An implicit cognition, associative memory framework for addiction

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2.1 Introduction
This chapter outlines a framework that applies basic research on implicit cognition and associative memory to addictive behaviours. The framework helps provide a basis for continued development of cognitive theories of addiction, and suggests how the approach can foster prevention and cessation efforts. Findings and theories from neural systems, memory, implicit processes and addiction research are considered in an attempt to derive basic principles for the framework. Measurement domains are briefly summarized. Concepts from this framework are compared with related ideas, from expectancy and cue-reactivity research areas. This framework calls for a greater focus on the specific principles derived from basic cognitive research in multiple disciplines and encourages more attempts at integration across these areas.

Implicit processes relevant to addiction can be understood at different levels of explanation. They can be understood in terms of neural processes and systems, as well as a wide range of cognitive responses produced in divergent research paradigms from different disciplines. The first general section of this chapter focuses on implicit cognition and its relevance to addiction, acknowledging this diversity of support. Many implicit processes can also be understood in terms of more global theories of associative memory, a focus of the second general section of this chapter. Such theories provide explanations for the development and activation of associations that probably form an integral part of many implicit cognitions. The time seems right for a more thorough application of basic theories of implicit cognition and associative memory to addiction, for the sake of improved understanding and possible intervention.

2.2 Implicit cognition
Implicit cognition, as defined in this chapter, is revealed on tests that do not require or encourage deliberate or conscious recollection or introspections
on addiction. Most of the best approaches to implicit cognition in addiction have been directly 'translated' from more basic research, whether in areas of learning, memory, cognitive neuroscience or social cognition. Some principles have been derived from both human and non-human animal basic research. Common principles that emerge from diverse paradigms and research areas in both humans and animals may constitute fundamental insights that should not be overlooked in either basic or applied research.

2.2.2 Implicit cognition and related concepts

Beyond the general definition of implicit cognition advanced earlier, there are a variety of different senses of this term and presumed functional characteristics, well articulated in previous work (De Houwer 2006). Operational definitions of the term need to be addressed in empirical tests and specific theoretical explanations, some of which are outlined later in this chapter. Implicit cognition also needs to be considered in terms of related concepts, such as automaticity and unconscious influences of memory.

In the present approach, implicit cognition is used as a broad category of phenomena that match the general definition. Different manifestations of implicit cognition, often studied in different research areas or disciplines (e.g. social cognition, cognitive neuroscience, memory), often involve additional definitions and functional characteristics, while still sharing common ground with the general definition. Consistent with this approach, automatically activated cognitions are a subset of a broader class of implicit cognition, rather than the other way around (cf. De Houwer 2006). Implicit memory is also a subset of this broader class. Placing both implicit memory and automatic cognition under the umbrella of implicit cognition has certain advantages over subsuming implicit memory or cognition under automatic processes. For example, many compelling findings involving implicit or unconscious memory do not reveal the functional quality of efficiency, often attributed to automaticity (for a recent review of automaticity, see Moors and De Houwer 2006). Responses attributed to implicit or unconscious memory are not necessarily efficient because, although the memory may be activated rapidly, the response usually takes time (e.g. at least more than a few hundred milliseconds). Thus, implicit cognition (as defined here) is proposed in this chapter as the most general category, providing a useful multidisciplinary umbrella. We also include attentional bias and pre-conscious processes under this category.

The definition of implicit cognition used here is general enough to cover a broad set of responses that, at least, do not require extensive deliberation, intentional retrieval or judgements based on self-perceptions to operate. Responses to some tasks require some cognitive resources and time (e.g., more than a second).
On the basis of arguments available for some time (Nisbett and Wilson 1977; Feldman and Lynch 1988), the latter processes plague and confound the types of cognitive responses that have been the priority in decades of research in addiction and other health behaviour research. A search for alternative processes and measures is further justified by various lines of basic and applied research, outlined below.

2.2.3 Examples of findings and measures in drug abuse

There are several recent reviews of the application of implicit cognition concepts and indirect cognitive measures to addictive behaviours, focusing on different behaviours or different research paradigms (McCusker 2001; Ames et al. 2006; Bruce and Jones 2006; Cox et al. 2006; Houben et al. 2006; Waters and Sayette 2006). It is beyond the scope of this chapter to reiterate all of these findings. The most general conclusion from this research is that a variety of indirect measures implicating implicit processes have been found to predict, or correlate with, drug use. In a few instances, prospective effects have been investigated. These findings are consistent with the view that implicit processes play an important role in addictive behaviours.

Several examples reveal relevant findings from diverse paradigms. Some assessment paradigms rely on reaction time assessments in various types of tasks that do not directly inquire about drug-use behaviour. These tasks can be grouped into two large categories: (1) tests that have comprehensive support from basic research and include within-subject comparisons essential for adequate inference; and (2) tests that may measure reaction time to some type of judgement but have not received widespread support or do not include very informative comparisons. This section is restricted to the former class of test. Reaction time tasks of this class found to be predictive of drug use can be further subdivided into measures that assess aspects of an attentional bias for a drug and measures that assess automatic associations with drugs. Examples of measures of drug-related attentional biases are the modified Stroop task including drug-related words (for reviews, see Bruce and Jones 2006; Cox et al. 2006), different versions of dot-probe tests (Field et al. 2006), which assess whether a drug-related picture is responded to faster when probed (a prime occurs before the target, either on the side where later a drug-related picture is shown or on the other side), and the more recently developed change blindness paradigm (Jones et al. 2002), in which it has now been demonstrated for a variety of drugs that problem users detect masked changes faster for drug-related changes than for changes in neutral materials. In this line of research, reaction time tests have been supplemented with registration of eye movements, which provide a measure of attentional subprocesses...
involved in attentional biases for drugs. Subprocesses include automatic *engagement* of attention versus latency in *disengagement* of attention from drug-related materials (Mogg *et al.* 2003; Field *et al.* 2004).

One example of reaction time tests of automatic or implicit associations is the Implicit Association Test (IAT; Greenwald *et al.* 1998), which has now been adapted for the assessment of drug-related associations, including alcohol (Wiers *et al.* 2002a, 2005; Jajodia and Earleywine 2003; Palfai and Ostafin 2003; De Houwer *et al.* 2004), cigarette smoking (Swanson *et al.* 2001; Sherman *et al.* 2003; Huijding *et al.* 2005) and cannabis smoking (Field *et al.* 2004). The advantage of the IAT is that it generates large and reliable effects; however, the interpretation of IAT effects is a topic of debate (see De Houwer 2002; Fazio and Olson 2003; Rothermund and Wentura 2004). Two recent studies tested to what extent alternative explanations such as the Figure-Ground account of IAT effects could account for previous findings concerning the alcohol-IAT (robust negative and arousal associations), and this proved to be partly but not fully the case: after accounting for Figure-Ground effects, the alcohol IATs remained predictive of behaviour (Houben and Wiers 2006a, b).

There are a number of alternative reaction time measures well supported in basic cognitive research that can be used to assess drug-related associations, such as semantic priming with lexical decision (Hill and Paynter 1992; Zack *et al.* 1999; O'Connor and Colder 2005) or naming (Weingardt *et al.* 1996; Zack *et al.* 2003); a primed Stroop (e.g. Stewart *et al.* 2002); the Extrinsic Affective Simon Task (EAST; De Houwer 2003); the Go–No Go Association Task (Nosek and Banaji 2001); and affective priming (Fazio 2001; Ostafin *et al.* 2003). However, among the well-researched reaction time tests relevant to implicit associations, the IAT has been studied the most with respect to addictive behaviour and psychometric properties. In general, reaction time tests of implicit processes have been found to be relevant correlates of drug use (for a more complete review, see Houben *et al.* 2006).

A different type of measure does not rely on reaction time tests but uncovers associations using word or picture association methods. Here again, there are essentially two classes of measures that vary in their relevance to implicit processes. In one class, measures are identical, or virtually identical, to those found to be effective in basic research on associative memory and implicit memory, while maintaining an indirect assessment of cognition, and often including within-subject comparisons. Measures in this class have included free association (e.g. Kelly *et al.* 2006), where participants are asked to write the first word that comes to mind in response to single word cues (e.g. fun:___), a variant of this method using continuous association
AN IMPLICIT COGNITION, ASSOCIATIVE MEMORY FRAMEWORK

(Szalay et al. 1999) to repeated cues (e.g. fun: _ / fun: _ / fun: _ ) and a variant using controlled association (Cramer 1968), in which responses are restricted in some fashion (e.g. respondents are asked for a category or verb). If measures within this class do not mention the target behaviour, or do anything to encourage recollection of previous events or introspections about the causes of one’s behaviour, they clearly can be classified as indirect tests. A recent review of basic research on word association concluded that responses to indirect measures of this type are often implicated in implicit processes, although inferences of implicit processes range from strong to weak (or suggestive) depending on the study (Stacy et al. 2006a). Responses to such measures have been found to be good correlates of alcohol and marijuana use in a number of studies, despite indirect assessment that does not mention the target behaviour or encourage self-perception attributions about that behaviour (Palfai and Wood 2001; Ames et al. 2006; Kelly et al. 2006). The second class of measure asks for a first response to some question, but departs from indirect assessment, either by mentioning the target behaviour (and thereby encouraging a host of alternative processes; Feldman and Lynch 1988), by encouraging recollection of events or by fostering self-perceptions of behaviour. Such measures also may not be compatible with inferences drawn in basic research using word association, and may be more reasonably classified under the general category of open-ended survey responses (Krosnick 1999).

Although a wide range of open-ended survey responses may be useful in addiction research because they can take advantage of important concepts such as top-of-mind awareness, self-generation and relative cognition (Stacy et al. 2006a), an implicit cognition, associative memory framework said to be derived from basic cognitive research should retain a close alignment to definitions and findings from that research.

A third type of assessment that can lead to reasonably good inferences about implicit cognition in addiction research comes from various types of memory testing paradigms that engage implicit processes across study-test trials. One of the best known paradigms in this domain is the testing of false memory (Deese 1959; Roediger and McDermott 1995). In an implicit processing perspective (McEvoy et al. 1999), false memories in recall and recognition arise from implicitly activated, associated cognitions (for a different explanation, see Brainerd and Reyna 1998). The pattern of recall or recognition can then uncover how this implicit process operates, as well as individual differences in the associations underlying the effects. In a recent extension of this paradigm to alcohol use, Reich et al.’s (2004) findings were consistent with implicit activation effects on illusory memory. Although they concluded that
these findings were most usefully described in terms of expectancy processes (see also Chapter 6), they also acknowledged that the results could be explained within the associative memory theory of Nelson, McEvoy and colleagues (e.g. Nelson et al. 1998; McEvoy et al. 1999), which focuses on implicitly activated associations. Other memory-testing paradigms that have been applied to addiction include process dissociation (Fillmore et al. 1999), the famous name paradigm (Krank and Swift 1994) and extralist-cued recall (Stacy 1994), each of which can yield inferences of implicit or unconscious effects of memory (Jacoby et al. 1989; Jacoby 1998; Nelson et al. 1998). A range of other paradigms from basic cognitive research are applicable to inferences of implicit processes. In a few instances, addiction researchers have developed paradigms not contemplated in basic cognitive research, leading to some findings that are nevertheless difficult to explain without acknowledging implicit processes (e.g. Roehrich and Goldman 1995).

Although not enough research has yet addressed longitudinal effects of implicit cognition on addictive behaviours, a few prospective studies have been done. Using indirect tests of word association, two studies have found that these measures prospectively predict substance use (alcohol or marijuana), adjusting for the predictive effects of covariates such as previous drug habits, outcome expectancies, background characteristics and personality (Stacy 1997; Kelly et al. 2006). Importantly, Kelly et al. (2006) found prospective effects across 1-year intervals even though they carefully minimized various sources of contamination and confounding, such as hypothesis guessing. Using the IAT, Wiers and his colleagues (Wiers et al. 2002) found that implicit associations predicted unique variance in 1-month prospective drinking in students, above explicit measures. Similar results have been found using different versions of the IAT (Houben and Wiers 2006a,b). In a recent study relevant to severe drinking patterns, Thush and Wiers (2006) found that adolescents’ implicit alcohol associations predicted binge-drinking 1 year later. Although there are remaining issues regarding the optimal assessment of implicit drug-related cognitive processes, these studies make it clear that the assessments provide unique information that goes well beyond the information provided by explicit measures in terms of prospective prediction of substance use; unique effects have also been found in terms of prediction of treatment outcome (Cox et al. 2002; Waters et al. 2003).

Cross-sectional and prospective results are quite promising, but they are not always consistent and predictive effects are not always strong (Waters and Sayette 2006). It is likely that much stronger effects could be seen when assessments are refined and optimized. Improved measurement will probably
require more attention to the functional properties of tests (Moors and De Houwer 2006). Improved measurement may also require advances in cognitive theory about the best concepts to apply to this area. As outlined below, concepts from cognitive neuroscience and associative memory may provide fertile ground for more detailed understanding of likely processes and presumed functional properties, as well as advances in assessment and improved prediction.

2.2.4 Emerging frameworks from cognitive neuroscience and the neural basis of addiction

Basic research on neural processes has attempted to pinpoint the precise nature and substrates of implicit cognition phenomena. This section provides a brief sample of this research, acknowledging a range of possibilities while providing neuropsychological evidence that distinct processes are likely to exist and thus should be investigated in research on cognition and addiction.

Moscovitch (2000) summarized several useful frameworks describing how implicit and explicit memory may be related, in terms of both functional (memory response) and structural (neural) levels of analysis. These models differ, for example, in whether implicit memory is a degraded, similar or distinct form of memory when compared with explicit memory. In more recent event-related functional magnetic resonance imaging (fMRI) research, Schott and his colleagues (Schott et al. 2005) found support for distinct neuroanatomy involved in implicit and explicit memory, as well as evidence for a further distinction involving intentional control of retrieval. Importantly, these investigators dissociated the neural correlates of intentional retrieval from those accompanying conscious recollection while showing that conscious recollection can occur in the absence of intentional control—an example of involuntary explicit memory (Richardson-Klavehn and Gardiner 1996). Further, some of the same neural correlates (e.g. decreased activation of bilateral occipital regions) accompanied both implicit memory and explicit (consciously recollected) memory, independent from intentional retrieval. Additional regions were affected during explicit (consciously recollected) memory (e.g. anterior prefrontal regions). These findings are compatible with the view that involuntary (or unintentional) explicit memory involves an initially automatic component, supported by at least some of the same regions that are involved in implicit memory, followed by conscious recollection, supported by distinct brain regions (Schacter and Badgaiyan 2001). Schott's findings are also consistent with the position that some memories may remain implicit under both primary senses of the term, i.e. activated without intention and unconscious, at least with respect to identification of
the source of the memory. Indeed, some forms of implicit cognition may be completely distinct in representation or process (e.g. Eldridge et al. 2002).

For many issues in addiction and cognition, the critical question may not involve conscious awareness of the source of cognition but whether deliberation or intention is necessary for retrieval. If behaviour-relevant cognitions are spontaneously activated, even without intentional effort to retrieve a particular event from memory or direct questioning about a particular behaviour, then they may be influential under a wider variety of conditions or situations than cognitions that require such effort. Such memories may (but do not have to, see Bargh 2005) be accompanied by at least one of two forms of awareness: (1) awareness of content, as in a thought that spontaneously comes to mind; and (2) awareness of the source of the memory, as in involuntary explicit memory. Avoiding the first form of awareness is not a necessary criterion in cognitive neuroscience approaches to implicit memory, which often use indirect tests that require content to pop into mind (e.g. Vaidya et al. 1999; Levy et al. 2004; Schott et al. 2005). The second form of awareness (i.e. of source) is trickier to deal with, because involuntary explicit memory involves both an automatic (in the sense of unintentional) process and conscious awareness of source. If conscious awareness emerges only after an initial automatic process not involving awareness of source, the initial process could be characterized as implicit. Note that the point is not to argue for abandoning conscious recollection of source as a defining characteristic of involuntary explicit memory but to suggest that some sequences of cognition may involve both implicit and explicit processes. If one form of cognition happens to accompany or follow the other, it does not necessarily mean that one form has ‘contaminated’ the assessment of the other. It does mean that inferences are more difficult, since independence in the absence of other evidence is not a necessary or sufficient criterion.

A number of additional details about different forms of implicit processes have recently emerged from cognitive neuroscience. As examples, implicit habit learning, involving cue-outcome associations, has been found to remain intact in Alzheimer’s patients, who show impaired implicit conceptual and explicit memory (Eldridge et al. 2002). The basal ganglia, presumably spared in Alzheimer’s disease, are implicated in habit learning, whereas the association cortices and medial temporal lobe are implicated in implicit conceptual memory and explicit memory, respectively (e.g. Monti et al. 1996). Alzheimer’s patients show normal levels of implicit perceptual memory (e.g. Park et al. 1998), whereas amnesic patients often show normal levels of both
conceptual and perceptual implicit memory (for a review, see Gabrieli 1998). A range of additional dissociations indicative of different implicit processes have been revealed in Parkinson's patients (Knowlton et al. 1996; Moody et al. 2004), patients with specific damage to modality-specific areas related to perceptual priming (Fleischman et al. 1995) and patients with amygdala damage related to emotional conditioning (Bechara et al. 1995). In addition, recent fMRI research on implicit versus explicit evaluations has indicated that emotional stimuli automatically activate subcortical structures (including the amygdala) and that explicit processes supported by the frontal cortex and anterior cingulate can later moderate the automatic initial emotional response (Cunningham et al. 2003, 2004). The automatic emotional responses also can occur when stimuli do not reach conscious awareness (e.g. Dehaene et al. 2003; Cunningham et al. 2004). Overall, these data are consistent with the view that explicit memory and at least several different forms of implicit cognition can be distinguished neurologically and behaviourally. However, research on implicit cognition assessments in drug use have not yet been comprehensively linked to findings from neuroscience revealing diverse implicit processes, and these processes usually are not differentiated in either addiction theory or assessment. If the neural basis of responses to different types of indirect cognitive assessments in addiction are better understood, it could lead to important advances in understanding the different implicit cognition processes involved in addiction. The neuropsychological research suggests that a range of processes, with possibly distinct intervention implications, should be studied.

Several forms of implicit or automatic learning and memory processes have been directly implicated as reflections of the likely neural basis of addiction. Although there are a range of major views from neuroscience that can be applied to this specific topic in addiction (e.g. White 1996; Ahmed and Koob 2005; Everitt and Robbins 2005; Cox et al. 2006), space limitations restrict this chapter to only one of these theories. In the 'Incentive Sensitization Theory of Addiction' (IST), proposed by Robinson and Berridge (1993, 2003), addictive drugs endurably alter nucleus accumbens-related brain systems that mediate a basic incentive-motivational function, the attribution of incentive salience to stimuli that signal reward. As a consequence, these neural circuits become endurably hypersensitive (or 'sensitized') to specific drug effects and to drug-associated stimuli. This drug-induced brain change is called neural sensitization. As a result, this system automatically draws attention to drug-related stimuli (attentional bias) and can activate drug-seeking behaviour in the absence of conscious awareness (this process is labelled 'wanting' in
quotation marks, to distinguish it from conscious wanting). The neural circuit involved, the mesolimbic dopamine (DA) system, has been related both to natural appetitive behaviours (e.g. food and sex) and to addiction (Berridge 2001). The general idea is that this subcortical system has evolved to signal cues for important resources (food, sex), by attributing incentive salience to the representations of cues that were associated with the appetitive reward. These cues then become ‘wanted’ themselves (Berridge 2001). As a result, behaviour can become ‘irrational’: cues to which incentive salience has been attributed automatically attract attention and induce an approach tendency, even when a deliberate cognitive evaluation of the situation would suggest staying away (Stacy 1997; Berridge 2001; Wiers et al. 2002). According to this view, the crucial difference between an addicted and a not-addicted individual lies in an enhanced mesolimbic dopaminergic reaction both to the substance itself and to cues that have been associated with the substance. The activation of this system can but does not have to enter conscious awareness; if it does, this will be experienced as wanting or craving.

The ‘wanting’ response in animal research has been theoretically linked to an attentional bias in humans (Franken 2003) and to implicit alcohol-arousal associations (Wiers et al. 2002b, 2005), but these hypotheses need further confirmation (cf. Mogg et al. 2005; Cox et al. 2006). In the present framework, associations established between cues and reward can be considered part of a larger associative memory process that includes different types of implicit associations supported by different neural circuits. Consistent with Robinson and Berridge, as well as the previously mentioned work in cognitive neuroscience, at least several different systems may operate autonomously though they may also sometimes appear to act either in concert or in opposition.

2.3 Applying general theories of associative memory and connectionist frameworks

General theories of associative memory have only rarely been applied in any detail to addictive behaviours, either in theory or in intervention. Yet, these theories may provide ways to integrate otherwise disparate findings, as well as to begin to understand the cognitive processes underlying addiction and its amelioration. As shown later, these theories, with minor extensions, may help model a variety of implicit associations that are involved in addiction as well as prevention and treatment. It is beyond the scope of this chapter to reconcile these general theories with all the relevant research on the neural basis of implicit cognition and addiction. Rather, the present framework has the more
and triggered. Yet, such theories have only rarely been applied to addictive behaviours. Because these theories are relevant to at least some of the forms of association that are likely to play a role in these behaviours, a greater focus on the propositions from these theories may prove important for this area. The theories outlined here not only explain certain types of associations relevant to addiction but also suggest cognitive processes that may be fundamental for prevention and treatment. To be effective, most interventions with individuals must teach something that is retained in memory at some level. Yet, specific memory processes consistent with major theories and research on memory are rarely a focus and seldom acknowledged. Indeed, an associative memory approach suggests that many of the same memory processes that are relevant to addiction are relevant to prevention and cessation of this behaviour. Such an approach needs to consider a wide range of potential associations in memory (Stacy et al. 2004).

The present framework applies several approaches at different levels of analysis, not focusing only on a single theory or single type of association. This section focuses primarily on general theories of associative memory applicable to addiction, rather than addiction-specific theories, in hopes that the two types of theories can become better integrated in future research. One addiction-specific theory was outlined in the preceding section, and many have been thoroughly addressed in the chapters in this book as well as other recent work (Wiers and Stacy 2006). Application of general theories of memory to this area has been less common. The general theories vary in the extent to which implicit or automatic processes are formally covered, but in all instances the theories provide some process through which implicit or automatic cognitive processes can affect habitual or addictive behaviour and intervention outcomes. Some also provide possibilities for integrating findings from neuroscience. Rather than outline theories in detail, or list all relevant theories, the authors summarize some of the key processes from several examples of general theories of associative memory readily applicable to addictive behaviour. The focus is on processes that develop or strengthen associations, on how these associations trigger subsequent cognitions, on a general characterization of the representation or form of memory in each theory, and implications for addiction.

### 2.3.2 Spreading activation

One of the first concepts widely applied to automatic cognition phenomena was spreading activation (e.g. Posner and Snyder 1975; Anderson 1983; Neely 1991). Cognitive theories applying this concept are also applicable to a range of processes often characterized as implicit. Several approaches to additive
of activation in memory. A variety of strategies may enhance memory for programme-related material or skills in ways that overlap with the situations and cognitive state that precede a risky behaviour, essentially fostering new associations between the elements of these situations and the programme material (Stacy and Ames 2000; Stacy et al. 2004).

2.3.6 Hintzman’s multiple-trace theory

This theory posits a dramatically different form of representation from the preceding theories; yet it has many implications for addiction because of its focus on the details of experiences encoded in memory. In this approach, the active representation of an experience is registered in primary memory (PM), akin to working memory. Each experience is then encoded as a trace in secondary (long-term) memory (SM). Memory traces lie dormant in SM until they are prompted by a ‘probe’ (cue). When a probe is active in PM, its information is broadcast in parallel to all traces in SM. A single ‘reply’, termed an echo, returns to SM. The content of the echo depends on the similarity between the probe and all traces in SM. Traces having the most similarity to the features of the probe are most strongly activated in the echo. In other words, the common properties of the strongly activated traces will predominate the echo. In addition to content, another important property of the echo is its intensity. Intensity depends on the total amount of activation in SM, which is determined by both similarity (between probe and traces) and the number of activated traces. Intensity provides a type of familiarity signal, which may affect recognition, frequency, familiarity and other judgements about content.

Abstract knowledge, such as schemas or categories, is activated only during retrieval, when relevant traces are activated in the echo. A schema, category or other abstract, meaningful unit is represented by a configuration of many memory traces having certain elements or features in common; this approach can thus solve the problem of lack of operational definition or circularity in some schema approaches. Associative effects arise when a probe’s features (e.g. feature set A) are shared with traces that not only involve set A, but also involve additional features (set B). The probe activates the traces in complete units, which include the elements in common with the probe (set A) as well as features not in common (set B). Thus, features from both set A and B become activated in the echo. Associative effects have been directly applied in the context of paired associate learning (Hintzman 1984) as well as false memory (Arndt and Hirshman 1998), and we see no reason why they would not apply to associative and semantic priming and other phenomena involving relations or transitions. In addition to schema abstraction, categorization, paired
associates and false memory, the theory has been extended recently to decision making and heuristics and biases (Dougherty et al. 1999; Dougherty 2001; Bearden and Wallsten 2004), as well as to memory and probability judgements in ageing (Spaniol and Bayen 2005), underscoring its generality. A similar approach, at least in its instance representation, has been applied to social cognition (Smith and Zarate 1992; Castelli et al. 2004). The extensive generality of application of multiple-trace and other instance theories suggests that details are well worth considering for addiction.

Although applications of Hintzman’s multiple-trace theory have rarely mentioned concepts of automaticity or implicit processes, it is clear that memory in this approach is thought to affect behaviour in an automatic fashion not dependent on executive or explicit processes.

Because information is abstracted from concrete experiences at the time of retrieval rather than during learning, no sophisticated executive routine is needed to decide when and how to tune, reorganize or abandon memory structures. Reminding is not confined to predetermined structures, and changes in behaviour follow automatically from the indiscriminate accumulation of new episodic traces in memory (Hintzman 1986, p. 423)

Although Hintzman is presumably equating ‘behaviour’ with memory performance, a number of approaches suggest that activated memories can then spontaneously influence a range of behaviours (e.g. Bargh 2005), including addictive ones (for a review, see Wiers and Stacy 2006). Logan (1988) offered an instance theory that explicitly addresses automatization but is otherwise quite similar to Hintzman’s model, especially in its representation of memory.

It is important to note that multiple-trace theory posits a single memory system. This system operates primarily at the level of traces of individual experiences, which influence memory activation and performance. However, Hintzman suggests a more rudimentary level that represents each trace, which is a record (possibly imperfect) of the activation of primitive properties that were engaged during an experience. Primitive properties may involve sensory, emotional and simple relational features. It is reasonable to consider a parallel between these primitive properties and the units in distributed connectionist networks, though Hintzman has not drawn this parallel. Indeed, given the evidence from cognitive neuroscience summarized earlier, primitive properties probably have diverse neural substrates. If so, then memories for features that are represented by certain substrates may sometimes be impaired depending on individual differences or the encoding situation.

This view can be seen, at least heuristically, as a single memory system at the level of the memory trace and echo, consistent with Hintzman, but as multiple
connectionist network differs in a number of ways from the Hopfield network, in its reliance on 'hidden' layers, learning through backpropagation, and modelling the distinction between associative and semantic (similarity) effects. Although it is an open question whether multilayer networks and the use of backpropagation (e.g. Rumelhart et al. 1986) add substantially to the explanation of addiction-related cognitions provided by the much simpler Hopfield network, the distinction between association and semantics seems quite relevant. Although both the Plaut/Booth and Hopfield models rely on a common conception of similarity effects (arising from similar patterns of activation across the network), Plaut and Booth's model also focuses on transition learning as an associative process distinct from similarity. Indeed, this is one of the few models that explicitly differentiate associative from semantic effects in cognition. In transition learning, the neural network learns that pattern B follows pattern A, no matter what their semantic relationship or similarity. Once learned, transitions will readily occur in the future. In similarity effects, pattern B will more rapidly emerge from pattern A if the two patterns are similar in activated characteristics or features.

A very different model of memory (Processing Implicit and Explicit Representations, PIER 2) is provided by Nelson, McEvoy and their colleagues (e.g. Nelson et al. 1998, 2003). Since they recently applied their model to addictive behaviour (McEvoy and Nelson 2006), this chapter only highlights a few characteristics of the model. PIER 2 proposes independent implicit and explicit processes underlying a variety of memory effects. Since the model relies primarily on patterns of associations among concepts, rather than rule-based effects, it would be classified as a connectionist model under some definitions (Hintzman 1990; Bechtel and Abrahamsen 2002; Dawson 2004), even though it does not propose distributed representations characteristic of the most popular connectionist approaches (e.g. Rumelhart et al. 1986). The model postulates that a pattern of asymmetric associations in memory governs implicit activation. Various parameters (such as set size, association strength, connectivity and resonance) describe this pattern in ways that predict activation. One of the intriguing implications is that the pattern of interconnections among concepts that are not even directly experienced in a given situation will influence implicit processing and memory, if one or more of these concepts are associated in memory with something in the situation. Individual differences in what gets spontaneously activated in memory are likely to influence a range of behaviour, including drug use or healthy alternatives. This theory provides another example of an approach that is capable of operationally defining the elements of a schema-like pattern
from a programme (not only goals or intentions) may serve as an important mediator or trigger of further intervention-related processing (Stacy et al. 2004). This view is also in accord with a larger cognitive bias perspective derived from social cognition, underscoring the importance of cognitive transitions that channel processing in healthy directions. Memory for almost anything compatible with intervention goals may be capable of channelling such processing, leading to a potential intervention effect.

Another common element across the theories outlined in this chapter is the lack of reliance on processes that require intention or deliberate retrieval, though these may sometimes operate before behaviour ensues. The memory processes of focus here operate primarily at an implicit level, in accord with the definition outlined earlier in the chapter. Cognitive transitions are essentially spontaneous where A activates B without ongoing planning, deliberation or engagement of control processes. This commonality, as well as each of the preceding ones, has implications for intervention strategies that take into account implicit associations (Stacy and Ames 2000; Wiers et al. 2004, 2006b; Wiers and Stacy 2006).

A final commonality, though not an asset, is that the theories say little, if anything, about different forms of implicit or automatic processes. The neuropsychological evidence outlined earlier is consistent with the view that different types of associations in memory are supported by different systems in the brain. If one takes this multiple-system view, then these theories would not necessarily model all types of associations. On the other hand, a simple extension of some of the theories is quite feasible. One such extension was already offered for Hintzman's multiple trace theory. For the neural network models, one might propose that different sets of elements are represented in different modules or systems (cf. Johnson and Multhaup 1992), and sometimes whole sets of elements may not be activated (i.e. all elements in a module are 'off' in the Hopfield net). Nonetheless, the underlying principles (e.g. learning rules, activation parameters) from at least some models may apply to the full range of different cognitive processes (Plaut and Booth 2000). More work needs to be done to integrate general theories of associative memory fully with the neuroscientific findings in cognition and addiction.

2.4 Other concepts and associative memory

2.4.1 Cue reactivity and associative memory

In the present framework, common principles govern memory for all forms of learned information relevant to addictive behaviour. Thus, the reliance on association here may be seen as somewhat more general than conditioning...
approaches focused on the behaviour and reactivity of addicts (Carter and Tiffany 1999). However, in the future, it might be possible to subsume some conditioning phenomena in addiction under one or more of the theories outlined here or to otherwise integrate the approaches in some fashion (Hermans and Van Gucht 2006). Some integrations of information processing, conditioning research on addiction and other theories have been successful in previous work (Tiffany 1990; Baker et al. 1986; Curtin et al. 2006).

2.4.2 Expectancy and associative memory

The concept of expectancy has a rich heritage (Tolman 1932; Bolles 1975) and has been usefully linked to memory and addiction concepts in a variety of approaches (e.g. Stacy et al. 1990; Goldman et al. 1999; Krank and Wall 2006), as addressed more thoroughly in Chapter 6. Expectancy has been regarded as a unifying concept that at a high level of abstraction may provide an umbrella subsuming a variety of cognitive phenomena relevant to addiction (Goldman et al. 2006). However, expectancy can also be seen more narrowly as a certain class of association (Yin and Knowlton 2006), as a belief analogous to social learning concepts of outcome expectancies (Rotter 1954; Bandura 1977) or as a post-access (i.e. after memory access) decision or control process in basic cognitive research (Neely 1991). There are different views regarding what to do about these differences in conceptualization and definition.

A view closely aligned with basic research on automatic memory effects (Neely 1991) finds it especially difficult to reconcile or bridge the definitions, because expectancy is reserved for non-implicit processes. Since the present framework claims to maintain a close allegiance to these basic cognitive approaches, it would be confusing to use the term expectancy for several different psychological processes, including both implicit and explicit processes. There would also be confusion with the cognitive neuroscience and addiction research outlined earlier, because of the reviewed evidence for different neural systems linked to different aspects of both cognition and addiction. In the addiction domain, recent research has demonstrated that conditioned incentive salience (underlying 'wanting') can be dissociated from expected outcomes. Several independent studies have shown that one system can be manipulated, without affecting the other. For example, blocking the mesolimbic dopamine system blocks the incentive salience attribution but leaves the expectations unchanged, while prefrontal and insular lesions affect the expectations but not incentive salience (for a review, see Berridge 2001). Finally, more general dual-process models from different theoretical backgrounds all distinguish between rapid associative memory processes that are not constrained by capacity and limited capacity reasoning abilities,
AN IMPLICIT COGNITION, ASSOCIATIVE MEMORY FRAMEWORK

spanning domains such as social cognition (Strack and Deutsch 2004), cognitive psychology (Evans 2003; Evans and Coventry 2006), decision theory (Kahneman 2003) and neuroscience (Bechara et al. 2006). Importantly, in these models, if beliefs (equated with outcome expectancies in several major literatures) are addressed, they are part of the explicit system. Both implicit and explicit cognitive processes are important in determining behaviour, but they need to be clearly differentiated in these approaches.

In an alternative framework, consistent with the influential work of Goldman and his colleagues, expectancies can be used to conceptualize and measure one broad underlying process, and they are not necessarily equivalent with beliefs. In this view, one can measure expectancies with either direct or indirect measures. Expectancy is the unifying construct, not association. In the present framework, association or connection is one of the unifying constructs underlying implicit processes, not expectancy, and a hybrid approach that suggests that explicit and implicit processes are essentially the same process is avoided. This is both simplifying and strategic for the present framework. It is simplifying because expectancy has different meanings in different literatures (often involving quite explicit processes, e.g. Bandura 1977), and these meanings often become inconsistent or not applicable when applying basic research on implicit cognition to addictive behaviour. It is strategic because it places more focus on frequently ignored concepts from basic theories of associative memory: more comprehensive application of these concepts may yield important advances in understanding and intervention that might not be uncovered without this emphasis. Readers are referred to Chapter 6 for an alternative framework that focuses on a more general view of expectancy.

We believe that multiple approaches with different foci (e.g. associative memory, expectancy) may each lead to important advances if their unique contributions are taken to their limit, as is common in other areas of research. At the same time, commonalities across approaches should continue to be considered and acknowledged.

2.5 Need for integration with dual-process models and interventions

It is beyond the scope of this chapter to attempt a detailed account of dual-process models. However, it is important to note that an integration of connectionist/implicit cognition models with other processes is probably necessary for a complete understanding of addictive behaviour. Dual-process
models propose how implicit or automatic cognitions and more controlled, explicit or executive processes may unite to govern behaviour. Several useful dual-process models have been proposed for the addictions; several examples can be found in Wiers and Stacy (2006): a model based on neurobiological learning processes (Yin and Knowlton 2006), a model based on neuropsychological data (Bechara et al. 2006), a general dual-process model based on extensive cognitive research in reasoning (Evans 2003) modified to explain pathological gambling (Evans and Coventry 2006), a model based on many findings in social cognition research (Strack and Deutsch 2004) applied to addictive behaviours (Deutsch and Strack 2006), a model based on acute drug effects (Fillmore and Vogel-Sprott 2006) and a model integrating findings from alcohol research (Wiers et al. 2006). Common to all these models is that there are at least two relatively independent systems involved in addictive behaviours, one based on automatic associative processes in response to drug-related stimuli, and a second lower capacity control system that (if motivation and capacity permit) may steer the person away from the drug-related stimuli (in contrast to the automatic approach reaction triggered by the automatic process). Some models involve more processes (e.g. Bechara et al. 2006; Yin and Knowlton 2006) and there are also indications that an automatic aversive reaction may play some role (Wiers et al. 2006). However, across the models, one important road to addiction concerns a process in which the automatic appetitive reactions gain relative strength over the controlled processes, over the time the addictive behaviour develops. Further, the same occurs more strongly once a drug-using episode has been initiated, given the strong immediate deleterious effects of drugs on the controlled processes, in the absence of impairing effects on the associative processes (Fillmore and Vogel-Sprott 2006).

From this perspective, individual differences in vulnerability for addictive behaviours can come from different sources, which matches the now common idea that many different genes are important in the vulnerability of addictions (see Chapter 8), of which some appear to be related to a general risk for addictive behaviours, while others are related to a vulnerability (or an invulnerability) to develop a specific addiction (Goldman and Bergen 1998; McGue 1999). Concerning general factors, individuals differ in their sensitivity to reward (cf. Gray 1990; Bechara et al. 2006) as well as in their sensitivity to punishment (Finn et al. 1994). There is also evidence that individuals differ in the speed with which they develop sensitization (Robinson and Berridge 2003), i.e. the rewarding effects of drugs get stronger, once drug use has initiated; there also appear to be genetic predispositions in the development
2.6 CONCLUSION

Associative memory and connectionist theories are relevant to addictions because they provide global models capable of integrating cognitive, emotional, sensory and motor aspects of addiction within a system that learns from experience, biases decisions, and acquires and perpetuates habits. Thus, such theories provide frameworks from which diverse empirical phenomena obtained from different levels of analysis can be seen in a larger explanatory context. Under such an umbrella, observations at different levels of analysis (e.g., neural versus cognitive) are reflections of a more general architecture that translates experience into cognitions that bias and influence later behaviour. One of the primary reasons for a focus on associative memory theories is that they provide at least several specific propositions that may be fundamental for understanding how these biases operate and how they influence addictive behaviour and its prevention or treatment. Yet, the theories must be extended, at least slightly in some instances or substantially in others, to cover the full range of phenomena uncovered in research on addiction and implicit cognition.

A focus on implicit processes, at least those not requiring deliberation, is relevant to addictive behaviours because they suggest how certain cognitions can spontaneously affect behaviour that is otherwise difficult to understand. The idea that there is a cognitive system, or set of systems, that is not governed
When one considers the evidence, this state of affairs is probably in common across all cognitive models of behaviour. Incorporating non-implicit systems into the mix further complicates things but is certainly important for future research and intervention. Indeed, dual-process models provide an exciting range of possibilities for further development. The present framework suggests that a greater linkage to measures and theories derived from basic cognitive research on both implicit and non-implicit processes may dramatically increase progress in cognitive research on addiction.

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AN IMPLICIT COGNITION, ASSOCIATIVE MEMORY FRAMEWORK


AN IMPLICIT COGNITION, ASSOCIATIVE MEMORY FRAMEWORK


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