related stimuli (Cox et al., 2006; Phaf & Kan, 2007; Williams et al., 1996). To capture the many findings discovered using the Stroop task we first describe a general neural network model (see Cohen, Dunbar, & McClelland, 1990) and then show how it can be extended to salient stimuli, particularly alcohol related stimuli. Although we focus on the Stroop task here a similar approach has been taken for modeling the findings from the dot-probe task using emotionally salient stimuli (see Frewen, Dozois, Joanisse, & Neufeld, 2008).

In the Stroop task how is it that when asked to name the ink color of a word one is able to ignore the word (the prepotent or default response) and respond to the ink color? Network models have been used to capture the processes that we think the brain uses to do this task. The basic model provides a simple associative framework where there are connections from input stimuli to output responses and with information flowing initially in a bottom-up fashion from input to output (see Fig. 7.1). Often a hidden layer is used to associatively

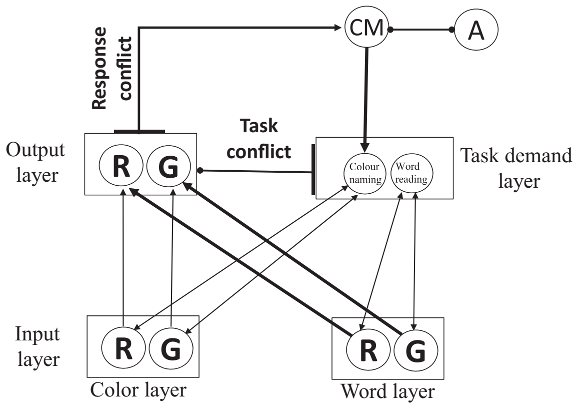

FIGURE 7.1 A network model adapted from Wyble et al. (2008) and Kalanthroff et al. (2015). Response conflict triggers additional top-down activation via the conflict monitoring unit (CM) to color naming as in Botvinick et al. (2001). Task conflict is represented as the inhibitory connection between the task demand layer and the output layer. When a unit (circles) is activated within a layer (rectangles) that unit inhibits other units within its layer. R = red, G = green, A = alcohol or affectively relevant stimuli.

connect the inputs to the outputs, however, to simplify description, this layer will remain hidden to show the direct connections from input to output (Cohen, Dunbar, & McClelland, 1990; Cohen & Huston 1994).

In this network model when a word (e.g. a word CHAIR, or GREEN) is presented (irrespective of which color the word is written in) the default response is to read the word (say 'chair' or 'green'). This is commonly represented in the model as a stronger association between the word inputs and the response output (indicated by thicker lines in Fig. 7.1). The stronger association indicating that greater attention is given to this aspect of processing. So how is it that when asked to respond to the color in which a word is written we are able to overcome this default response? The extra feature needed is supplied by the task demand layer. The task demand layer allows the task instructions (aka task goals) to have an influence along the ink color processing pathway. Such instructions or goals are thought to be a key function of our central executive system and located in the prefrontal cortex (Cohen & Servan-Schreiber, 1992; Zhao et al., 2014). This top-down influence ("name the ink color") can help to override the activity of the default response (respond to the word). In this simple model the Stroop effect is thought to be the result of response competition, that is, competition between the color units in the output layer. Typically competition is implemented by inhibitory connections between the units within each layer. Inclusion of the task demand layer highlights one mechanism of proactive control, that is, one way that the information processing pathways can be influenced in a top-down manner by deliberate strategic thinking.

More recently there has been interest in more automatic top-down control mechanisms. In particular the trial by trial adjustments in cognitive control that can take place during the performance of a task (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Braver, 2012). In the Stroop task there has been an emphasis on understanding how an incongruent trial (e.g. the word RED printed in the ink color green) can lead to speeding up on a subsequent incongruent trial (also referred to as the Grattan effect, sequential congruency effect, or conflict adaptation effect) (Botvinick et al, 2001; Gratton, Coles, & Donchin, 1992). Here we will refer to this finding as the sequential congruency effect (SCE). A dominant explanation of the sequential congruency effect is the conflict monitoring hypothesis which suggests that there is a conflict monitoring (CM) unit that detects the level of competition in the output layer (see Fig. 7.1) and subsequently increases activation of the color naming task goal in the task demand layer (Botvinick et al., 2001). Increasing the activation of the color naming unit simulates increased attention to the task goal whilst at the same time shifting attention away from the word reading. This top-down control mechanism is thought to result in the response conflict on subsequent incongruent trials being reduced and thus speeding up performance.

Although early models emphasized response conflict as the main source of conflict, recent models suggest there is also competition between the color naming and word reading units in the task demand layer. This competition is referred to as task conflict (Goldfarb & Henik, 2007). The consequence of task conflict is that it leads to a general inhibition of responses in the output layer (see Fig. 7.1; Kalanthroff, Avnit, Henik, Davelaar, & Usher, 2015; Kalanthroff, Davelaar, Henik, Goldfarb, & Usher, 2018). The introduction of task conflict helps to explain several unexpected findings. (i) A reversed facilitation effect. Usually congruent stimuli (e.g. the word GREEN printed in the ink color green) are faster to respond to than control stimuli, however, under certain conditions (e.g. when top-down control is reduced) even a congruent word can take longer to respond to than a non-word (Goldfarb & Henik, 2007; Kalanthroff et al., 2015). This is thought to be because any word (even a congruent word) can activate task conflict in the task demand layer resulting in a general slowdown of responses. (ii) Initially it was thought that conflict monitoring indicated activity in the dorsal anterior cingulate cortex (dACC). However, MacLeod and MacDonald (2000) have highlighted that both congruent and incongruent trials activate the dACC. As both congruent and incongruent trials both include words one suggestion is that the dACC is activated by task conflict rather than response conflict. (iii) More recent work provides further support that task conflict can be triggered in a top-down manner by priming goals proactively. Sharma (2018) showed that words that had earlier been studied for an upcoming memory task took longer to respond to than words that were not studied. It is thought that studying words results in greater top-down activation of the word reading task demand unit which in turn increases task conflict leading to a general slowdown in performance.

In summary this model provides an established framework to understand how we can selectively attend to ink color and ignore the word even when the word is the default response. Such a mechanism can be generalized to other behaviors that are triggered by emotional inputs. There is considerable evidence that emotionally negative stimuli produce longer color naming responses than neutral stimuli (i.e. the emotional Stroop effect). Initially models assumed that negative or threat related stimuli had their influence on response competition. For example, Matthews and Harley (1996) explored different ways in which threatening stimuli could be implemented in a neural network model. Their main suggestion was to include additional threat units in the input word layer and the output layer as well as adding stronger connections between these input-output threat units relative to other non-threat word units. Activating threat output units would result in greater competition between the threat unit and the other color units in the output layer which could explain the attentional bias to threat stimuli. Adding alcohol inputs that have stronger connections to alcohol units in the output layer would also be consistent with the general finding of an attentional bias to alcohol. It would also be consistent with the general conclusion that threat and alcohol related stimuli automatically capture attention particularly in groups who are emotionally vulnerable.

Research using negative emotional stimuli indicates not only the fast automatic capture of attention but also slow effects indicative of perseveration onto subsequent stimuli (McKenna & Sharma, 2004; Phaf & Kan, 2007). This slow effect has also been reported for addiction related stimuli (Cane, Sharma, & Albery, 2009; Clarke et al., 2015). Wyble, Sharma, and Bowman (2008) have suggested that the slow effect could be modeled if it is assumed that negative stimuli reduce top-down cognitive control. This was implemented in their model by adding reciprocal inhibitory connections between the conflict monitoring unit and threat input units (see Fig. 7.1). Thus in the presence of a threat word proactive control is inhibited allowing subsequent words to more strongly influence color naming performance. Further support that negative stimuli reduce top-down cognitive control comes from the work of Padmala, Bauer, and Pessoa (2011) who show that the sequential congruency effect (an index of top-down cognitive control) is reduced for negative stimuli. This approach is synonymous with other approaches that highlight that negative stimuli draw on cognitive resources to either facilitate performance, when task relevant, or interfere with performance, when task irrelevant (see Pessoa, 2017). A straightforward extension of the Wyble et al. (2008) model would allow alcohol related stimuli (in a similar way to negative stimuli) to inhibit the conflict monitoring unit. A recent finding suggests this line of inquiry is promising. Sharma (2017) has shown that the sequential congruency effect is also reduced by alcohol related stimuli in a group of heavy drinkers.

A lot of further work is required to fully explore the consequences of alcohol related stimuli in reducing top-down control. For example, an important question is related to the representation of goals in the task demand layer. It would be interesting to investigate how positive and negative alcohol expectancies could affect both response conflict and task conflict. Equally important would be to model the effects of individual differences, the effect of alcohol priming as well as any differences for different substances of abuse. Neural network models could provide the vehicle to explicitly implement the underlying mechanisms, which is important for testing complex models that involve many interactive elements.

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