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Seeking Happiness: Understanding the Mechanisms of Mixing Music and Drugs

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With the rise of individuals attending music festivals each year, some have turned to illicit substances like 3,4-methylenedioxymethamphetamine (MDMA) in hopes to enhance their experience. MDMA is known to activate dopaminergic mesolimbic reward pathway areas of the brain such as the ventral pallidum, the ventral striatum, and the nucleus accumbens. In addition, the perception of positive consonant music also increases the activation of similar areas of the mesolimbic pathway as activated by MDMA, thus reinforcing any addictive behaviors during the consumption of MDMA at music festivals. Recently, the reappearance of opioids, such as fentanyl, with MDMA has contributed to fatalities correlated to MDMA consumption at music festivals. This review evaluates evidence of hyper-activation of the mesolimbic pathway by both MDMA and musical stimuli through simultaneous consumption. Through this hyperactivation, large amounts of dopamine are continuously released which increase the chances of developing an addiction to MDMA consumption in musical environments. Understanding the effects of these stimuli as a whole may launch further research for possible therapies and for proper legislation on drug regulation to prevent further overdose fatalities at music festivals.

INTRODUCTION

Music festivals of today attract hundreds of thousands of people every year with their visual lights, pyrotechnic shows, heart-pumping sounds, and positive friendliness with other attendees. However, increased popularity of these festivals also increases popularity of common festival behaviour like the consumption of alcohol and drugs. 3,4-methylenedioxymethamphetamine, commonly referred to as MDMA, ecstasy, M, or Molly, has slowly become the popular drug of choice amongst festival-goers (Palamar, Acosta, Sherman, Ompad, & Cleland, 2016).

MDMA is a recreational drug that affects the brain to induce changes in mood and perception by stimulating a larger release and slower reuptake of serotonin (5-HT), norepinephrine (NE), and dopamine (DA). MDMA heavily activates systems of reward and emotion within the brain, thus allowing users to feel more connected with those around them and heightening their senses to the external world (Meyer, 2013). Combining the psychoactive effects of MDMA with the sensory-stimulating atmospheres of music festivals, individuals using the drug report high levels of happiness and euphoria while experiencing the visual, audio, and tactile stimuli presented to them at such events (Van Havere et al., 2011). Adversely, some effects of MDMA usage include paranoia, an increase in body temperature, and profuse sweating, with the latter two associated with common causes of death (Meyer, 2013).

With no known beneficial medical uses, the production, possession, and distribution of MDMA is widely criminalized worldwide (Meyer, 2013). The drug itself is produced and distributed illegally at the street level in tablet or capsule form, derived from a compound found in sassafras oil and ocotea cymbarum oil called safrole which is then further isomerized and oxidized (de la Torre et al., 2004; United Nations Office on Drugs and Crime, 2014). Unfortunately, with the rising popularity of MDMA use at music festivals, the production of the drug has become increasingly dangerous due to higher demand, forcing manufacturers to lace their drugs with other substances, such as cocaine or opioids. The lacing of other substances makes consumption more harmful for the users and increases the risk of overdose and death caused by these extra substances (Palamar et al., 2016). Although overdosing linked to MDMA consumption has received widespread media attention across the world, there is a steady increase in number of individuals who consume the drug each year in hopes of experiencing a “good time” while attending a music festival (Friedman et al., 2016).

Musical auditory stimuli and psychoactive stimulants like MDMA are known to promote happiness in the perceiver (Bedi, Phan, Angstadt, & de Wit, 2009; Menon & Levitin, 2005). Understanding the mechanisms of how MDMA and musical stimuli work and to where they may interact could lead to a better understanding of the motivating factors of combining the two and could potentially lead to solutions in preventing fatal overdosing caused by the consumption of MDMA at music festivals. This review paper will integrate what is known about the effects of music and MDMA on an individual’s happiness, respectively, and as a whole.

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Having both music and MDMA working simultaneously on the individual's happiness, it is thought that the chance of developing a behavioral addiction is increased through overproduction and continuous activation of dopaminergic neurons. Additionally, this review will add a context to the need of research for developing methods to prevent the development of addictions and thus preventing fatal overdoses.

Music and the Brain

Sounds are amplified through the canals and membranes in the auditory pathway, and then encoded in the cochlea into neural signals that are sent to the brain via the cochlear nerve (Zatorre, Belin, & Penhune, 2002). The pitch of sound is encoded in the cochlea – from lower pitches at the base of the cochlea to higher pitches at the apex (Patterson, Uppenkamp, Johnsrude, & Griffiths, 2002). The perception of music is formed within the brain after the reception of the cochlear pitch encoding is sent from the cochlea. The combinations of pitches perceived while listening to music is the physical stimulus which the brain interprets once it is received by the auditory system (Patterson et al., 2002). In multiple studies, music has been classified into different categories in regard to their perceived sound: dissonant or consonant, joyful or fearful, happy or sad, and violation of musical expectancy (Bidelman & Krishnan, 2009; Steinbeis, Koelsch, & Sloboda, 2006). With these classifications, researchers distinguished the types of sound perceived during music listening which could provoke feelings of reward or evoke emotions (Blood, Zatorre, Bermudez, & Evans, 1999).

Multiple regions and structures are activated in the perception of musical stimuli, including the hypothalamus, the hippocampus, the amygdala, the ventral striatum, the pre-supplementary motor area, the caudate nucleus, the ventral pallidum, and the auditory cortex (Menon & Levitin, 2005). Together, these regions interact to produce emotional and motor responses in the individual perceiving the musical stimuli. This includes the sensation of happy or sad emotions and motor functions that help strengthen the perception of the stimuli.

The hypothalamus acts as a center for various functions in the human body, controlling somatic bodily functions like heart rate, blood pressure regulation, neurotransmitter release (including neurotransmitters like oxytocin), learning, sleeping, and memory alongside the hippocampus (Koelsch, 2010). Through hypothalamic and hippocampal activation, musical stimuli can induce memories that pertain to the musical stimulus in question, such as personal experiences. They can induce bonding-like feelings between individuals through the release of oxytocin, and may trigger a heightened or lowered bodily response in congruency with the activation of the amygdala by altering the threshold for a fear response, beside changing internal blood pressure and heart rate (Koelsch, 2010). Through the activation of the nucleus accumbens (NAcc), musical stimuli may produce a reinforced feeling of reward and thereby consumption of the stimuli; increasing the individual's motivation in seeking the applied stimulus at later times (Blood & Zatorre, 2001). Interestingly, musical stimuli also have

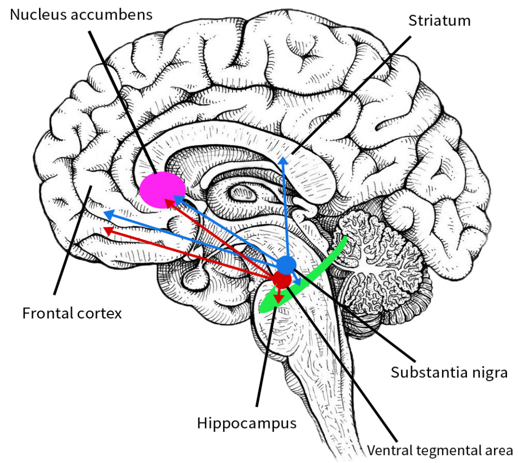

Figure 1. The mesolimbic reward pathway. Pleasurable factors on an individual act upon the ventral tegmental area and the substantia nigra; both which have dopaminergic projections to the hippocampus, the striatum, the nucleus accumbens and the frontal cortex. These projections trigger behavioural changes, emotional changes, and can even stimulate pleasurable memories (Adinoff, 2004).

the ability to activate the ventral pallidum, which is activated in times of addictive behavior in reward-induced activity (Blood & Zatorre, 2001). Together with the ventral striatum and the ventral pallidum, the pre-supplementary motor area is activated secondarily to produce motor movements in seeking pleasurable music (Blood & Zatorre, 2001). Finally, musical stimuli may also activate the caudate nucleus, which plays a role mainly in associative and procedural learning. Caudate nucleus is dominantly activated in individuals who learn better through auditory methods – either through information association with music or information learning through verbal input (Salimpoor et al., 2013).

How MDMA and Music Affect the Reward System

MDMA

The consumption of MDMA triggers an abnormal activation of the mesolimbic pathway – the cortical pathway which comprised of dopaminergic neurons that project from the ventral tegmental area (VTA) to the NAcc (Figure 1), by blocking dopamine (DA) transporters and triggering the release of greater amounts of DA (de la Torre et al., 2004). In the mesolimbic pathway, dopamine is the primary activating neurotransmitter released that leads to feelings of reward and conditioning behavior of addiction (de la Torre et al., 2004). Dopaminergic neuron bodies within the VTA produce large amounts of DA ready to be released to the NAcc which can result in both physical and sensory responses (Bedi et al., 2009). The NAcc is comprised of two different areas, the core and the shell. Although both areas are activated by dopaminergic neurons, each distinct area controls different outputs to other cortical areas resulting in different responses (Cadoni et al., 2005).

Neurons in the NAcc core project to areas of the brain that are primarily activated in the control of motor function, like the globus pallidus (Cadoni et al., 2005). In the activation of the core, the sequential and congruent activation of the globus pallidus re-wires neural circuitry for motor movements that can retrieve and apply the rewarding stimulus (Cadoni et al., 2005). Not only are new neural circuits created, the constant activation of these two structures by the same external factor can strengthen these circuits and result in addictive behavior. In the case of MDMA use, motor actions to seek and consume the drug are what lead individuals to continue the behavior (Cadoni et al., 2005).

The NAcc shell is primarily responsible for the immediate cognitive effect of desire and enjoyment of the stimulus, including MDMA (Cadoni et al., 2005). The shell is also the site at which a majority of the dopaminergic neurons projecting from the VTA synapse, therefore MDMA is able to excessively activate the NAcc shell (Cadoni et al., 2005). The activation of the shell ultimately results in the positive reinforcement for the consumption of MDMA (Di Chiara et al., 2004). Once taken, MDMA acts upon the dopaminergic neurons in the VTA by inhibiting the DA transporter within the synapses in the NAcc. This results in an increase of cytoplasmic DA production, stimulation of DA release, and inhibition of the reuptake and degradation of DA. With excess amounts of DA present within the synapses, this ultimately results in a constant overstimulation through sequential overproduction of DA (Orejarena, Berrendero, Maldonado, & Robledo, 2009).

Consequently, overstimulation within the NAcc may eventually lead to the desensitization of the post-synaptic cell by regular levels of DA (Cadoni et al., 2005). Therefore, to perceive reward and pleasure, larger amounts of DA are needed as time goes on during the use of MDMA, which becomes a negative cycle of desensitization upon the post-synaptic cells (Cadoni et al., 2005). Through the facilitation of physical and mental motivation caused by the shell and core of the NAcc, MDMA users may begin to seek out and consume the drug with increasing frequency (Orejarena et al., 2009). Thus, individuals who use MDMA are not necessarily addicted to the drug itself, but to the feelings of pleasure caused by its consumption.

Music

With the input of musical stimuli, the dopaminergic mesolimbic pathway is activated but in lieu of having initial activation from the VTA projecting signals to the ventral striatum, the ventral striatum receives its input from the cochlear nerve to initiate activation (Zatorre, 2015). It should be noted that different types of music stimuli, as per the ones previously mentioned (consonant, dissonant, joyful, fearful, sad, happy, and violation of musical expectancy), are not significant factors in the feeling of reward felt by an individual when listening to music. This is because different individuals have preference to different types of music, which reduce their significance in their effect of musical reward (Zatorre, 2015).

Through the consequential activation of the pre-supplementary motor area and ventral pallidum, motivated seeking behavior is produced; depending on whether the individual's preferred music is being perceived (Lima et al., 2016; Peretz & Zatorre, 2005). Although not a tangible item that is being ingested, the action of seeking pleasurable music can involve motions such as changing the radio stations, putting on or turning on machinery that helps achieve being able to listen to music, and buying or searching for music that suits their pleasurable preference (Peretz & Zatorre, 2005).

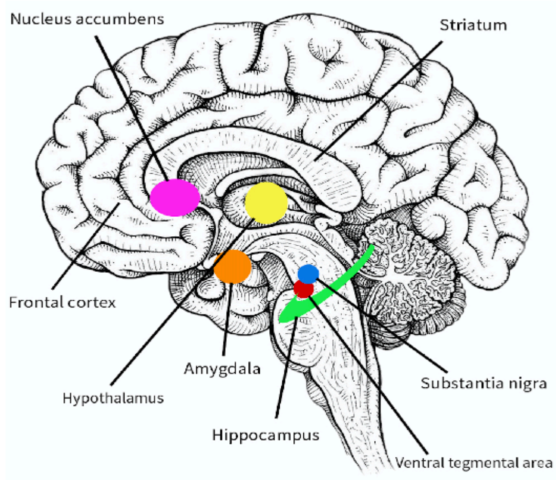

Figure 2. Cortical areas activated in the onset of emotion. The activation of different cortical areas cause the onset of different possible emotions in which an individual can experience. Positive emotions are correlated with the activation of mesolimbic structures such as the frontal cortex, the nucleus accumbens, the striatum, the ventral tegmental area, the substantia nigra, and the hippocampus. Negative emotions are correlated with the activation of structures such as the hypothalamus, the amygdala, the nucleus accumbens, and the hippocampus (Baumgartner, Esslen, & Jäncke, 2006).

How MDMA and Music Affect the Emotional System

The effect on emotions by MDMA occurs through alterations within the ventral striatum and the amygdala. The ventral striatum is largely involved in motivational and reward cognition and reinforcement, while the amygdala is primarily involved in response to fear, aggression, and anxiety (Bedi et al., 2009) (Figure 2). Generally, MDMA has a greater effect on both brain structures in social settings than in solitary settings (Hysek et al., 2014). It was found that positive social stimuli, like smiling and laughter, perceived by an individual under the influence of MDMA had a higher activation of the ventral striatum through dopaminergic neuron firing (as seen earlier in dopaminergic neurons in the NAcc (Hysek et al., 2014).) Through this ventral striatal activation, the consumer of MDMA feels a heightened sense of pleasure, reward, and positive affirmation of their use of the substance (Wardle & de Wit, 2014). This can also be explained by that ventral striatum is comprised of the NAcc, which, as discussed earlier, is heavily involved in the rewarding and pleasurable aspect in the consumption of MDMA.

In concurrency to heightening reward response through the activation of the ventral striatum, MDMA was also found to lower the effect of negative social stimuli, like aggression and perceived fearful facial expressions, on the individual (Wardle, Kirkpatrick, & de Wit, 2014). To achieve this, MDMA acts upon NE and 5-HT transporters within the amygdala, blocking both NE and 5-HT from reentering their pre-synaptic neurons and allowing those neurotransmitters to continuously act upon their associated receptors on the post-synaptic cell (Verrico, Miller, & Madras, 2006). However, unlike its effect on DA neurons, it does not promote the production and release of NE or 5-HT (Verrico et al., 2006). NE can increase heart rate and induce a state of euphoria, while 5-HT in the amygdala decreases the capability of the individual to react to negative perceived stimuli and, in some cases, may not even notice the presence of these stimuli (Bexis & Docherty, 2006).

With a heightened sense of reward in social settings and a decrease in reaction to negative stimuli, individuals under the influence of MDMA display a greater sense of compassion towards others no matter the situation (Hysek, Domes, & Liechti, 2012). In addition, individuals also demonstrate the ability to recognize positive moods given off by other individuals as well as friendly personas in close proximity (Hysek et al., 2012). However, it has been hypothesized in studies that the use of MDMA is related to increase in levels of oxytocin, a neurotransmitter associated with bonding and sociable aspects between individuals, within cortical areas (Kirkpatrick, Lee, Wardle, Jacob, & de Wit, 2014). Unfortunately, there has been no concrete evidence on which specific areas of the brain are affected and how much of a role oxytocin plays during the use of MDMA (Kirkpatrick et al., 2014).

Emotional activation due to musical stimuli occurs primarily through the activation of the hypothalamus and hippocampus, and the altered activation of the amygdala. Different types of musical stimuli can elicit different emotions perceived by the receiver, which are discussed below (Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007).

In the perception of sweet and pleasant sounds of consonant stimuli, individuals report positive and happy feelings and the recall of positive memories and higher instances of bonding with others (Sammler, Grigutsch, Fritz, & Koelsch, 2007). In this case, activation of the hypothalamus and hippocampus occurs concurrently with the inhibition of activity in the amygdala. Activation of the hypothalamus and hippocampus results in the down-play of stress response caused by the amygdala and strengthens sensations of positive emotions (Mitterschiffthaler et al., 2007). Concurrently, the release of oxytocin from hypothalamus in the presence of consonant music is the primary source of bonding sensations (Chanda & Levitin, 2013).

In the perception of dissonant musical stimuli, individuals have the memories of more negative experiences evoked in the activation of the hippocampus and a lower activation of the hypothalamus – signifying a less pleasurable sensation and a less rewarding effect (Mitterschiffthaler et al., 2007). It was also observed that there was no decrease of function in the amygdala as seen in the onset of consonant musical stimuli (Mitterschiffthaler et al., 2007). Contrary to the perception of consonant music, the release of oxytocin is significantly lower (Mitterschiffthaler et al., 2007).

Interestingly, the pairing of consonant musical stimuli with a positive visual cue strengthens the positive activation of the hippocampus and hypothalamus, causing individuals to express higher sensations of euphoria. Moreover, using musical and visual cues together further increases blood pressure and heart rate in comparison to the effects exerted by only one of the cues (Baumgartner, Esslen, & Jäncke, 2006; Rickard, 2004). In addition to the increase in euphoric sensations and heart rate, a larger release of oxytocin may be induced, which can generate a more grandiose sensation of bonding with others (Tarr, Launay, & Dunbar, 2014). In contrast, if dissonant sounds are perceived at the same time as negative visual stimuli, negative emotions are more strongly expressed by the perceiver – eliciting the expression of fearful and/or sad emotions (Tarr et al., 2014).

The amygdala is primarily activated when there is a violation of musical expectation. This activation is associated with the physical and emotional response of the individual being startled (not expecting the sudden change of musicality of the auditory stimulus), generating a fight-or-flight like response (Koelsch, Fritz, & Schlaug, 2008). This activation generates the same physiological effects as a physical danger would to the individual, which include changes in electrical conduction of the skin (goose bumps), the increase of heart rate and blood pressure, and a heightened sense of awareness (Koelsch et al., 2008). This heightened sense of both physiological and emotional awareness, however, is equally perceived as pleasant and rewarding in some individuals as it is unpleasant and unwanted in others (Egermann, Pearce, Wiggins, & McAdams, 2013).

Not only does the hypothalamus play a key role in emotional expression at the onset of auditory stimuli, it plays an interconnected role between the activation of positive and pleasurable feelings and rewarding effects through the mesolimbic pathway (Menon & Levitin, 2005). Auditory stimuli do not have the ability to stimulate major motor functions in the body by stimulating presupplementary motor areas through projections from the cochlear nerve. Nevertheless, reinforcing motivational activation from the hypothalamus triggered by the seeking of reward (seeking behavior) promotes the motor area to induce physical action (Lima et al., 2016; Menon & Levitin, 2005). However, without the stimulation of the mesolimbic pathway, the presence of seeking behavior is absent, which supports the fact that emotions induced by factors such as consonant or dissonant musical stimuli are key to producing addiction-like motor function (Zatorre, Chen, & Penhune, 2007).

Reward Activation of MDMA and Music

Both MDMA and music affect the mesolimbic pathway. In the contemporary model, external stimuli initiate a reward response with the initial activation at the VTA projecting dopaminergic neurons to the NAcc in the ventral striatum and the ventral pallidum causing a sense of reward and pleasure, which deems to be true in the introduction of MDMA within the brain (Polston, Rubbinaccio, Morra, Sell, & Glick, 2011). However, musical stimuli do not follow this classic model. They stimulate the pathway from an alternative point of entry – the activation of the hypothalamus and the ventral pallidum through inputs received from the cochlear nerve (Salimpoor et al., 2013). It is the sequential activation of the NAcc, the ventral striatum, the ventral pallidum, and the hypothalamus that ensures a reward response in the application of MDMA or musical stimuli. The continuous and frequent activation of these structures caused by MDMA and musical stimuli is what leads to the development of addictions and addictive behaviors (Polston et al., 2011).

With the key structures of reward activated both in the consumption of MDMA and the perception of musical stimuli, it can be assumed that a tremendous amount of DA would be released continuously if both MDMA and musical stimuli are being applied simultaneously (Feduccia & Duvauchelle, 2008). With MDMA already acting upon dopaminergic mechanisms, in the ventral striatum as previously mentioned, additional DA would be introduced into the ventral striatum with the introduction of a pleasurable musical stimulus through interactions with the hypothalamus (Menon & Levitin, 2005). Moreover, with the musical stimulus activating the hypothalamus, this activation occurring simultaneously with MDMA could produce not only a reinforced motivational response to the musical stimulus but also a reinforced motivational response to the consumption of MDMA (Polston et al., 2011). Therefore, the simultaneous consumption and application of MDMA and a pleasurable musical stimulus could reinforce each other's motivated consumption to achieve a rewarding experience.

Emotional Activation of MDMA and Music

Both the consumption of MDMA and the perception of music have the ability to cause positive and negative emotions on an individual (Feduccia & Duvauchelle, 2008). While MDMA elicits positive emotions through sentiments of reward and pleasure via the ventral striatum of the mesolimbic pathway, consonant musical stimuli are able to induce positive emotions through the activation of the hippocampus in stimulating the memory of positive experiences and through activation of the hypothalamus for feelings of reward by the mesolimbic pathway (Bidelman & Krishnan, 2009). An increased release of oxytocin in the hypothalamus at the onset of pleasurably rewarding music increases social bonding in the presence of others and is reinforced by positive visual cues like a smile (Baumgartner et al., 2006). While an increased release of oxytocin is perceived in various parts of the brain with the consumption of MDMA, and not one specific part of the brain is targeted, it could be possible that the release of the neurotransmitter triggered by MDMA could induce additional release of oxytocin within the hypothalamus during the perception of pleasurable music, resulting in an additional increase in the sensation of social bonding (Bedi et al., 2009; Tarr et al., 2014).

In a similar fashion, both MDMA and musical stimuli affect function of the amygdala, whether they are positive or negative emotions (Bedi et al., 2009). During the ingestion and processing of MDMA, an increased release of 5-HT and NE induces a cascade of physical sensations; adding a physical response of pleasurable excitation in addition to the positive emotions and bonding induced by the drug (Verrico et al., 2006). A physical sensation is also triggered by positive emotions while listening to consonant music, but through the excitation of the hypothalamus (Zatorre, 2015). In contrast, the perception of positive consonant music is found to down-regulate the activation of the amygdala in relation to the stress-response pathway (Bidelman & Krishnan, 2009). The amygdala, however, is activated in terms of the stress-response in the perception of dissonant music, causing negative emotions, whereas in the perception of musical expectation violations, activation of the amygdala causes startling emotions and hyperawareness of surroundings (Bidelman & Krishnan, 2009).

Presented are two opposing outcomes in which amygdala function may be altered in the presence of consonant or dissonant musical stimuli. The role of MDMA and its effects on the amygdala do not change between the perception of consonant music or dissonant music (Bedi et al., 2009). Thus, the type of musical stimuli being perceived in conjunction to the consumption of MDMA would play a bigger role in determining the emotional outcome of the individual. In the combination of consonant music with MDMA, the inactivation of the stress-response through MDMA and the down-regulation of activation of the amygdala through consonant music would reinforce inhibition of the stress-response. In addition, the activation of excitatory physical sensations through the amygdala caused by MDMA may be reinforced by the same sensations that are caused by stimulation of the hypothalamus through consonant music. This would lead to an increase in intensity of occurrences such as heightened heart rate, increased blood pressure, tingling caused by changes in the electrical conduction of the skin, and sweating.

While perceiving dissonant music or music with musical expectation violations, the activation of the processes involved in the stress-response in the amygdala occur simultaneously with the physical sensations brought on by MDMA (Bedi et al., 2009; Sammler et al., 2007). While MDMA causes the release of neurotransmitters like NE and 5-HT to induce physical sensations, the activation of stress response releases the same neurotransmitters for hyperawareness. Separately, the two outcomes are different in terms of objective, yet as a whole, the release of similar neurotransmitters could reinforce each other to achieve a heightened response.

Consequences of MDMA Consumption at Music Festivals

Being conditioned gradually to the relative amounts of stimulation for reward in the consumption of MDMA at music festivals, users will begin to seek larger amounts of the drug or increase the frequency of consumption. Consequently, these users put themselves at higher risk of fatally overdosing; overstimulating the amygdala to elicit physiological responses such as heightened blood pressure, anxiety attacks or even seizures due to over-excitation (Meyer, 2013). In recent times, drugs used by recreational drug users appear to contain potentially deadly opioids, such as fentanyl. Fentanyl proves to be one of the deadliest drugs currently present illegally on the streets, with only fractions of a gram being enough to kill an average adult male (Fischer, Russell, Murphy, & Kurdyak, 2015). Unfortunately, it has also been observed that trace amounts of fentanyl have begun to be cut into tablets of MDMA found at music festivals, which put MDMA consumers in this environment at further risk (Bremer et al., 2016). Therefore, individuals conditioned to consuming MDMA in musical environments like music festivals are at much higher risk of a fatal overdose due to the reinforcement of their rewarded addiction to the consumption of MDMA.

As discussed above, the combination of visual and auditory cues strengthens the sensations of pleasure and reward. However, at the moment, there are no documented cases that highlight the possibility that these cues strengthen the development of addiction to MDMA. As seen in prior research, visual cues can further stimulate the production of DA within the mesolimbic pathway. Together with the additional production of DA caused by auditory cues, the amount of DA within the mesolimbic pathway increases significantly. With the backing of these strong arguments, research into the development of addiction caused by the correlation of visual and auditory cues present at music festivals and the consumption of MDMA should be considered.

CONCLUSION AND FUTURE STEPS

Although the perception of MDMA and musical stimuli differ from each other, hyperactivation of structures associated with reward and pleasure such as the NAcc, the ventral striatum, and the ventral pallidum is caused by the presence of both stimuli. The continuous presence of DA and its functions on post-synaptic receptors in these structures are believed to cause the development of addictive behaviors in the consumption of MDMA while perceiving pleasant auditory stimuli. These behaviors are strengthened as feelings of euphoria occur in MDMA consumption due to the increase of bonding with others in large group settings and the perception of visually appealing stimuli at music festivals in concurrency of the perception of pleasant auditory stimuli. As desensitization occurs due to the continuous consumption of MDMA, feelings of reward dwindle at music-filled spaces, thereby causing individuals to seek for larger amounts of drugs. With the prevalence of potentially fatal opioids such as fentanyl being cut into pills of MDMA, individuals who seek for more MDMA to satisfy their wants and needs are now in greater danger than ever before.

Currently, MDMA used by the public is obtained and consumed illegally; consequences of being caught selling or in possession of MDMA include heavy fines and possible jail time. This form of legislation against the use of the drug contributes to individuals consuming dangerous variations of the drug as they are unaware of exactly what is present, which could lead to potentially fatal outcomes. With overdosing occurring at multiple music festivals each year across North America, governments are beginning to consider measures to protect festival goers from drug consumption, but all with various stances and approaches; from completely banning events to installing public health booths at these events to provide education and the ability for individuals to dispose of or test their drugs with no consequence. However, even with these measures, overdosing is still happening and taking lives. Fortunately, research has been carried out over the past decade in the field of vaccinations to combat the development of drug addiction.

Vaccinations against drugs of abuse are being considered as a functionality to prevent individuals from becoming addicted to substances while still feeling its effects (Shen, Orson, & Kosten, 2012). To prevent the development of an addiction, vaccines block the drug molecules from entering the mesolimbic pathway (Shen et al., 2012). Tests for vaccines developed for different drugs are at various levels of research, from animal models for cocaine and methamphetamines to clinical trials for nicotine (Brashier, Sharma, & Akhoon, 2016; Domingo, Shorter, & Kosten, 2016; Goniewicz & Delijewski, 2013; Miller et al., 2015). Although promising as a preventative measure, in the case of MDMA where the functionality of positive emotion is triggered within the reward system, more research is still required to determine whether the vaccination would be helpful in deterring addiction development yet still providing users with the pleasure they expect. After research has been performed in the effects of the vaccine on MDMA, further research with the addition of reinforcing factors such as auditory and visual stimuli on their effects with those of MDMA may be conducted.

Understanding the mechanisms which lead to the consumption of MDMA in social and musical settings, such as at music festivals, provides the basis for the prevention of fatal overdosing. Only through this understanding can proper steps be taken into further research in preventative measures and the development of appropriate legislation to be implemented in the regulation of MDMA to the public.

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