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Citation: Tapper, K. (2018). Mindfulness and craving: effects and mechanisms. *Clinical Psychology Review*, 59, pp. 101-117. doi: 10.1016/j.cpr.2017.11.003

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Mindfulness and craving: effects and mechanisms

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Abstract

Mindfulness meditation has a long tradition of being used to manage cravings. This paper reviews 30 experimental studies that have examined the effects of different types of mindfulness practice on cravings for food, cigarettes and alcohol. The findings are interpreted in light of relevant theories of craving. The studies show most support for the elaborated intrusion theory of desire and conditioning models. They suggest that whilst mindfulness strategies may bring about immediate reductions in craving, such effects are likely to stem from working memory load, and will not necessarily be superior to alternative strategies that also load working memory. Likewise, reductions in craving over the medium term may occur due to extinction processes that result from the individual inhibiting craving-related responses. Again, alternative strategies that promote response suppression may be equally effective. Nevertheless, a smaller number of studies show promising results where mindfulness exercises have been repeatedly practiced over a longer period of time. The results of these studies provide tentative support for Buddhist models of craving that suggest mindfulness practice may confer unique benefits in terms of both craving reduction and reducing the extent to which craving leads to consumption. Further research would be needed to confirm this.

Keywords

mindfulness; craving; food; cigarettes; alcohol; behavior change

Mindfulness and craving: effects and mechanisms

Craving can be defined as an intense, conscious desire, usually to consume a specific drug or food (Drummond, 2001; May, Kavanagh & Andrade, 2015; Tiffany & Wray, 2012; Pelchat, 2002). Although the clinical relevance of craving has been questioned (Wray, Gass & Tiffany, 2013), there is also a significant body of research that suggests it is causally linked to behavior. For example, craving predicts relapse episodes in substance use (Serre, Fatseas, Swendsen & Auriacombe, 2015) and food cravings predict both eating and weight gain (Boswell & Kober, 2016). As such, cravings are often considered an appropriate target for intervention, the assumption being that reducing craving, or changing a person's response to craving, will impact upon the related behavior.

Mindfulness meditation has a long tradition of being used to address cravings. According to ancient Buddhist texts, craving leads to suffering but can be avoided through mindfulness meditation practice (Dhammacakkappavattana Sutta: Setting in Motion the Wheel of Truth [SN 56.11], 2013). More recently, mindfulness-based interventions have been used to explicitly target cravings with the aim of bringing about clinically relevant changes to behavior (e.g., Alberts, Mulken, Smeets & Thewissen, 2010; Ruscio, Muench, Brede & Waters, 2016; Zemestani & Ottaviani, 2016). However, such interventions often comprise a range of mindfulness and non-mindfulness components, making it difficult to unequivocally attribute any changes in craving to the mindfulness-based elements of the intervention (e.g., Bowen et al., 2009; Bricker et al., 2014; Garland, Robert-Lewis, Tronnier, Graves & Kelly, 2016; Zemestani & Ottaviani, 2016; see also Tapper, 2017). As such, the effects of mindfulness practice on craving have yet to be scientifically established.

Mindfulness interventions also typically employ a range of different types of strategy, for example they may include exercises designed to promote greater awareness of bodily sensations, to develop an attitude of acceptance toward uncomfortable feelings, or to help individuals see themselves as separate from their thoughts and emotions (Tapper, 2017). However, we currently have limited understanding of the ways in which these different types of strategy may influence craving-related outcomes, either independently, or in combination. Although some authors have proposed models to account for potential effects (Brewer et al., 2013), many aspects of these have yet to be tested experimentally. As such we lack a full understanding of the ways in which mindfulness practice might influence cravings. This is important because a sound theoretical basis is essential for the development of effective interventions (Michie & Abraham, 2004).

The current article aims to address these limitations by reviewing studies that have examined the independent effects of mindfulness on craving. In other words, the review is restricted to studies in which the experimental manipulation or intervention consists only of mindfulness components. Such an approach inevitably excludes interventions that combine mindfulness strategies with other therapeutic approaches¹

¹ A number of existing reviews already examine the effects of these types of multi-component mindfulness-based interventions in areas relevant to craving, including substance use disorders (Chiesa & Serretti, 2014; Zgierska et al., 2009), substance misuse (Li, Howard, Garland, McGovern & Lazar, 2017), smoking cessation (Maglione et al., 2017), binge eating, emotional eating and weight loss (Katterman, Kleinman, Hood, Nackers & Corsica, 2014; Olson & Emery, 2015; O'Reilly, Cook, Spruijt-Metz & Black, 2014).

(e.g., Mindfulness-Oriented Recovery Enhancement, see Garland, 2013; Acceptance and Commitment Therapy, see Hayes, Strosahl & Wilson, 1999). However, restricting the review in this way should allow any effects on craving to be more confidently attributed to the mindfulness manipulation. It should also make it easier to compare the effects of different types of mindfulness practice as well as evaluate potential mechanisms of action. As such, the review has three key aims: (a) to examine the effects of mindfulness-based practices on craving, (b) to compare the effects of different types of mindfulness-based practices on craving, and (c) to explore the mechanisms via which mindfulness-based practices may exert any effects on craving.

The review is informed by conceptualizations of mindfulness that distinguish between three key components; present moment awareness, acceptance and decentering (Creswell, 2017; Tapper, 2017). Present moment awareness refers to the self-regulation of attention so that it is maintained on present moment experience, for example ones breath, bodily sensations or the content of ones thoughts; acceptance involves taking a non-judgmental attitude towards ones thoughts, feelings and bodily sensations; decentering means viewing ones thoughts and feelings as transient events that are separate to oneself. In practice it may be difficult to completely distinguish between the effects of these three different techniques since acceptance and decentering likely require a certain amount of present moment awareness. It is also possible that acceptance and decentering arise spontaneously from repeated present moment awareness (Bishop et al., 2004; Brown & Ryan, 2004; Shapiro, Carlson, Astin & Freedman, 2006). Nevertheless, it is possible to target these techniques independently and different theories of craving make differential predictions about their relative importance. For this reason, the current review is guided by the emphasis each study places on each of these three different components.

The review begins by looking at the ways in which mindfulness relates to selected theories of craving, in order to identify potential mechanisms of action and specific predictions that can be experimentally tested. It then examines studies of mindfulness and craving in light of these theories with a view to identifying future directions for more experimental work in the area as well as informing the development of more evidence-based mindfulness interventions designed to tackle cravings.

Theories of Craving

A wide range of different theories and models have been put forward to account for cravings (see Skinner & Aubin, 2010). A full discussion of these is beyond the scope of the current article; only those with relevance to the potential impact of mindfulness practice on craving will be considered here. These are grouped under the broad headings of conditioning-based models, cognitive models, and Buddhist models.

Conditioning-based models. Conditioning-based models draw on classical or Pavlovian conditioning. They state that cues that predict either drug use itself, or withdrawal from a drug can come to elicit physiological responses that occur due to use of the drug, or in homeostatic response to the use of the drug. These in turn result in a feeling of craving (Skinner & Aubin, 2010). Such models have also been applied to food cravings (Jansen, Havermans & Nederkoorn, 2011). For example, if a person always stops for a doughnut on their way to work, cues associated with travel to work may eventually come to elicit insulin and salivary responses. According to conditioning-based models, these will be experienced by the individual as a craving and they will be more likely to eat. Where a cue is associated with drug use, or eating, preventing the behavioral response will eventually extinguish the association with the cue. In other words, the cue will no longer predict drug use or eating and therefore will no longer

elicit the physiological response and the experience of craving. According to such models, cravings could also be reduced by simply avoiding the cues that elicit them.

Thus in terms of mindfulness, any strategy that promotes exposure to relevant cues in the absence of the behavioral response will, according to such models, reduce both the frequency and strength of cravings through extinction. This could apply to acceptance strategies in which the individual is encouraged to accept uncomfortable thoughts and feelings rather than try to avoid or control them. Although such a strategy would not have any effect on cravings in the short term, we may see a reduction over a longer time period if the technique is consistently applied and provided the individual manages to successfully inhibit the behavioral response. If the individual is unable to suppress the behavior we would not expect to see any change in level of craving. However, it is unclear whether this technique would be any more successful compared to other programs or motivational strategies that promote response suppression (e.g. Jansen et al., 2011). One way in which it might be more effective is if it leads to increased exposure to conditioned stimuli. For example, if the individual is encouraged to accept cravings rather than try to avoid them, they may be more willing to maintain exposure to relevant cues. This in turn would lead to more rapid extinction, again assuming the individual is able to resist the target substance. The same type of effects may also apply to present moment awareness techniques that direct the individual's attention to relevant cues (which may be internal, such as negative mood, as well as external); providing the behavioral response is inhibited, increased exposure may lead to more rapid extinction and hence to a relatively faster reduction in the frequency and strength of cravings.

One potential difficulty with this type of strategy in relation to food cravings, is that individuals need to eat. This means that it may be difficult to consistently inhibit

eating in response to a particular cue. For example, if one is applying an acceptance strategy to chocolate cravings in general, but is aiming to reduce, rather than quit eating chocolate, effects on cravings may be more limited since on the occasions when chocolate is eaten, associations between cues (e.g. the sight of chocolate) and eating will inevitably be strengthened. Acceptance and present moment awareness strategies may be more successful at reducing cravings where they are used to target a very specific cue-response association, and where the individual is prepared to completely quit that specific response, such as eating a chocolate bar during a mid-morning coffee break. Nevertheless, even where such strategies are applied more generally, if the individual successfully manages to inhibit their eating, this may increase self-efficacy in relation to resisting cravings. Since self-efficacy is an important determinant of behavior change (Bandura, 1998; Teixeira et al., 2015) this may help promote reduced consumption. Under these circumstances we may see changes in eating behavior in the absence of any change in cravings. Indeed, there is some evidence to support this type of decoupling effect in research on smoking, among participants who have simply cut back on smoking rather than abstained completely (Bowen & Marlatt, 2009; Elwafi, Witkiewitz, Mallik, Thornhill & Brewer, 2013, see also Levin, Luoma & Haeger, 2015).

Cognitive models. Whilst cognitive models of craving may include reference to conditioning processes, they differ from conditioning models in that they also assume that higher order cognitive processes, such as attention and memory play an important role in the craving response. The three cognitive models with most relevance for mindfulness practice are the cognitive processing model (Tiffany, 1990; Tiffany & Conklin, 2000), the elaborated intrusion theory of desire (Kavanagh, Andrade & May, 2005; May, Andrade, Kavanagh & Hethrington, 2012; May et al., 2015), and the theory of grounded cognition (Barsalou, 2008). These will each be considered in turn.

Cognitive processing model. The cognitive processing model (Tiffany, 1990; Tiffany & Conklin, 2000) was developed to account for drug addiction. It states that in the addict, drug use is controlled by action plans that are stored in memory and carried out in an automatic manner. According to this theory, episodes of craving only arise when something interrupts the execution of this action plan, preventing the individual from consuming the drug. This may occur because of an external event, such as the drug being unavailable, or as a result of the individual's internal efforts to abstain from the drug.

According to this theory, episodes of craving are not causally related to drug use or relapse and therefore efforts to reduce craving are unlikely to impact upon drug use behavior. Instead, the theory suggests that intervention efforts should be focused on (a) removing the stimuli that elicit the action plans, or (b) protecting or enhancing the processing resources that are needed to inhibit the execution of the action plan (Tiffany & Conklin, 2000). Mindfulness-based present moment awareness techniques are relevant for this theory because of their emphasis on becoming aware of what is happening at that moment in time, in other words bringing conscious awareness to what might otherwise be automatic processes and behaviors. Thus for an individual who is motivated to abstain from drugs, increased present moment awareness may help better enable them to recognize when they are about to automatically consume a drug which would in turn allow them to inhibit the action; in other words, mindfulness may increase a person's ability to regulate automatic behaviours. However, although this might lead to a reduction in drug use behavior we would expect this to be coupled with an increased frequency in episodes of craving.

Elaborated intrusion theory of desire. The elaborated intrusion (EI) theory of desire (Kavanagh et al., 2005; May, Andrade, Kavanagh et al., 2012; May et al., 2015)

emphasizes the role of cognitive processes in the experience and maintenance of episodes of craving. In keeping with conditioning models, it maintains that the initial source of cravings are learned associations between specific internal or external cues and a particular behavior (e.g. eating). These, together with associated physiological responses, may result in intrusive thoughts. When these thoughts elicit powerful affective reactions, or a sense of deficit, they lead to cognitive elaboration. Cognitive elaboration is a controlled process in which relevant information is sought from memory then manipulated in working memory in order to construct vivid sensory images related to the object of desire and its acquisition. According to EI theory, it is this cognitive elaboration that is experienced as desire or craving and, because of the similarity between mental imagery and real cues, it also serves to maintain and augment craving. Thus according to this model, anything that prevents or interrupts the elaborative processes will serve to prevent or limit the duration of the craving episode.

In terms of mindfulness techniques, both present moment awareness and decentering strategies may serve this function. Attending to present moment experience may mean that attentional processes are directed toward a range of different sensory inputs, rather than internal image construction. This may prevent the elaboration of intrusive thoughts, and thus prevent craving from occurring. Or it may interrupt a craving episode, restricting its duration. As with conditioning-based models of craving, if this technique is repeatedly practiced, with the behavioral response repeatedly suppressed, associations between cues and the relevant behavior will be extinguished such that there will be fewer intrusive thoughts, and a reduction in the frequency of craving episodes. The technique of decentering may have a similar effect; encouraging a person to see their thoughts as simply thoughts may interrupt their elaboration. For example, if thoughts about the pleasurable smell of cigarette smoke are

followed by an awareness of this as simply a 'thought', this may be more likely to be followed by thoughts about abstinence-related goals, rather than thoughts about the satisfying effects of smoking a cigarette (Tapper & Ahmed, 2015). However, it is not clear that these strategies of present moment awareness and decentering would necessarily be more successful than other techniques that prevent or interrupt elaboration, such as diverting attention or engaging in tasks that load working memory (e.g. Kemps & Tiggemann, 2007; 2013; Van Dillen, Papies & Hofmann, 2013).

In terms of acceptance strategies, according to EI theory, it is possible that they may actually exacerbate cravings; if an individual is, in the absence of any other instruction, encouraged to accept their thoughts and feelings, this may result in them engaging in more elaboration, which may in turn increase both the strength and duration of the craving episode.

Negative affect also plays an important role in EI theory; by increasing the individual's sense of deficit it increases the likelihood that intrusive thoughts will be elaborated. There is evidence to suggest that mindfulness can improve emotional regulation and decrease negative affect (Chambers, Gullone & Allen, 2009). A range of different mechanisms have been put forward to explain this effect, including reduced rumination (Williams, 2008), reduced reactivity to potentially emotive stimuli (Chambers et al., 2009), exposure and extinction processes (Hölzel et al., 2011) and positive reappraisal (Garland, Gaylord & Park, 2009; Hölzel et al., 2011). As such, reductions in negative affect represents an additional pathway via which mindfulness strategies may reduce the frequency and duration of craving episodes. However, such processes are unlikely to be captured in a laboratory setting.

Additionally, present moment awareness exercises typically involve attention regulation. Continued mindfulness practice may therefore result in improvements in

attention regulation (Chiesa, Calati & Serretti, 2011; Mrazek, Franklin, Phillips, Baird & Schooler, 2013). Consistent with EI theory, this improved attention regulation could impact upon craving via a number of different pathways. First, there is some evidence to suggest that mindfulness practice may help reduce attentional bias toward substance-related stimuli (Garland, Boettiger, Gaylord, Chanon & Howard, 2012; Garland & Howard, 2013), presumably by enhancing attentional disengagement (Garland, Froeliger & Howard, 2014). Research suggests that, in keeping with EI theory, attentional bias and craving have reciprocal effects on one another, such that attentional bias can increase craving and increases in craving can also lead to attentional bias (Field & Cox, 2008; Field et al., 2016). As such, if mindfulness practice can improve attentional disengagement, and in doing so lead to reductions in attentional bias, it should also result in reduced craving frequency.

A similar process could also come into effect after a craving episode has been initiated since improved attentional disengagement could enhance the individual's ability to divert their attention away from elaborative processes involved in the construction of sensory images. As such we may see reductions in the duration of craving episodes.

Finally, the two processes outlined above (diverting attention away from stimuli that elicit craving, and diverting attention away from elaborative processes involved in the maintenance of craving) could also be applied to stimuli and rumination associated with negative affect. As such, improved attention regulation could also reduce craving via a reduction in negative affect, as detailed previously.

Thus, according to EI theory, mindfulness practice could help limit the frequency and duration of craving episodes via improvements in attention regulation. However,

we would only expect such effects to occur after a certain period of repeated mindfulness practice.

Theory of grounded cognition. The final cognitive theory that will be considered here is the theory of grounded cognition (Barsalou, 2008). According to this theory, individuals draw on previous experience to simulate interacting with stimuli they encounter in their environment, and these stimulate similar areas of the brain to real interactions, triggering associated bodily responses, increasing both conscious desire and appetitive behaviors outside of conscious awareness (Papies & Barsalou, 2015). According to this theory, applying the mindfulness technique of decentering, should help reduce the believability of these mental simulations, and in doing so reduce the extent to which they elicit desire. As such we should see immediate effects on the strength of craving episodes. Again, where these are coupled with suppression of the behavioral response, we should also eventually see reduced craving frequency, due to extinction processes.

Buddhist-based models. Several academics have proposed models of craving and desire derived from traditional Buddhist accounts (Brewer et al., 2013; Grabovac, Lau & Willett, 2011). Interestingly, these are similar to EI theory in that craving is conceptualized as a cognitive response to automatic, conditioned associations. According to Buddhist texts, perceptual stimuli or thoughts result in automatic affective reactions, based on our previous experience with those, or related stimuli. These affective reactions lead to mental elaboration and a feeling of desire (or craving), either to maintain positive feelings or avoid negative feelings. This feeling of desire motivates a particular behavioral response. Where this behavior is reinforced (i.e. through maintenance or avoidance of positive or negative feelings respectively), a habit may start to emerge (Brewer et al., 2013; Grabovac et al., 2011). For example if, upon visiting

a new bar, we sampled and enjoyed an exotic liqueur, on our next visit the sights and sounds of the bar may elicit a feeling of pleasure associated with the taste of the liqueur. This feeling of pleasure may lead to a desire to maintain this pleasure. The desire comprises both thoughts and emotions and is experienced as a craving. The craving leads us to order a glass of the liqueur, which is enjoyable and so reinforces the behavior of drinking liqueur in this particular bar in order to maintain a feeling of pleasure. With repetition we may get into the habit of always drinking this particular liqueur in this particular bar.

According to this account there are several ways in which mindfulness practice influences cravings. First, similar to EI theory, Buddhist-based models state that an individual can only maintain attention on one object at a time. Thus increasing present moment awareness of perceptual stimuli, and/or our affective reaction to these, will prevent the subsequent thoughts and reactions that constitute craving (Grabovac et al., 2011). As such, we should see a reduction in the frequency and duration of episodes of craving. According to Grabovac et al. (2011), an attitude of acceptance facilitates the individual's ability to maintain their attention on their present moment experience as it helps prevent negative thoughts such as self-judgment. As such we would not expect acceptance strategies alone to influence craving but we would expect acceptance plus present moment awareness to reduce the frequency and duration of craving episodes to a greater extent than just present moment awareness.

Additionally, Buddhist-based models suggest that by more closely observing their affective reactions, the individual develops an insight into their causes, their transient nature and the futility of attempting to sustain or avoid them. This increased metacognitive awareness motivates the individual to avoid acting on their cravings (Brewer et al., 2011; Grabovac et al., 2011). As such, where an individual's craving

related behavior is at odds with their goals, we would expect to see a decoupling between craving and behavior, with episodes of craving no longer predicting consumption. Eventually, because craving is no longer being reinforced, we would also expect to see a reduction in craving frequency and strength.

Summary of key predictions based on models of craving

Table 1 provides a summary of key predicted effects of different mindfulness strategies on craving according to the models described above.

Table 1.

Key predicted effects of present moment awareness, acceptance and decentering strategies on craving frequency, strength and duration over the short, medium and long term according to different models of craving.

Mindfulness strategy	Relative point at which effect should appear	Type of effect on craving	Model(s) that predict such an effect
Present moment awareness	Immediate	Reduced frequency and duration	EI; Buddhist
	Medium term	Increased frequency (where individual is motivated to inhibit craving-related behavior)	Cognitive processing
	Medium term	Decoupling of the relationship between craving and craving-related behavior	Buddhist
	Medium to long term	Reduced frequency and strength (where craving-related behavior is consistently suppressed)	Conditioning; EI, Buddhist
	Medium to long term	Reduced frequency and duration (via improved attention regulation)	EI
Acceptance	Immediate	Increased strength and duration	EI
	Immediate	Reduced frequency and duration (when employed with present moment awareness)	Buddhist
	Medium to long	Reduced frequency and	Conditioning

	term	strength (where craving-related behavior is consistently suppressed)	
	Medium to long term	Reduced frequency and strength (when employed with present moment awareness and where craving-related behavior is consistently suppressed)	Buddhist
Decentering	Immediate	Reduced frequency and duration	EI
	Immediate	Reduced strength	Grounded cognition
	Medium to long term	Reduced frequency and strength (where craving-related behavior is consistently suppressed)	EI
	Medium to long term	Decoupling of the relationship between craving and craving-related behavior	Buddhist

Table 1 illustrates the ways in which different models make different predictions. For example, EI theory and Buddhist models are the only ones that predict immediate reductions in craving as a result of increased present moment awareness, the cognitive processing model is the only one to predict increased craving as a result of present moment awareness, and EI theory is the only one that predicts immediate increases in craving as a result of acceptance strategies. Likewise, Buddhist models are the only models to explicitly predict a decoupling between craving and craving-related behavior and EI theory and grounded cognition are unique in predicting immediate reductions in craving as a result of decentering. The next section reviews relevant studies on mindfulness and craving in light of these predictions.

Effects of Mindfulness on Craving

Literature search and study selection. A literature search of English language publications was conducted during May 2016 using Web of Science and the search

terms 'mindful*', 'attentive eating' and 'intuitive eating', each paired with the terms 'craving', 'desire' and 'urge'. This search was repeated in May 2017 and September 2017 to identify any additional publications. These searches led to the identification of 294 records. The titles and abstracts of these were reviewed and 250 were excluded on the basis of at least one of the following: (a) no mindfulness manipulation, (b) no control or comparison group, (c) no craving or desire related outcome, (d) a non-ingestive craving or desire related outcome (e.g. sexual desire or gambling), (e) meeting abstract providing limited information. The remaining 44 papers were examined in full. Of these, 27 were excluded on the grounds that they (a) combined mindfulness with non-mindfulness techniques, (b) did not include a craving related outcome, (c) had no control or comparison group and/or (d) reported secondary analysis of data already included in the review. A further six papers were identified from the reference sections of these publications and also examined in full. Two of these were subsequently excluded for having no craving related outcome and examining non-ingestive related craving. An additional five papers were identified on the basis of author knowledge.

This resulted in a total of 26 publications, describing 30 studies, 16 of which examined food-related cravings, 11 cravings for cigarettes, and three cravings for alcohol. The key features of these studies are summarized in Appendix A. They are ordered according to the time period over which cravings were assessed. Unless otherwise stated, measures of craving and desire primarily refer to strength of craving whilst measures of 'trait craving' include assessments of strength, frequency and duration.

Immediate effects. A total of 21 studies included measures of craving taken either during or immediately following the mindfulness manipulation (see Appendix A). Within these 21 studies there were a total of 44 comparisons; 14 showed significantly

lower levels of craving in the mindfulness condition compared to a control condition (Caselli, Gemelli, Spada & Wells, 2016; Cropley, Ussher & Charitou, 2007; Hamilton, Fawson, May, Andrade & Kavanagh, 2013; May, Andrade, Willoughby & Brown, 2012; Schumacher, Kemps & Tiggemann, 2017; Ussher, Cropley, Playle & Mohidin, 2009; Westbrook et al., 2013), one showed a trend in this direction (Papies, Pronk, Keesman & Barsalou, 2015), 22 showed no difference (Adams et al., 2013; Alberts, Thewissen & Middelweerd, 2013; Arch et al., 2016; Bowen & Marlatt, 2009; Fisher, Lattimore & Malinowski, 2016; Hamilton et al., 2013; May, Andrade, Batey, Berry & Kavanagh, 2010; Murphy & MacKilop, 2014; Schumacher et al., 2017; Szasz, Szentagotai & Hofmann, 2012; Ussher et al., 2009; Vinci et al., 2014), six showed a higher level of craving in the mindfulness condition (Alberts et al., 2013; Arch et al., 2016; May et al., 2010; Murphy & MacKilop, 2014; Szasz et al., 2012; Vinci et al., 2014;), and one showed a trend in this direction (Arch et al., 2016). Thus, taken together, these results fail to provide compelling evidence for an immediate beneficial effect of mindfulness on craving. However, given the diversity of mindfulness strategies and comparison conditions employed in these studies, it is worth examining them more closely.

Of the 15 comparisons that showed significant or near significant benefits of mindfulness, five employed present moment awareness (Cropley et al., 2007; Hamilton et al., 2013; May, Andrade, Willoughby et al., 2012; Ussher et al., 2009), one employed both present moment awareness and acceptance (Westbrook et al., 2013) and nine used decentering (Caselli et al., 2016; Papies et al., 2015; Schumacher et al., 2017). However, the control conditions in 12 of these 15 comparisons comprised listening to (as opposed to decentering from) a pre-recorded audio of alcohol related thoughts (Caselli et al., 2016), listening to an audio recording of a natural history text (Cropley et al., 2007; Ussher et al., 2009), no strategy (Westbrook et al., 2013), mind wandering (Hamilton et

al., 2013; May, Andrade, Willoughby et al., 2012; Schumacher et al., 2017) and viewing pictures of food in a relaxed manner (as opposed to decentering from reactions to them; Papies et al., 2015). Thus, arguably, these studies may not have controlled for the additional working memory load the mindfulness strategies likely entailed. As noted previously, according to EI theory any strategy that engages working memory, particularly the visuospatial sketchpad, will prevent the elaboration of intrusive thoughts and in doing so reduce cravings. As such we cannot be certain that the mindfulness strategies brought about reductions in craving over and above what might have been achieved with other strategies that placed an equivalent load on working memory, for example visualization strategies.

Out of the 44 comparisons, 14 specifically used control conditions that are likely to have drawn on visual working memory, through the use of guided imagery, imagery diversion, word puzzles and isometric exercises (Arch et al., 2016; Fisher et al., 2016; Hamilton et al., 2013; May et al., 2010; Schumacher et al., 2017; Ussher et al., 2009). Of these 14 comparisons nine found no difference between the mindfulness and control conditions (Arch et al., 2016; Hamilton et al., 2013; May et al., 2010; Schumacher et al., 2017; Ussher et al., 2009), three found lower levels of craving in the mindfulness condition (Schumacher et al., 2017), one found higher levels of craving in the mindfulness condition (Arch et al., 2016), and one found a trend in this direction (Arch et al., 2016). The three comparisons that found lower levels of craving in the mindfulness condition used a decentering technique (Schumacher et al., 2017). These findings support the theory of grounded cognition that predicts that decentering will have beneficial effects over and above guided imagery. However, a replication of this study failed to show any significant differences between these two conditions (Schumacher et al., 2017). The studies that used present moment awareness techniques

(Arch et al., 2016; Fisher et al., 2016; Hamilton et al., 2013; May et al., 2010; Ussher et al., 2009) all found no difference in craving, or higher levels in the mindfulness condition. These results are consistent with EI theory in that they suggest that present moment awareness does not lead to immediate reductions in cravings over and above what can be achieved via other techniques that also prevent the elaboration of craving-related thoughts.

A further three studies used listening to audio as a control condition, either a natural history text (Cropley et al., 2007; Ussher et al., 2009), or a description of a rainforest (Fisher et al., 2016). One might expect these to effectively prevent the elaboration of craving-related thoughts only insofar as they included visual imagery and engaged participants' attention. Where present moment awareness was compared to the description of a rainforest it showed no relative reductions in craving on two separate occasions (Fisher et al., 2016); where it was compared to listening to an audio recording of a natural history text, both studies showed greater reductions in craving in the present moment awareness condition (Cropley et al. 2007; Ussher et al., 2009). Arguably however, the natural history text employed in the latter two studies (*Natural History and Antiquities of Selborne*, first published in 1789) may not have fully engaged the participants' attention or their visual working memory.

In terms of the types of mindfulness strategies employed across these 21 studies, 16 involved some type of present moment awareness, for example of bodily sensations, cravings or the sensory properties of food. Just one study (Szasz et al., 2012) attempted to manipulate acceptance in isolation and this showed no significant effect on cravings compared to those who engaged in thought suppression, and increased cravings compared to those who engaged in reappraisal. Four studies manipulated decentering in isolation (Caselli et al., 2016; Papiés et al., 2015; Schumacher et al., 2017). As noted

previously, whilst one of these studies (Schumacher et al., 2017) showed beneficial effects of decentering over and above guided imagery, this effect was not replicated in a second study (Schumacher et al., 2017). Also as noted previously, although two other studies also showed lower cravings in the mindfulness condition (Caselli et al., 2016; Papies et al., 2015), it is possible that the effects were driven by working memory load rather than the decentering strategy per se. Further research would be needed to explore this interpretation as well as establish any immediate benefits of decentering over and above guided imagery.

Thus in terms of relevant theories of cravings, identified in Table 1, the results are broadly consistent with EI theory; where present moment awareness and decentering strategies have brought about immediate reductions in craving, this may be because they entailed a greater load on working memory that interrupted elaborative processes; where present moment awareness strategies have been compared to other strategies that also engage working memory, they lose their advantage. Additionally, consistent with EI theory, the only study to attempt to examine acceptance in isolation, found that it increased cravings relative to a reappraisal strategy (Szasz et al., 2012).

The other two theories that relate to the immediate effects of mindfulness are grounded cognition and Buddhist models. Grounded cognition predicts that decentering strategies would produce immediate reductions in craving, and whilst three studies have shown such effects (Caselli et al., 2017; Papies et al., 2015; Schumacher et al., 2017), as mentioned previously only one of these studies compared decentering with guided imagery and the advantage of decentering was not replicated in a second study (Schumacher et al., 2017). As such, further research would be needed to test this prediction and distinguish between an EI versus grounded cognition account of decentering effects. Likewise, it is difficult to draw any firm conclusions about Buddhist

models from these studies. Buddhist models would predict immediate reductions in craving as a result of present moment awareness strategies, with acceptance enhancing these effects. Although such effects are not supported by the studies reviewed here, it is important to note that in none of these studies did participants receive mindfulness training; they were instead simply provided with brief instruction to help them employ a specific technique. It is possible that such techniques can only be employed effectively with a certain amount of practice. As such one could argue that these particular studies are not a good test of Buddhist models of craving. Further research looking at the immediate effects of present moment awareness strategies, among individuals who have received some training in this technique, would be a more appropriate test.

Later effects: within 24 hours. Twelve studies included measures of craving taken at least 5 minutes after the manipulation, but within 24 hours. Of these twelve studies, one showed significant beneficial effects of the mindfulness strategy (Schumacher et al., 2017), five showed no significant effects of the mindfulness strategy (Bowen & Marlatt, 2009; Fisher et al., 2016; May, Andrade, Willoughby et al., 2012; May et al., 2010), four showed a mix of significant beneficial effects and non-significant effects (Cropley et al., 2007; Ussher et al., 2009; Nosen & Woody, 2013; Schumacher et al., 2017) and two showed a mix of significant detrimental effects and non-significant effects (Alberts et al., 2013; Szasz et al., 2012). Thus once again, taken together, the overall evidence for an effect of mindfulness on craving is not very compelling.

Of the five studies that found significant beneficial effects, two are those discussed previously that compared a present moment awareness strategy with listening to an audio recording of a natural history text (Cropley et al., 2007; Ussher et al., 2009). As such one cannot rule out the possibility that the mindfulness manipulation exerted its effect simply by loading working memory. Nevertheless, these studies

provide a useful insight into the time course of such effects; in one of these studies, reduced cigarette craving extended to 5 minutes after the manipulation, but had disappeared by 10 minutes (Cropley et al., 2007), whilst in the other study reduced cigarette craving inside (but not outside) the laboratory was still maintained when assessed 30 minutes after the manipulation (Ussher et al., 2009). These findings could be interpreted as indicating that strategies that interrupt the elaboration of craving-related thoughts may have benefits that extend beyond the point at which they are implemented. This could be due to a reduction in the likelihood of craving-related intrusive thoughts after the mind has been occupied with unrelated subject matter. This interpretation would be consistent with the fact that effects were more short-lived outside the laboratory (Ussher et al., 2009) where one would expect participants to be exposed to a greater number of cues that would elicit smoking-related intrusive thoughts.

Two of the studies that found significant beneficial effects are also those discussed previously that compared decentering with both guided imagery and mind wandering conditions (Schumacher et al., 2017). In one of these studies the decentering strategy maintained reduced levels of craving intensity 10 minutes after the manipulation, relative to both mind wandering and guided imagery conditions. In the second study the decentering strategy was only superior to the mind wandering condition.

The fifth study that found beneficial effects for mindfulness (Nosen & Woody, 2013) compared 60-90 minute instruction in present moment awareness and acceptance of cigarette cravings with the provision of standard psycho-educational material or no treatment. Eight assessment of smoking urges were then made across the course of 1-day period of ad lib smoking and a 1-day period that coincided with a quit

attempt. Whilst there were no significant differences in cravings between the three groups during the period of ad lib smoking, during the quit attempt the pattern of cravings across the course of the day varied such that during the evening, smoking urges were significantly lower among those in the mindfulness group compared to both those in the psycho-educational group and no treatment control; but only amongst participants who successfully managed to abstain from smoking (n=122). When those who had failed to abstain were included in the analysis (n=153), these differences disappeared.

These results are consistent with EI, conditioning and Buddhist models of craving that predict that where a craving-related behavior is successfully suppressed, cravings may subside more rapidly where present moment awareness and acceptance strategies are employed, due to the increased contact with conditioned stimuli that present moment awareness and acceptance entail. However, it is important to note that this study was conducted with smokers who were attempting to quit smoking; these theories would predict that such effects would be less likely to occur for behaviors that one cannot completely quit, for example as may occur in relation to food related cravings. Future research would also be needed to establish whether a mindfulness-based intervention may be more likely to lead to relapse, particularly in the early part of the intervention.

Again, the majority of the twelve studies that took measures of craving within a 24-hour period used either present moment awareness or a combination of present moment awareness and acceptance. Only two studies examined decentering (Schumacher et al., 2017) and only one study (Szasz et al., 2012) attempted to examine acceptance in isolation; this latter study found increased cravings relative to a

reappraisal strategy and no significant difference in cravings when compared to a suppression strategy.

Thus again, these studies are consistent with EI theory, and conditioning models of craving. There is some tentative support for the theory of grounded cognition but further research would be needed to confirm this. There are no studies within this group that test specific predictions made by cognitive processing theory.

Later effects: after 24 hours. Eleven studies included measures of craving taken later than 24 hours after the initial manipulation or intervention delivery (see Appendix A). The time frame over which these measures were taken ranged from 3 days to 7 weeks. Of these 11 studies, three found significant reductions in craving in the mindfulness group (Alberts et al., 2010; Davis, Manley, Goldberg, Smith & Jorenby, 2014; Tang, Tang & Posner, 2013), two found a mixture of significant and non-significant reductions in the mindfulness group (Lacaille, Zacchia, Bourkas, Glaser & Knauper, 2014; Ruscio, Muench, Brede & Waters, 2016), five found no significant differences (Bowen & Marlatt, 2009; Forman, Hoffman, Juarascio, Butryn & Herbert, 2013; Moffitt, Brinkworth, Noakes & Mohr, 2012; Murphy & MacKilop, 2014; Nosen & Woody, 2013;) and one found a trend towards higher craving in the mindfulness group (Hooper, Sanoz, Ashton, Clarke & McHugh, 2012). However, if we look at the pattern of significant and non-significant effects according to the time frame over which craving is observed, a clearer relationship begins to emerge. The three studies showing significant reductions in the mindfulness group assessed craving over the longest durations: 7 weeks (Alberts et al., 2010), 6 weeks (Davis et al., 2014), and 2 weeks (Tang et al., 2013). The six studies showing no significant differences, or a trend toward higher craving in the mindfulness group, assessed craving over the shortest durations, ranging from three days (Forman et al., 2013) to seven days (Bowen & Marlatt, 2009; Moffitt et

al., 2012; Murphy & MacKilop, 2014). The two studies that found a mixture of significant and non-significant effects assessed craving over a 2-week period (Lacaille et al., 2014; Ruscio et al., 2016).

There are several possible explanations for this pattern of results; it may be that those studies that were carried out over a longer timeframe employed higher intensity interventions that led to participants more effectively implementing the mindfulness techniques. Similarly, participants may have acquired these skills only after a more extended period of practice. Alternatively, consistent with conditioning, EI and Buddhist models of craving, it may be that effects only start to emerge after a certain period of practice.

It is difficult to clearly distinguish between these three possibilities on the basis of the studies reported in Appendix A. The three studies showing significant effects included the most intensive mindfulness practice, equivalent to 5 hours (Tang et al., 2013), more than 24 hours (Davis et al., 2013) or a 7-week manual that participants worked their way through (Alberts et al., 2010). By contrast, in the studies that found no significant effects, instruction ranged from what is described as 'brief' (Murphy & MacKilop, 2014), to 5-10 minutes (Hooper et al., 2012), to 2 hours (Forman et al., 2013). Additionally, all the studies that reported significant reductions in craving on at least one measure asked participants to repeatedly practice the technique on a daily basis as well as apply the technique each time they had a craving. This type of specific instruction to repeatedly practice the technique is generally not reported in those studies that did not find any significant effects. Thus those studies that did find significant effects are not only more likely to have assessed craving over a longer timeframe, they are also more likely to have included more mindfulness practice and to have ensured participants were repeatedly practicing these techniques on a daily basis.

Only one study (Ruscio et al., 2016) took longitudinal measures of craving allowing for the assessment of change over time. This showed no effect of mindfulness practice on levels of craving assessed at random times throughout the day. Cravings assessed immediately following a 20-minute mindfulness meditation, versus a sham meditation, were significantly lower, but this effect did not change over time. As such, and given that the sham meditation included instructions to 'go back to letting your mind wander freely', the effects could be explained by working memory load. However, the timeframe for this study was restricted to just 2 weeks so may not have been sufficient for other effects to emerge.

Similarly, the other studies that showed significant effects on craving did not necessarily control for the effects of working memory load. As discussed previously, according to EI theory, any strategy that loads visual working memory should reduce craving. Lacaille et al. (2014) compared mindfulness strategies to reciting the alphabet then multiples of 2s until 100, which is unlikely to involve significant amounts of visual working memory. Likewise Davis et al. (2014) and Alberts et al. (2010) compared mindfulness-based interventions to standard alternatives. Whilst these would help control for important variables such as halo effects and social support, they are unlikely to have included strategies that loaded visual working memory to the same degree as the strategies employed in the mindfulness conditions. The study that best controls for such effects is one conducted by Tang et al. (2013). They compared mindfulness meditation with relaxation training that involved guided relaxation, focused on different parts of the body. Participants completed 10 daily 30-minute sessions of either mindfulness meditation or relaxation training. Results showed significantly reduced levels of craving at 2 weeks compared to baseline in the mindfulness condition but not in the relaxation condition. These findings provide support for the notion that

mindfulness can bring about reductions in craving over and above what might be achieved by distraction or simple visualization strategies. They provide support for Buddhist models of craving that suggest that increased metacognitive awareness helps motivate the individual to avoid acting upon their cravings, which in turn results in a reduction in craving frequency and strength. The fact that this study also found a significant reduction in smoking in the mindfulness group relative to the relaxation group is consistent with this view. However, contrary to this interpretation, participants were not selected on the basis of wanting to quit smoking, and those who intended to quit did not outperform those with no intention to quit, suggesting that the effects on behavior may be mediated by unconscious processing. The authors suggest that they may have been mediated by stress reduction, though an alternative explanation is that the effects of increased metacognitive awareness referred to in Buddhist models prompt the individual to avoid responding to feelings of craving even where they do not hold goals that are incompatible with the relevant behavior; it is possible that insight into the futility of pursuing cravings is sufficient for behavior change.

Most of the studies within this group employed a combination of strategies, or used 'mindfulness meditation' (Tang et al., 2013), or 'general mindfulness training' (Davis et al., 2014) that are likely to have incorporated several different types of mindfulness strategy. The exceptions are Hooper et al. (2012) and Moffitt et al. (2012) who examined decentering in isolation and found a trend toward higher cravings in the decentering condition and no significant effect respectively. Similarly, Lacaille et al. (2014) compared different combinations of present moment awareness, acceptance and decentering. After two weeks they found no significant difference in cravings for chocolate among those who had been instructed to use acceptance (either with present moment awareness, or with present moment awareness and decentering) but

reductions amongst those who had employed present moment awareness in isolation or present moment awareness plus decentering. In contrast to the studies conducted by Hooper et al. (2012) and Moffitt et al. (2012), participants were instructed to listen to 5 minutes of audio every day. Again, in line with EI theory, these findings question the utility of acceptance strategies for craving reduction, at least when employed in the context of limited mindfulness training and in relation to a behavior one is not intending to quit completely.

As noted above, the results of the study by Tang et al. (2013) provide some support for Buddhist models of craving. Unlike other models of craving, Buddhist models also predict a decoupling of craving and craving-related behaviors (see also Levin et al., 2015). In other words, craving-related behaviors may decline even in the absence of any reduction in craving. This is assumed to be because of increased metacognitive awareness. Research by Bowen and Marlatt (2009) supports this view. They looked at the effects of a brief present moment awareness and acceptance intervention on smokers interested in cutting down or quitting. Although they found no significant effect on smoking urges, either during the manipulation, 24 hours later or 7 days later, they did find a reduction in the number of cigarettes smoked over the 7-day period among those in the mindfulness group, but not in the control group. Similarly, Elwafi et al. (2013) reported on 33 adults who had received eight sessions of mindfulness training as part of a randomized controlled trial for smoking cessation. They found that whilst there were strong correlations between levels of craving and smoking at baseline ($r = 0.582$), these were much lower by the end of treatment ($r = 0.126$) suggesting that the mindfulness treatment was decoupling the relationship between craving and behavior. This decoupling effect seemed to be driven by the amount of informal, home practice participants engaged in. However, the effect was not

sustained when assessed 2-weeks after the end of treatment or at 3- or 4-month follow-ups, suggesting that the decoupling effect may only be maintained for as long as the individual continues to practice the mindfulness strategies.

Thus there is provisional support for some of the predictions made by Buddhist models of craving; first that there may be reductions in craving over the medium to long term, over and above what might be achieved by other strategies that interrupt elaborative processes (Tang et al., 2013), and second that over the medium to long term there may be a decoupling between cravings and craving-related behaviors (Bowen & Marlatt, 2009; Elwafi et al., 2013). However, given the very limited number of studies these conclusions are based on, they are necessarily tentative.

Conclusions

Some of the beneficial effects seen for mindfulness strategies in relation to craving are likely to stem from (a) interrupting craving related elaboration by loading working memory, and (b) extinction process that result from the individual inhibiting the craving-related behavior. Whilst it is important not to diminish the value of such outcomes, it is unclear whether mindfulness-based strategies have any advantages over other techniques that also promote such effects. For example, guided imagery may be just as effective at loading working memory, whilst education about response suppression may be equally effective at motivating an individual to resist their craving urges. Further research could usefully compare such approaches. In the meantime, it is important to be aware that such effects may not be unique to mindfulness-based strategies.

However, a key question is whether these types of mindfulness-based strategies may have an advantage over other strategies because they are easier to sustain over a longer timeframe. For example, learning to focus on the present moment when cravings

occur may be a technique that can be more easily and flexibly applied in a wide range of different settings compared to a specific visualization strategy that may feel more effortful and, over time, become rather repetitive. It is also possible that level of meditation experience moderates the effects of such strategies; most of the studies that have tested the immediate effects of present moment awareness techniques on craving were conducted in the absence of more intensive meditation training. More longitudinal research, and research examining user views of different strategies would help address such questions.

There is also limited evidence to support the beneficial effects of acceptance strategies on craving and, as predicted by EI theory, a possibility that such strategies may even exacerbate cravings (Szasz et al., 2012) or undermine the effects of other strategies (Lacaille et al., 2014). Again however, such effects have only been examined in the context of relatively limited mindfulness practice; it is possible that acceptance strategies have different effects when employed by those with more experience of mindfulness meditation.

The theory of grounded cognition predicts that decentering strategies would reduce levels of craving over and above any effects that occur because of working memory load. However, only a few studies have examined decentering specifically. Where beneficial effects have been found (Caselli et al., 2016; Lacaille et al., 2014; Papies et al., 2015; Schumacher et al., 2017), replication has been inconsistent (Schumacher et al., 2017) or it is difficult to rule out the possibility that effects occurred due to working memory load (Caselli et al., 2016; Lacaille et al., 2014; Papies et al., 2015). Thus, at present, there is an absence of good evidence to show that decentering strategies have unique, immediate beneficial effects on craving. Additional studies that manipulate decentering whilst controlling for visualization are needed.

More promising findings occur among those studies that have asked participants to engage in regular practice of mindfulness techniques, and have assessed the effects of these over a longer timeframe. However, such studies would benefit from controlling for the effects of working memory load in order to better establish whether such interventions have benefits over and above what might be achieved by simple distraction or visualization strategies.

In terms of the models of craving outlined in Table 1, there is most evidence to support EI theory, together with the conditioning effects it encompasses. In particular, research suggests that strategies that load working memory bring about an immediate reduction in cravings. Additionally, and consistent with EI theory, conditioning and Buddhist models of craving, where a behavior is consistently suppressed, present moment awareness and acceptance strategies may lead to a more rapid reduction in craving than other techniques. However, since this conclusion is based on data from just one study (Nosen & Woody, 2013), it should be viewed as preliminary.

There is also some evidence to support Buddhist models of craving in relation to the development of insight effects and a decoupling of craving and behavior. However, more research would be needed to fully test this model. Longitudinal data tracking change in cravings and behavior over time, together with their association, would be helpful. Likewise, there are currently insufficient data to fully test the grounded cognition account of cravings or the cognitive processing model.

Recommendations for Future Research

In terms of laboratory-based experimental work, it would be helpful to determine whether decentering strategies can have an immediate effect on craving over and above what could be achieved by simple visualization or distraction strategies. This should be relatively easy to establish with studies that compare levels of craving

following a visualization and decentering task, a visualization only task and a no strategy control group. Such studies should help clarify the immediate effects of decentering and inform its use in intervention development.

Another important priority must be research that examines the effects of extended periods of regular mindfulness practice. Whilst several studies suggest such an approach may be promising for tackling cravings and craving-related behaviors, existing data make it difficult to identify the mechanisms underlying such effects and to rule out more prosaic explanations. The use of carefully matched comparison conditions that control for factors such as halo effects and working memory load would help test Buddhist accounts of craving and establish whether mindfulness practice can influence craving and craving-related behaviors over and above alternative approaches. Such studies would benefit from including longitudinal measures of craving and behavior in order to track changes over time. Again, this would help test Buddhist models as well as inform the development of interventions. Likewise, manipulating, or at least measuring, frequency and length of practice would also help identify any minimal level of practice that is required to see benefits.

Relatedly, more measures are needed to identify the mechanisms underlying any beneficial effects of mindfulness. It seems likely that increased self-efficacy and reduced stress and/or negative affect may play some role, though measures of these tend not to have been included in studies of craving. It would be relatively straightforward to incorporate such measures in future.

Likewise there is evidence to suggest that mindfulness can improve attention regulation (Chiesa et al., 2011; Mrazek et al., 2013). Improvements in attention regulation may bring about reductions in craving by reducing attentional bias and also by helping individuals maintain their attention on whatever task is at hand, rather than

engage in cognitive elaboration of craving-related thoughts. Although there is some evidence to suggest that mindfulness-based intervention can reduce attentional bias (Garland & Howard, 2013), such possibilities have yet to be fully explored in more controlled studies of mindfulness and craving.

Similarly, research by Tang et al. (2013) raises the question of whether effects are mediated by conscious versus unconscious processes. This is worth exploring as it has implications for the types of populations who may most benefit from mindfulness-based interventions; if effects are mediated by unconscious processes then an individual's motivation to change their behavior may be less important. We may also see effects generalizing across a wide range of different domains. However, if effects are mediated by conscious processes, interventions may be better targeted at those who are already motivated to change their behavior. We may also expect effects to be more domain specific.

Another important area for future research is to consider whether any beneficial effects of mindfulness differ between those who experience cravings within the context of clinical disorders versus those who experience them in other areas, such as when trying to lose weight or eat more healthily. Given that individuals with substance use disorders tend to exhibit dysregulated neurocognitive processes (Koob & Volkow, 2010) it seems plausible that effects may differ between clinical and non-clinical populations. The studies included in the current review comprise mainly of those without a clinical diagnosis, with just one study (Caselli et al., 2016) focusing on individuals at an addiction center. It is possible that beneficial effects of mindfulness on craving only emerge for more severe instances of craving. As such, more experimental work conducted with clinical populations, would be informative. Dismantling studies of

multi-component interventions for clinical populations would also be helpful, in order to establish the unique contribution of the mindfulness-based elements.

Finally, researchers should take care to describe in detail the strategies employed in any mindfulness study, together with any comparison conditions. As illustrated in the current review, a wide range of different practices are labeled as mindfulness but, according to a number of theories, these will not necessarily have equivalent effects. Having full details of such procedures will allow for easier and more accurate comparisons across studies.

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Appendix A

Characteristics of Studies Examining the Independent Effects of Mindfulness on Craving

Craving type	Study	Sample size¹	Sample details	Gender (% female)	Primary mindfulness strategy(ies) / intervention	Control strategy(ies) / intervention	Dependent variable	Results²
Food	Hamilton et al. (2013)	94	University students, abstained from breakfast.	77%	Present moment awareness of bodily sensations and thoughts.	1. Guided imagery. 2. Mind wandering.	Food cravings at ten time-points during the manipulation.	No significant difference between the mindfulness and imagery conditions. Craving showed a significant increase in the mind wandering condition but not in the mindfulness or imagery conditions.
Cigarettes	Bowen & Marlatt (2009)	123	University students, smokers interested in cutting down or quitting, abstinent for at least 12 hours.	27%	Present moment awareness and acceptance of thoughts, sensations and urges.	Asked to cope with urges in the manner they usually would.	Smoking urges assessed at 4 time points during the manipulation, during a cue exposure session.	No significant differences.

							Smoking urges 24 hours later.	No significant differences.
							Smoking urges 7 days later.	No significant differences.
Alcohol	Caselli et al. (2016)	8 (repeated measures design)	Patients at an addiction center with a diagnosis of alcohol use disorder, abstinent from alcohol, aged 35-50 years.	50%	Decentering from a pre- recorded audio of their own alcohol related thoughts.	Habituation to a pre-recorded audio of their own alcohol related thoughts.	Intensity of urge to drink assessed at 1, 3 and 5 minutes during the manipulation.	Significantly greater decreases in the mindfulness condition.
Food	Arch et al. (2016)	81	University students.	59%	Present moment awareness of the sensory properties of food.	Word puzzles.	Desire to eat another chocolate chip, assessed on five occasions, each immediately after applying the strategy.	A trend towards higher desire in the mindfulness condition; $p = .056$.

		136	University students.	77%	Present moment awareness of the sensory properties of food.	Word puzzles.	Desire to eat another raisin, assessed on five occasions, each immediately after applying the strategy.	Higher desire in the mindfulness condition.
		102	University students, abstained from eating for at least 2 hours.	42%	Present moment awareness of the sensory properties of food.	1. Word puzzles. 2. No strategy.	Desire to eat another raisin, assessed on five occasions, each immediately after applying the strategy.	No significant difference between groups in overall level of desire. Those in the mindfulness condition showed a steeper initial increase and slower decline in desire over the five time-points.
Alcohol	Vinci et al. (2014)	207	College students, reporting at-risk drinking, endorsement	76%	Present moment awareness of bodily sensations,	1. Relaxation. 2. No strategy.	Urge to drink immediately after the manipulation.	No significant differences.

			of affective-regulation motives for drinking.			acceptance.		Urge to drink immediately after practicing the strategy during a neutral or negative mood induction.	Significant increases in the mindfulness and relaxation conditions, after a negative mood induction.
Cigarettes	Adams et al (2013)	64	University students, smokers, temporarily abstinent.	100%	Present moment awareness of breath. Present moment awareness and acceptance of thoughts and feelings.	No strategy.		Desire to smoke immediately after the manipulation that was presented simultaneously with either a body image challenge or no body image challenge.	No significant differences.
Cigarettes	Westbrook et al. (2013)	54	Community sample, smoke at least 10 cigarettes a day, strong desire to quit within the following month, temporarily	31%	Present moment awareness and acceptance of thoughts, feelings, memories and bodily sensations.	No strategy.		Cigarette craving assessed on 12 occasions, each immediately after applying the strategy whilst viewing smoking related images.	Significantly lower cravings in the mindfulness condition.

			abstinent.					
Food	Papies et al. (2015)	75	University students.	Not reported	Decentering from reactions to pictures of food.	Viewing pictures of food in a relaxed manner.	Food cravings immediately following the manipulation.	A trend towards lower cravings in the mindfulness condition; $p = .058$.
Cigarettes	May, Andrade, Willoughby et al. (2012)	27	University staff, students, friends and family, smoke at least 10 cigarettes a day over the last 6 months, abstinent for at least 2 hours.	59%	Present moment awareness of bodily sensations.	Mind wandering.	Cigarette cravings immediately after the manipulation. Cigarette cravings after a subsequent 10-minute mind wandering session.	Significantly lower cravings in the mindfulness condition. No significant difference.
Food	Schumacher et al. (2017)	94	University students, like chocolate	100%	Decentering from thoughts about chocolate	1. Guided imagery 2. Mind wandering	Intrusiveness of chocolate cravings immediately following the manipulation.	Significant reduction in the decentering condition; no change in the imagery or mind wandering conditions.

					Vividness of chocolate cravings immediately following the manipulation.	Significant reduction in the decentering condition; no change in the imagery or mind wandering conditions.
					Intensity of chocolate cravings immediately following and 10 minutes after the manipulation.	Significant reduction in the decentering condition, maintained at 10 minutes; no change in the imagery or mind wandering conditions.
97	University students, crave chocolate at least once a day, want to reduce their consumption of chocolate.	100%	Decentering from thoughts about chocolate	1. Guided imagery 2. Mind wandering	Intrusiveness of chocolate cravings immediately following the manipulation. Vividness of chocolate cravings immediately following the manipulation.	Significant reductions across all three conditions. Significant reductions across all three conditions.

							Intensity of chocolate cravings immediately following and 10 minutes after the manipulation.	Significant reduction in the decentering and imagery conditions, maintained at 10 minutes; no change in the mind wandering condition.
Food	Fisher et al. (2016)	40	University staff and students.	100%	Present moment awareness of thoughts, emotions and bodily sensations.	Audio description of a rainforest.	Food craving 10 minutes after the manipulation.	No significant difference.
							Food craving immediately after 10 minutes of self-practice / sitting in the presence of foods.	No significant difference.
							Desire to eat 10 minutes after the manipulation.	No significant difference.
							Desire to eat immediately	No significant difference.

Food	May et al. (2010)	48	University students, trying to cut down on snack foods, abstained from eating for 2 hours.	81%	Present moment awareness of the breath, decentering from thoughts about snack foods.	1. Thought suppression. 2. Imagery diversion. 3. Mind wandering.	after 10 minutes of self-practice / sitting in the presence of foods. Craving for snack food immediately following the manipulation.	No significant differences between the mindfulness, imagery diversion and mind wandering conditions. Significantly lower cravings in the thought suppression condition
		49	University students.	63%	Present moment awareness of bodily sensations.	1. Guided imagery. 2. Mind wandering.	Craving for snack food 10 minutes after the manipulation. Craving for snack food immediately following the manipulation.	No significant differences.

Cigarettes	Cropley et al. (2007)	30	Sample recruited via adverts at a university, smoked at least 10 cigarettes a day for at least 3 consecutive years.	40%	Present moment awareness of bodily sensations.	Audio recording of a natural history text.	Craving for snack food 10 minutes after the manipulation. Strength of desire to smoke immediately following the manipulation.	No significant differences.
							Strength of desire to smoke 5 minutes after the manipulation.	Significantly lower in the mindfulness group.
							Strength of desire to smoke 10 minutes after the manipulation.	Significantly lower in the mindfulness group.
							Strength of desire to smoke 15 minutes after the manipulation.	No significant difference.
Food	Alberts et al (2013)	61	University students.	80%	Present moment awareness of	1. Suppression of cravings and craving related	Food cravings immediately following the	No significant difference between the mindfulness

					food cravings, acceptance of food cravings and craving related thoughts.	thoughts. 2. No strategy and option to eat food.	manipulation.	and suppression groups. Significantly higher cravings in the mindfulness and suppression conditions compared to the no strategy condition. No significant difference between the mindfulness and suppression groups. Significantly higher cravings in the mindfulness and suppression conditions compared to the no strategy condition.
Cigarettes	Ussher et al. (2009)	48	Community sample, ordinarily smoked at least 10 cigarettes a day for at least 3 years,	35%	Present moment awareness of bodily sensations.	1. Isometric exercises. 2. Audio recording of a natural history text.	Strength of desire to smoke immediately following the intervention in the laboratory.	Food craving 20 minutes after the manipulation. Significantly lower in the mindfulness condition compared to the text condition. No significant difference between the mindfulness

temporarily
abstinent.

and isometric
conditions.

Strength of
desire to smoke
5 minutes after
the intervention
in the
laboratory.

Significantly lower
in the mindfulness
condition
compared to the
text condition.
No significant
difference between
the mindfulness
and isometric
conditions.

Strength of
desire to smoke
10 minutes after
the intervention
in the
laboratory.

Significantly lower
in the mindfulness
condition
compared to the
text condition.
No significant
difference between
the mindfulness
and isometric
conditions.

Strength of
desire to smoke
30 minutes after
the intervention

Significantly lower
in the mindfulness
condition
compared to the

in the laboratory.	text condition. No significant difference between the mindfulness and isometric conditions.
Strength of desire to smoke immediately after the intervention outside the laboratory.	Significantly lower in the mindfulness condition compared to the text condition. No significant difference between the mindfulness and isometric conditions.
Strength of desire to smoke 5 minutes after the intervention outside the laboratory.	Significantly lower in the mindfulness condition compared to the text condition. No significant difference between the mindfulness and isometric conditions.

Cigarettes	Szasz et al. (2012)	94	University students, smoke more than 10 cigarettes a day, have smoked for at least 1 year, would like to quit.	88%	Acceptance of thoughts and feelings.	1. Reappraisal. 2. Suppression.	Strength of desire to smoke 30 minutes after the intervention outside the laboratory. Cigarette cravings assessed at four time points: baseline, following the manipulation, following a 3-minute craving induction, following a dot probe and serial addition task.	No significant differences. No significant differences between the mindfulness and suppression groups. Cravings significantly lower in the reappraisal group compared to the suppression and mindfulness groups.
Alcohol	Murphy & MacKilop (2014)	84	Community sample, heavy drinkers, aged 21-29 years.	50%	Present moment awareness of experience including cravings, acceptance, decentering.	1. Distraction. 2. No strategy	Alcohol craving assessed at seven time points immediately following the manipulation.	No significant difference between the mindfulness and no strategy conditions. Significantly lower cravings in the distraction condition.

							Distress from alcohol craving assessed at seven time points immediately following the manipulation.	No significant difference between the mindfulness and no strategy conditions. Significantly lower distress in the distraction condition.
Cigarettes	Nosen & Woody (2013)	122	Community sample, smoked at least 10 cigarettes a day for the previous 2 years, expressed a commitment to quit.	35%	Present moment awareness and acceptance of cravings.	1. Standard psycho-education; information about smoking cessation methods. 2. No treatment.	Alcohol craving 1 week later. Eight assessments of smoking urges during a 1-day period of ad-lib smoking, the day after the manipulation.	No significant differences. No significant differences.
							Eight assessments of smoking urges during a 1-day period coinciding with a quit attempt, the day after the	Significantly lower in the mindfulness group compared to the psycho-education and no treatment groups in the evening. Significantly lower

							manipulation.	in the mindfulness group compared to the no treatment group in the morning. No significant difference between the mindfulness group and psycho-education group in the morning. No significant differences between groups during midday/afternoon.
Food	Forman et al (2013)	48	Community participants, overweight or obese.	100%	Acceptance of cravings, decentering from cravings.	Distraction and cognitive restructuring.	Smoking urges 4 days later, after manipulation. Sweet craving assessed at three time points per day over 3 days.	No differences between groups. No significant difference.
Food	Hooper et al. (2012)	47	University students, not dieting.	59%	Decentering from feelings of chocolate craving and thoughts about	1. Thought suppression. 2. No strategy.	Frequency of chocolate cravings experienced over 6 days,	A trend towards a significant group difference, with those in the mindfulness

					chocolate craving.		reported at the end of each day.	condition experiencing most cravings, and those in the no strategy condition experiencing least cravings; $p = .091$.
Food	Moffitt et al. (2012)	110	Community sample, regularly crave and eat chocolate, desire to better manage eating behaviors.	85%	Decentering from food related thoughts.	1. Cognitive restructuring of food related thoughts. 2. No strategy.	Strength of chocolate cravings experienced 'throughout the day today', assessed 7 days after the intervention. Trait food cravings 7 days after the intervention.	No significant differences.
Food	Lacaille et al. (2014)	126	Sample recruited from in and around a university,	89%	Present moment awareness of cravings.	Recital of the alphabet then multiples of 2s until 100.	Trait chocolate cravings 2 weeks after the intervention.	Significantly lower cravings in the mindfulness condition.

chocolate
cravers,
interested in
reducing
chocolate
cravings.

Present
moment
awareness and
acceptance of
cravings.

Present
moment
awareness and
decentering
from cravings.

Chocolate
cravings
following a
craving
induction
administered 2
weeks after the
intervention.

Trait chocolate
cravings 2
weeks after the
intervention.
Chocolate
cravings
following a
craving
induction
administered 2
weeks after the
intervention.

Trait chocolate
cravings 2
weeks after the
intervention.

Chocolate
cravings
following a

Significantly lower
cravings in the
mindfulness
condition.

No significant
difference.

No significant
difference.

Significantly lower
cravings in the
mindfulness
condition.

Significantly lower
cravings in the
mindfulness

					Present moment awareness, acceptance and decentering from cravings.		craving induction administered 2 weeks after the intervention. Trait chocolate cravings 2 weeks after the intervention.	condition. No significant difference.
							Chocolate cravings following a craving induction administered 2 weeks after the intervention.	No significant difference.
Cigarettes	Ruscio et al. (2016)	44	Community sample, 18-65 year olds, smoked at least 10 cigarettes a day for at least 2 years.	50%	Present moment awareness of bodily sensations, thoughts and emotions. Present	Sham meditation.	Urge to smoke assessed at four random time points throughout the day over a period of 2 weeks.	No significant difference.

					moment awareness and acceptance of urges and cravings.		Urge to smoke assessed immediately after completing daily mindful or sham meditation over a period of 2 weeks.	Significantly lower in the mindfulness group.
Cigarettes	Tang et al. (2013)	27	University students, smokers with no intention to quit.	30%	Mindfulness meditation	Relaxation	Severity of cravings to smoke before and after 2 weeks of training.	Significantly reduced cravings in the mindfulness condition but not the control condition.

Cigarettes	Davis et al. (2014)	95	Community sample, living in areas of low socio-economic status, smoking at least 5 cigarettes a day, high motivation to quit.	48%	General mindfulness training.	Standard smoking cessation intervention.	Strength of smoking urges over the previous 24 hours, assessed via telephone on three occasions during the week before and three occasions during the week after the quit date. The quit date was scheduled during week 5 of the intervention.	Significantly greater reduction in post quit versus pre quit urges in the mindfulness condition.
Food	Alberts et al (2010)	19	Community sample, overweight or obese.	89%	Present moment awareness of bodily sensations, eating behaviors and craving related thoughts.	Information and physical activity.	Trait food cravings 7 weeks from baseline.	Significantly greater reduction in cravings in the mindfulness condition.

Acceptance of
craving related
bodily
sensations and
thoughts.

¹ Restricted to participants included in the analyses of interest.

² Differences are statistically significant, unless otherwise stated.