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When Triggers Become Tigers: Taming the Autonomic Nervous System via Sensory Support System Modulation

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Abstract

Personalized recovery technologies may enable individuals with Substance Use Disorder (SUD) to monitor and manage acute craving and drug use urges in ways that improve drug-seeking decisions in real-time. Direct and indirect regulation of the autonomic nervous system through sensory input monitoring and modulation may enhance control over behavioral decisions and prevent relapse. A personalized sensory support system that monitors neurophysiological reactivity and offers non-pharmacological point-in-time personalized digital interventions may increase awareness of and control over craving reactivity. It is critical to be able to detect these warning signs and intervene early and effectively. The use of wearable technologies that assess point-in-time neurophysiological escalation and shape behavioral response through personalized interventions could be transformative in allowing individuals to better manage their recovery as they transition out of institutions and move back into community settings.

Keywords

addiction; recovery cues; self-regulation; social support; wearables; mobile technologies; recovery avatar

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The current COVID-19 pandemic has caused unprecedented widespread uncertainty, worry, social isolation, anxiety, fear and unemployment across the country and the world, all significant risk factors for SUD relapse. The High Intensity Drug Trafficking Areas (HIDTA) Program, a federal grant program administered by the White House Office of National Drug Control Policy (ONDCP) is also compiling anecdotal news report evidence that opioid-related deaths associated with COVID-19 are on the rise (High Intensity Drug Trafficking Areas, 2020). The social isolation is particularly worrisome. Adults with SUD show statistically higher levels of emotional, social, familial, and romantic loneliness (Hosseinbor, Yassini Ardekani, Bakhshani, & Bakhshani, 2014), emphasizing the need for those recovering from SUD to be connected, in real time, to their social support networks. This need for social connection is perhaps, now more than ever, crucial in preventing relapse and overdose deaths. For example, for those particularly vulnerable SUD populations during this pandemic, like those who have a Traumatic Brain Injury (TBI) and Opioid Use Disorder (OUD) where serious mood and cognitive alterations are common, systematic and prolonged engagement of supports and avoidance of environments that can cue relapse are important (Adams, Corrigan & Dams-O'Connor, December, 2019). In this time of COVID-19 physical distancing restrictions, the overwhelming risk to adverse mental health consequences and relapse require urgent attention.

In the face of this novel coronavirus, equally novel behavioral health interventions for SUD are necessary. We present a mobile sensory support system intervention aimed at monitoring physiological response to inter-intra and environmental cues, offering a three-pronged personalized intervention approach for rapid real-time response. These three facets include a 1) Recovery Avatar which offers a representation of the individual with SUD in his/her best regulated state to help bring that person back to a state of balance; 2) Recovery Cues which offer calming and reassuring stimuli to bring the individual back to a state of regulation; and; 3) Connection to Live Recovery Support System which automatically connects, through text and call, the individual to his sponsor and others in the immediate area who can offer sober support. We propose that this type of recovery system could be especially beneficial now, as we move into the mental health aftermaths of a long post-pandemic recovery, being particularly mindful of the compounded needs of individuals struggling with addiction. While the COVID-19 viral pandemic will come to an end, the mental health pandemic that will assuredly follow will likely be even more far reaching, affecting both those who were sickened and those who witnessed, firsthand, the devastating disease (Parrish, 2020). There is substantially increased risk of people experiencing symptoms similar to PTSD, suicidal ideations, depression, physical and social isolation and substance use as a direct result of COVID-19 (Parrish, 2020; Pfefferbaum & North, 2020). Our proposed recovery system directly addresses the heightened isolation that those with SUD experience (Hosseinbor, Yassini Ardekani, Bakhshani, & Bakhshani, 2014) and the powerful stimuli and cravings that drive continued substance abuse. In the following sections we review the role for social support in SUD recovery, briefly examine the science behind drug addiction, the rationale for a recovery cue intervention, then present our proposed multifaceted intervention technology and plan.

SUDs are among the most costly health conditions affecting Americans (U.S. Department of Health and Human Services, 2016). In 2018, 20.3 million people in the United States

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aged 12 or older had a SUD, 10.3 million misused opioids, and 164.8 million (60.2%) used substances (tobacco, alcohol, and/or illicit drugs) in the past one month (Substance Abuse and Mental Health Services Administration, 2019). In 2018, 2.4 million (11.1%) of individuals aged 12 or older who needed SUD treatment received such services at a specialty facility. Of those needing but not receiving treatment at a specialty facility, one-third could not afford the cost or did not have adequate health insurance coverage (Substance Abuse and Mental Health Services Administration, 2019). Substance misuse and SUD also have serious economic consequences, costing more than $400 billion annually in lost productivity, health, and crime (Sacks, Gonzales, Bouchery, Tomedi, & Brewer, 2015; National Drug Intelligence Center, 2011). Additionally, current illicit drug users are more than twice as likely as those who are not to have been fired or changed employers three or more times in the past year (Larson, Eyerman, Foster & Gfroerer, 2007). People who abuse drugs or alcohol are three and one-half times more likely to be involved in a workplace accident, resulting in increased workers' compensation and disability claims (U.S. Department of Health and Human Services, 2000). As such, the human and economic costs of addiction to society are enormous.

A particularly high yield time for targeted intervention is when individuals with SUD are transitioning out of institutional care (e.g,. jails, hospitals, rehabilitation centers, emergency departments), and entering back into their natural communities when relapse risk is high. It is at this crucial juncture that we hypothesize that our proposed intervention would be most effective. While, overall, approximately half of individuals will relapse within the first year after treatment (McLellan, Lewis, O'Brien, Kleber, 2000), one-month post-discharge is a particularly vulnerable time for relapse. For example, the first few weeks immediately following incarceration is a risky time for untreated mental health symptoms to spiral into housing, economic, and social instability. Many have experienced trauma, which has not been adequately addressed, and face the danger of going back to unhealthy relationships. For example, justice-involved women with mental health conditions are more likely to be hospitalized post-release and to experience difficulty finding housing and work, as compared to women without such conditions. Formerly incarcerated individuals often return to risk-saturated communities that create serious impediments to labor market attachment post-release. Many have diminished social networks and may be geographically distanced from good jobs (Sugie & Lens, 2017). Additionally, Americans report that they distance themselves both socially and in terms of relationships from those with SUD and that they possess a greater willingness to discriminate on a basis of employment (Barry et al., 2014; Pescosolido et al., 1999; Parcesepe and Cabassa, 2013).

The most prevalent causes of drug relapse are stress (Sinha, 2007), negative mood state, desire for positive mood state, social/family problems, external pressure to use, environmental triggers, sleep problems, cravings/urges, concentration difficulties (Hammerbacher & Lyvers, 2009; Kadam, Sinha, Nimkar, Matcheswalla & De Sousa, 2017), maladaptive coping strategies, and undesired life experiences (Mattoo, Chakrabarti & Anjaiah, 2009). Social support seems all the more crucial for individuals with SUD, not only to enhance coping strategies (Birtel, Wood & Kempa, 2017) and improve general wellbeing, but also in its proven ability to significantly decrease the likelihood of relapse (Ellis, Bernichon, Yu, Roberts & Herrell, 2004). Furthermore, social support is protective

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against initially developing alcohol and substance use disorder, is associated with positive SUD treatment outcomes, and perceived social support and substance use frequency is inversely related in socially stigmatized populations (Rapier, McKernan, & Stauffer, 2019).

Addiction as a Self-Regulation Disorder

Addiction is a self-regulation disorder where chronic exposure to and compulsive consumption of the drug creates dysregulation in the reward, stress and executive functioning regions of the brain, intensifying emotional reactivity and impairing cognitive and behavioral control (Volkow, Koob, & McLellan, 2016). Reward and stress system dysregulation, drug cue exposure, and impaired executive functioning lead to increased relapse risk.

Reward and Stress System Dysregulation

Reward system dysregulation and reduced cognitive control capacity are signature neural changes associated with addiction (Verdejo-Garcia, Chong, Stout, Yucel, & London, 2018). Previously pleasurable experiences and activities lose their rewarding value, a hyperreactive stress response system produces extreme distress and impairs executive functioning which, combined, leads to poor behavioral decision-making (Verdejo-Garcia, Chong, Stout, Yucel, & London, 2018) – “Selective energization to drug cues occurs at the cost of motivation for alternative reinforcers” (p.101). Behavior is directed by the functioning and control of the reward and executive systems (Bickel, Mellis, Snider, Athamneh, Stein, & Pope, 2018; Guttman, Moeller & London, 2018), and treatment success is associated with ability to delay reward gratification (Koffarnus, & Kaplan, 2018).

Exposure to SUD Stimuli Poses Relapse Risk

A solid evidence base suggests clients who participate in formal substance use treatment experience high relapse rates upon discharge in large part because they are repeatedly exposed to SUD-related stimuli (Kalivas, & Volkow, 2005; Koob & Kreek 2007; Koob & Volkow, 2010; Sinha, & Li, 2007). Exposure to such triggers leads to heightened autonomic arousal, craving, and further undermines emotional regulation capacity potentiating relapse (Strack & Deutsch, 2004; Uhart & Wand, 2008). Humphreys, Malenka, Knutson, & MacCoun (2017) found that, with that prolonged use of addictive substances, previously benign cues connected with the drug experience that held little signaling significance for the user start to become desirable on their own and create overwhelming cravings for further drug experiences. They expand on this noting that multiple sensory modes (tactile, visual, auditory, olfactory) can activate the brain’s motivational circuitry that stimulates appetitive behavior (any activity that increases the likelihood of satisfying needs or cravings). The abundance of these multisensory cues in a person’s environment makes it far more likely that the person with SUD will continue to use drugs.

Interoceptive Cues

Interoceptive dysregulation, or the inability to match internal signals with a desired state, is characteristic of SUD (Stewart, Khalsa, Kuplicki, Puhl, T1000 investigators, Paulus,

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2019); craving and drug urge are associated with higher insula (a region of the brain involved in the detection of novel stimuli across sensory modalities and associated with interoception) activation and more severe addiction. Internal physiological sensations are experienced but are not processed in the brain region responsible for helping to control those responses. Internal processing signals associated with insular activation and precipitated by drug cue exposure, impairs the reflective system, with insula activity as a mediator between craving and drug use (Bickel, Mellis, Snider, Athamneh, Stein & Pope, 2018). For example, SUD heart-related sensations were higher than controls, and individuals with more recent drug use showed heightened sensitivity to heartbeat, which corresponded with greater insula activation. Greater insula activation was shown in response to drug cues and less activation to nondrug cues (Stewart, Khalsa, Kuplicki, Puhl, T1000 investigators, Paulus, 2019), indicating self-regulation difficulties associated with drug cue exposure. Sensitivity in processing bodily states is associated with craving in addiction (Paulus & Stewart, 2014). Therefore, “interoceptive awareness”, as is the focus in mindfulness training, may help modulate craving. Studies demonstrate that “interoceptive awareness” is a key skill in helping individuals in SUD recovery manage triggers and cope with bodily and emotional reactions to persons, places, and events, ultimately prevent relapse (Price, Thompson, Crowell, Pike, Cheng, Parent, & Hooven, 2018).

Exteroceptive Cues

Several theories of addiction, including the incentive salience sensitization theory (Berridge and Robinson, 2016) and stress surfeit disorder (Koob, Buck, Cohen, Edwards, Park, Schlosburg,& George, 2014), suggest that drug cues hold motivational power through the reinforcement learning process, which can lead to relapse when triggered by the cues. Exteroceptive cues, those experienced by stimuli outside the body such as the sensory characteristics of the drug itself (visual, smells, tastes) or rituals used to obtain and consume the substance, can activate autonomic (physiological changes), attention, and motor activity and are hypothesized to lead to substance use (Cofresi, Bartholow, & Piasecki, 2019). Such cues increase Heart Rate (HR) even when mental imagery is used as the cue-elicited task (Oberlin, Dzemidzic, Eiler, Carron, Plawecki, Grahame, O’Connor, & Kareken, 2018). Behavior (i.e., drug-seeking) is affected when exposed to cues, even when the cue was not followed by substance ingestion in the past; this can be referred to as drug cue reactivity (Cofresi, Bartholow, & Piasecki, 2019). While there are many drug treatment options that attempt to address the psychological factors and the surrounding social environment influences that may lead to relapse, they still leave those with SUD vulnerable because they fail to effectively address or limit drug cue reactivity (Cofresi, Bartholow, & Piasecki, 2019).

Stress and Prior Trauma

Past trauma creates a vulnerability to drug cue reactivity (Gawrysiak, Jagannathan, Reiger, Suh, Kampman, Vickery & Childress, 2017). Exposure to other stressors amplifies drug-induced stress system dysregulation. For example, it is recognized that other behavioral and stress reduction interventions are necessary to improve the efficacy of Medication Assisted Therapy (MAT), an approach that uses drugs such as Buprenorphine to treat drug addiction. MacLean, Armstron and Sofuoglu (2019): “Therefore, among those who are on MAT, negative affect, craving, and withdrawal may persist and contribute to higher appraised

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stress in addition to individual challenges present in daily life" (MacLean et al., 2019, p. 8). Traumatic stress creates hyper-reactivity to environmental stimuli in brain regions involved in the stress response, such as the amygdala, similar to the brain response observed following exposure to drug-related cues (Regier et al, 2016). The unprecedented burden of trauma experienced by individual and families during this COVID-19 pandemic creates heightened vulnerability to relapse or overdose if individuals in SUD recovery are not able to manage cue exposure, particularly when social supports are not consistently engaged.

Impaired Decision-making

In SUD, drug taking continues over alternative behaviors and despite experienced negative consequences. Habit-formed, automatic behavior associated with Type I thinking (Kahnemann, 2011) exerts more control over behavior than Type II rational thinking processes. Context-response associations that develop increase the probability of continued drug-use. Alternative competing and repeating recovery-relevant behaviors are necessary to disrupt existing learning mechanisms (e.g., social support, natural positive rewards associated with recovery (Lamb & Ginsburg, 2018). Thus, diminished rewarding experiences, increased stress reactivity and distress, and impaired cortical regulatory control leads to continued drug use despite negative consequences (Volkow, Koob, & McLellan, 2016) and to poor treatment outcome (Aharonovich, et al., 2008). Individuals in recovery from SUD are not able to "think through" cue-induced intense emotional experiences which is why cognitive-only relapse prevention strategies are not always effective, particularly in the very early stage of recovery and in the vulnerable first hours after leaving a treatment institution where individuals have a short history of abstinence, and yet are going back to a community where they have a long history of substance use, and will be exposed to substance-related stimuli.

Restoring Regulation

The depth of literature on the neuroscience of addiction clearly shows the effects of SUD on brain and behavior and demonstrates its impact operates at cognitively unconscious or implicit levels of awareness. Thus, SUD intervention efforts must be designed in ways that effectively respond to these brain-based changes that influence behavior. A personalized sensory support system – sensory stimuli associated with recovery – could offer a point-in-time counter-conditioning regulation tool when confronted with SUD-associated cues. Mobile recovery technologies that enable individuals in recovery to become aware of *when* their brains and bodies are reacting to drug-related stimuli, and by providing personalized recovery-stimuli substitutions at that moment, along with immediate connections to their virtual and/or live sober support networks, will help individuals gain awareness and control over cravings that, over time, will decrease relapse (Matto, 2015; Matto & Seshaiyer, 2018).

In a review of the literature partially examining existing technological interventions that incorporate biosensor feedback, Tofighi, Abrantes and Stein (2018) note that "most work has been conducted with transdermal alcohol sensors such as the commercially available Secure Continuous Remote Alcohol Monitoring device (SCRAM; Alcohol Monitoring Systems, Inc, Littleton, CO). SCRAM takes measurements every 30 minutes and is able

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to wirelessly convey transdermal readings to a remote server" (pg. 721) so that those with SUD can be monitored for continued sobriety. This is most commonly used within the criminal justice system to monitor those convicted of drunk driving for adherence to the terms of their probation. Needless to say, this technology is more punitive in nature, is alcohol specific, does not address drug cues or the need for intervention and regulation, and is largely ex post facto of relapse. In the literature they do find that future technologies could hypothetically, "in concert with artificial intelligence, continuous physiologic monitoring, wireless connectivity, and smartphone computation, be able to detect when an individual is experiencing craving for alcohol or drug use and could receive a just-in-time intervention to prevent substance use during times of greatest need" (pg. 722) but add that these technologies and the algorithms they use for predicting cravings are largely in the developmental stages and do not identify the actual personalized interventions themselves.

Managing cue reactivity in one's natural environment is of significant focus for recovery maintenance. Emotional dysregulation is a signature of SUD and emotional regulation the key component in treatment. In fact, psychological self-regulation (affect regulation) and interpersonal dysfunction in childhood and adolescence were most significant characteristics associated with later SUD outcomes (Jing, Hu, Fan, Xue, Wang, Tarter, Kirisci, Wang, Vanyukov & Xie, 2019). Thus, direct and indirect regulation of the autonomic nervous system through sensory input monitoring and modulation may enhance control over behavioral decisions. More specifically, research shows modulation of the amygdala-to-visual cortex pathway may change craving response and regulate drug urge and drug-seeking behavior (McHugh, Demers, Salmeron, Devous Sr., Stein & Adinoff, 2014), suggesting a route to amygdala modulation via changing visual sensory input. For example, in a recent pilot study, we examined the effect of personalized recovery cues (e.g., self-selected recovery-oriented images, photos, soundscapes, etc.) on reducing drug cue exposure reactivity, as measured by Heart Rate Variability (HRV) change, in a pilot sample of young adults in substance use recovery (N=8). Results showed that a person's recovery intervention was associated with a more relaxed physiological state immediately after drug cue exposure (HRV rMSSD drug cue Mean = 53.55 vs HRV rMSSD recovery cue Mean = 71.90; $P \leq .05$) (Matto & Seshaiyer, 2018). RMSSD is the root mean square of successive differences between beats, and is one of the metrics of HRV. Higher HRV has been suggested as a clinical indicator of mental health (Beauchaine & Thayer, 2015).

Personalized Sensory Support intervention: Sensory Input Modulation

Competing recovery-relevant rapid (not delayed) reward experiences are necessary and need to operate within environmental conditions that facilitate recovery. New recovery behaviors need to be experienced frequently to become new "habits", recovery associated stimuli may facilitate regulatory capacity in the face of drug cue stressors. Asking clients to consider: "*What brings you back to safety*"? is an important initial guiding question in helping the client develop their personalized sensory support system. Stimuli need to have personal connections and relate to the self to produce meaningful learned outcomes (Ann, & Hidi, 2019). Thus, we propose a personalized sensory support system with recovery cue

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interventions that includes three core features: 1) Recovery Avatar; 2) Recovery Cues; and; 3) Connection to Live Recovery Support System.

Recovery Avatar

Activation of a recovery avatar (the individual in a simulated recovery-regulated state) provides step-by-step recovery regulation instructions as a guide to “doing the right thing”, and to accelerate relationship with one’s recovery self, when experiencing an in vivo SUD-triggering event. These recovery avatars – personal recovery companions -- digitized to a smartwatch and included as part of a holistic personalized sensory support intervention, are programmed to activate when neurophysiological relapse risk is detected in real-time.

Recovery Cues

Similar in concept to sensory rooms on college campuses that offer a variety of sensory experiences to choose from for neurodiverse populations to self-regulate, we propose a digitized sensory support system with personalized recovery cues offering individuals in recovery real-time regulation. Examples of recovery cues that emerged as important from our prior pilot studies (Matto, Seshaiyer, Newcomb, Rothberg & Lopez-Piper, 2019; Matto & Seshaiyer, 2018) include: *Tactile features* such as vibration, one’s own regulated heartbeat; *visual features* such as video bubbles, photos/images, music visualization; *audio features* such as a sponsor’s voice for examples saying “you are safe”, one’s own voice reading a gratitude list, music, soundscape/nature sounds. Other studies that have examined transforming a drawn stressor image into a coping resource show stress reduction, particularly when minimizing the size of the stressor in the new integrated drawing (Segal-Engelchin, Achdut, Huss & Sarid,2020). Taking control over a stressful image/cue by changing its characteristics can bring healing and growth and decrease stress (Huss & Sarid, 2014). In other studies, researchers have found that mindful self-regulation 'acting with awareness' techniques (Cavicchiolia, Ramellaa, Vassenaa, Simonea, Prudenziatia, Sirtoria, Movallia & Maffeia, 2020) were helpful regulation strategies for alcohol use disorder. We propose that maximizing the size of recovery cues when presented can enhance the regulatory effect of the sensory support intervention and suggest that with guidance from the recovery avatar in modeling the minimizing drug cues-maximizing recovery cue strategy, the individual may train one’s attention towards recovery engagement, decreasing real-time relapse risk.

In this light, we propose that in addition to passive presentation of an individuals’ repertoire of personalized recovery cues, an interactive component whereby a recovery cue could be digitally transformed when projected onto a smartphone app with interactive screen for modulation of the sensory characteristics (e.g, size, color, shape) could maximize physiological regulation through mindful attention to and control over those enhanced sensory changes.

Connection to Live Recovery Support System

Networked communities of care, where systems are inter-connected around the same goal of community stabilization, is essential in helping individuals in SUD recovery navigate the institution-community transition. For example, when a monitoring device activates

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neurophysiological threshold for relapse risk, those in the individual's recovery support system who are in real-time within their own recovery-regulation range, can be alerted and can opt-in to respond to the individual for support. Lynch and colleagues (2018) emphasize the importance for both individuals in recovery and their mentors to have access to each other 24 hours a day, as challenges are unpredictable in their timing and onset. Mobile recovery support systems that allow for real-time monitoring and connection to an in-person or virtual recovery support network could help individuals maintain adherence to their recovery goals. Connecting to a larger support network may result in shared learning experiences and collective success.

Machine learning will be used to train the mobile recovery system to learn from daily activation and modulation patterns, to detect time, location, and frequency of activation, as well as measure time-to-stabilization corresponding to specific sensory support system intervention. The system learns which of the interventions (recovery avatar, recovery cues, engagement with virtual or live supports) had the strongest effect in changing neurophysiological functioning back to the person's regulated state. Users see prompts, such as daily graphs and other visualizations that show activation patterns and corresponding neurophysiological changes associated with the four core intervention features and thus, users will gain awareness of their craving activation-modulation patterns.

Personalized Sensory Support System in Action

"A picture is worth a thousand words" --- and while research has not quantified the exact number of words that a picture is worth, research does suggest that pictures offer greater value than words alone in many instances (Strekalova & Krieger, 2017). With this in mind, we paint the following picture of a hypothetical day in the life of a person with SUD who is using our personalized sensory support system in action.

> J., an individual in recovery for Opioid Use Disorder (OUD) walks out of her last day of inpatient treatment program where she received her Buprenorphine and cognitive behavioral therapy for the treatment of her opioid dependence. She gets in the taxi the front desk has called for her and heads to the airport to fly home. Before she gets in the taxi, her personalized sensory support system smart watch vibrates and she reads the display. "It's 1:00pm. Are we having any cravings now?" The device knows from previous input that the majority of J.'s cravings happen in the early afternoon when she would usually wake and need to use. J. selects "No" from the menu. Yet as she later boards the plan, she realizes that it has been over a decade since she flew without prescription opioids in her system and she becomes anxious and begins to long for the relaxation that meds have offered. Her smart watch reads her low baseline levels of heart rate variability which are associated with increases in drug cravings and again vibrates, displaying a new scrolling message: "It appears we are having cravings, let's get back to recovery....remember we have had cravings before and overcame them and we will again this time...great I can detect that our heart rate variability is returning to a non-craving pattern so our body is balancing....things will be ok." The user lands and calls an Uber. On the way home, she knows that she must pass by the pain management clinics

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where she used to doctor shop to get her opioids. As she passes by the first clinic, her smart watch beeps and vibrates this time, then displays the message: “We are within ¼ mile of a location that causes cravings for you, let’s look at pictures of your children for a few minutes.” J. looks at the display of her children which she uploaded to the device. While she finds comfort in these images, passing by Florida’s multiple pain management treatment centers is proving too much for these initial interventions and her cravings persist. The smart watch’s alarm goes off and vibrates. A new message reads: “Our heart rate variability has been low for over 20 minutes and we are still close to locations known to trigger cravings in you in the past, I have sent text messages to five people in your Recovery Community who are within their own recovery-regulation range and three have opted-in and will be calling or texting momentarily to support us. I have also connected to our phone and it will call our sponsor now.” The user relaxes knowing that there are now people on board to help her through this. Things will be ok.

Conclusion

The human, social, and economic impact of SUD on society is tremendous. In the current COVID-19 pandemic, social isolation, anxiety, fear, and grief and trauma compound the risk for relapse and overdose. We propose that recovery technologies that enhance self-regulation and recovery network engagement stand to increase behavioral commitment to recovery goals and are, now of utmost importance. Personalized learning technologies, such as a mobile recovery support system, may enable individuals with behavioral health challenges to live well and remain in their communities of choice by helping them monitor and manage symptoms. A personalized sensory support system that monitors neurophysiological reactivity and offers a non-pharmacological point-in-time personalized digital intervention can shape behavioral decision-making when executive functioning capacity is limited due to disease or disorder. In this way, individuals may gain control over symptom expression in community settings, where they may not be continuously connected to formal systems of care, with the goal of decreasing the emotional and physiological escalation that leads to poor behavioral decision-making.

Self-managed recovery regulation is important in reducing craving and preventing relapse. Along with enhancing self-regulation capacity, individuals in SUD recovery need strong and supportive recovery relationships that promote adherence to recovery goals. Using digital technologies may be a way to extend supportive real-time recovery-focused social engagement. Research has shown bonding and positive attachment experiences can decrease craving intensity (Sanjuan, Pearson, Fokas & Leeman, 2019). A system that promotes real-time relational engagement, both to a virtual community and to real-time live supports, would facilitate in vivo recovery regulation.

Relationships are important in times of distress. For example, themes from semi-structured interviews we conducted with five women in recovery identified similar challenges. Specifically, finding supportive and permanent housing; gainful employment; and meaningful reconnection with children and family members, were the immediate concerns. A common distress was worry over medical and dental care. Another participant

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worried about getting sick from an upcoming medical treatment, wondering who would care for her during and after the procedure. A common theme that produced both distress and extreme motivation to "do the right thing" was their relationship with their children. Some discussed the "waiting" as being very difficult; other significant stressors were finding affordable housing and a job, and their relationships with other people (not family or friends) that often trigger emotional distress: "*I'm scared to fall back. Finding a job is stressful"*. On the other hand, positive connections to family and friends can bring comfort. It was clear individuals need mentors to assist them in completing education, finding jobs, and providing recovery support and encouragement as they integrate back into society. These themes suggest that being able to connect in meaningful ways to the people, services and opportunities that will help them meet their needs, will also help these returning community members stay in recovery. These findings are consistent with other similar studies (e.g., see Manual, Yuan, Herman, Svikis, Nichols, Palmer & Deren, 2017).

In summary, persons with SUD lived experience suggest that our scientific focus needs to be on understanding barriers and recovery opportunities in the environment and in areas of social support. We need to "treat the whole person", and to understand that individuals may be in relapse mode long before actual relapse, and so we need to be able to detect these warning signs and intervene early and effectively. The next step to treating the person as a whole is encouraging the person to come to know his/her whole self. Guiding the person in using mindfulness tactics and focusing on the present moment, while calmly acknowledging and accepting feelings, thoughts, and bodily sensations both while in a state of recovery-regulation and dysregulation, can promote recovery and social connection.

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References

Adams RS, Corrigan JD, & Dams-O'Connor K (12, 2019). Opioid use among individuals with Traumatic Brain Injury: A perfect storm? Journal of Neurotrauma, 37(1), . 10.1089/neu.2019.6451.

Aharonovich E, Amrhein PC, Bisaga A, Nunes EV, & Hasin DS (2008). Cognition, commitment language, and behavioral change among cocaine-dependent patients. Psychology of Addictive Behaviors, 22, 557–562. [PubMed: 19071981]

Ann K, & Hidi SE. (2019). Supporting the development of interest in the workplace (pp. 19–34) in Workforce Readiness and the Future of Work (Society for Industrial and Organizational Psychology Frontiers Series , Editors Oswald FL, Behrend TS and Foster LL. Routledge, New York.

Bakken NW, & Visher CA (2018). Successful reintegration and mental health. Criminal Justice and Behavior, 45 (8), 1121–1135.

Barry C, McGinty E, Pescosolido B, & Goldman H (2014). Stigma, Discrimination, Treatment Effectiveness, and Policy: Public Views About Drug Addiction and Mental Illness. Psychiatric Services, 65(10), 1269–1272. [PubMed: 25270497]

Beauchaine TP, & Thayer JF (2015). Heart rate variability as a transdiagnostic biomarker of psychopathology. International Journal of Psychophysiology, 98, 338–350. [PubMed: 26272488]

Berridge KC, & Robinson TC (2016). Liking, wanting, and the incentive-sensitization theory of addiction. American Psychologist, 71(8), 670–679.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Bickel WK, Mellis AM, Snider SE, Athamneh LN, Stein JS, & Pope DA (2018). 21st century neurobehavioral theories of decision making in addiction: Review and evaluation. Pharmacology, Biochemistry and Behavior, 164, 4–21.

Birtel M, Wood L, & Kempa N (2017). Stigma and Social Support in Substance Abuse: Implications for Mental Health and Well-Being. Psychiatry Research, 252, 1–8. [PubMed: 28237758]

Cavicchiolia M, Ramellaa P, Vassenaa G, Simonea G, Prudenziatia F, Sirtoria F, Movallia M, & Maffeia C (2020). Mindful self-regulation of attention is a key protective factor for emotional dysregulation and addictive behaviors among individuals with alcohol use disorder. Addictive Behaviors, 105, 10.1016/j.addbeh.2020.106317

Cofresi RU, Bartholow BD, & Piasecki TM (2019). Evidence for incentive salience sensitization as a pathway to alcohol use disorder. Neuroscience and Biobehavioral Reviews, 107, 897–926. [PubMed: 31672617]

Gawrysiak MJ, Jagannathan K, Reiger P Suh JJ, Kampman K, Vickery T, & Childress AR (2017). Unseen scars: Cocaine patients with prior trauma evidence heightened resting state functional connectivity (RSFC) between the amygdala and limbic-striatal regions. Drug and Alcohol Dependence, 180, 363–370. [PubMed: 28957777]

Guttman Z, Moeller SJ, & London ED (2018). Neural underpinnings of maladaptive decision-making in addictions. Pharmacology, Biochemistry and Behavior, 164, 84–98.

Ellis B, Bernichon T, Yu P, Roberts T, & Herrell J (2004). Effect of social support on substance abuse relapse in a residential treatment setting for women. Evaluation and Program Planning, 27(2), 213–221.

Hammerbacher Melissa, and Lyvers Michael. (2006). Factors associated with relapse among clients in Australian substance disorder treatment facilities. Journal of Substance Use, 11(6),387–394.

High Intensity Drug Trafficking Areas (2020). COVID-19. Retrieved from: http://www.hidta.org/category/covid-19/

Hosseinbor M, Yassini Ardekani SM, Bakhshani S, & Bakhshani S (2014). Emotional and social loneliness in individuals with and without substance dependence disorder. International Journal of High Risk Behaviors & Addiction, 3(3).

Humphreys K, Malenka RC, Knutson B, & MacCoun RJ (2017). Brains, environments, and policy responses to addiction. Science, 356 (6344), 1237–1238. [PubMed: 28642399]

Huss E, & Samson T (2018). Drawing on the Arts to Enhance Salutogenic Coping With Health-Related Stress and Loss. Frontiers in Psychology, 9 (1612).

Jing Y, Hu Z, Fan P, Xue Y, Wang L, Tarter RE, Kirisci L, Wang J, Vanyukov M, & Xie X-Q (2019). Analysis of substance use and its outcomes by machine learning I. Childhood evaluation of liability to substance use disorder. Drug and Alcohol Dependence, 10.1016/j.drugalcdep.2019.107605.

Kadam M, Sinha A, Nimkar S, Matcheswalla Y, & De Sousa A (2017). A Comparative Study of Factors Associated with Relapse in Alcohol Dependence and Opioid Dependence. Indian journal of psychological medicine, 39(5), 627–633. [PubMed: 29200559]

Kahneman D (2011). Thinking, fast and slow. Farrar, Straus, & Giroux: New York.

Kalivas PW, & Volkow ND (2005). The neural basis of addiction: A pathology of motivation and choice. American Journal of Psychiatry, 162, 1403–1413.

Koffarnus MN & Kaplan BA (2018). Clinical models of decision-making in addiction. Pharmacology, Biochemistry and Behavior, 164, 71–83.

Koob GF, Buck CL, Cohen A, Edwards S, Park PE, Schlosburg JE & George O (2014). Addiction as a stress surfeit disorder. Neuropharmacology, 76, 370–382. [PubMed: 23747571]

Koob G, & Kreek MJ (2007). Stress, dysregulation of drug reward pathways, and the transition to drug dependence. American Journal of Psychiatry, 164, 1149–1159.

Koob GF, & Volkow ND (2010). Neurocircuitry of addiction. Neuropsychopharmacology, 35, 217–238. [PubMed: 19710631]

Lamb RJ, & Ginsburg BC (2018). Addiction as a BAD, a Behavioral Allocation Disorder. Pharmacology, Biochemistry and Behavior, 164, 62–70.

Larson LS, Eyerman J, Foster MS, & Gfroerer JC (2007). Worker Substance Use and Workplace Policies and Programs. Rockville, MD: SAMHSA, OAS.

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Lynch M, Astone NM, Collazos J, Lipman M, & Esthapan S (2018). Arches transformative mentoring program: An implementation and impact evaluation in New York City. Urban Institute: Washington, DC.

MacLean RR, Armstrong JL, & Sofuoglu M (2019). Stress and Opioid Use Disorder: A systematic review. Addictive Behaviors, 98, Article 106010. [PubMed: 31238237]

Manual JI, Yuan Y, Herman DB, Svikis DS, Nichols O, Palmer E, & Deren S (2017). Barriers and facilitators to successful transition from long-term residential substance abuse treatment. Journal of Substance Abuse Treatment, 74, 16–22. [PubMed: 28132695]

Matto HC (2015). Bioehavioral Response Redirection: Innovations to Activate Personalized Recovery Cues and Decrease Relapse Risk. End Note: Journal of Social Work Practice in the Addictions, 15, 450–453.

Matto HC, & Seshaiyer P (2018). Harnessing the Power of the Recovering Brain to Promote Recovery Commitment and Reduce Relapse Risk. Social Work in Journal of the Society for Social Work and Research, 9(2), 341–358.

Matto H, Seshaiyer P, Newcomb A, Rothberg S & Lopez-Piper. (2019). A novel mobile biobehavioral regulation system for personalized trauma recovery support. Patient Exp. J 6, 83–92.

Mattoo SK, Chakrabarti S, and Anjaiah M. (2009). Psychosocial factors associated with relapse in men with alcohol or opioid dependence. The Indian journal of medical research, 130(6), 702–708. [PubMed: 20090130]

McHugh MJ, Demers CH, Salmeron BJ, Devous MD Sr., Stein EA, & Adinoff B (2014). Cortico-amygdala coupling as a marker of early relapse risk in cocaine-addicted individuals. Frontiers in Psychiatry, 5(16), 1–13. [PubMed: 24478729]

McLellan AT, Lewis DC, O'Brien CP, Kleber HD. Drug dependence, a chronic medical illness: implications for treatment, insurance, and outcomes evaluation.JAMA. 2000;284(13):1689– 1695. [PubMed: 11015800]

National Drug Intelligence Center. (2011). National drug threat assessment. Washington, DC: U.S. Department of Justice.

Oberlin BG, Dzemidzic M, Eiler WJA, Carron CR, Soeurt CM, Plawecki MH, Grahame NJ, O'Connor SJ, & Kareken DA (2018). Pairing neutral cues with alcohol intoxication: new findings in executive and attention networks. Psychopharmacology (Berl.), 235, 2725–2737). [PubMed: 30066136]

Parcesepe A, & Cabassa L (2012). Public Stigma of Mental Illness in the United States: A Systematic Literature Review. Administration and Policy in Mental Health and Mental Health Services Research, 40(5), 384–399

Parrish E (2020). The next pandemic: COVID-19 mental health pandemic. Perspectives in Psychiatric Care, 56(3), 485–485. [PubMed: 32602165]

Paulus MP & Stewart JL (2014). Interoception and drug addiction. Neuropharmacology, 76, 342–350. [PubMed: 23855999]

Pescosolido B, Monahan J, Link B, Stueve A, & Kikuzawa S (1999). The public's view of the competence, dangerousness, and need for legal coercion of persons with mental health problems. American Journal of Public Health (1971), 89(9), 1339–1345.

Pfefferbaum B, & North C (2020). Mental Health and the Covid-19 Pandemic. The New England Journal of Medicine.

Price CJ, Thompson EA, Crowell SE, Pike K, Cheng SC, Parent S, & Hooven C (2018). Immediate effects of interoceptive awareness training through Mindful Awareness in Body-oriented Therapy (MABT) for women in substance use disorder treatment. Substance Abuse, DOI: 10.1080/08897077.2018.1488335

Pu L, Moyle W, Jones C, & Todorovic M (2019). The effectiveness of social robots for older adults: A systematic review and meta-analysis of randomized controlled studies. The Gerontologist, 59(1), e37–e51. [PubMed: 29897445]

Rapier R, McKernan S, & Stauffer CS (2019). An inverse relationship between perceived social support and substance use frequency in socially stigmatized populations. Addictive behaviors reports, 10, 100188. 10.1016/j.abrep.2019.100188 [PubMed: 31294075]

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Regier PS, Monge ZA, Franklin TR, Wetherill RR, Teitelman A, Jagannathan K, … Childress AR (2017). Emotional, physical and sexual abuse are associated with a heightened limbic response to cocaine cues. Addiction Biology, 22(6), 1768–1777. [PubMed: 27654662]

Sacks JJ, Gonzales KR, Bouchery EE, Tomedi LE, & Brewer RD (2015). 2010 national and state costs of excessive alcohol consumption. American Journal of Preventive Medicine, 49(5), e73–e79 [PubMed: 26477807]

Sanjuan PM, Pearson MR, Fokas K, & Leeman LM (2019, 12 12). A mother's bond: An ecological momentary assessment study of Posttraumatic Stress Disorder symptoms and substance craving during pregnancy. Psychology of Addictive Behaviors. Advance online publication. 10.1037/adb0000543

Segal-Engelchin D, Achdut N, Huss E, & Sarid O (2020). CB-Art Interventions Implemented with Mental Health ProfessionalsWorking in a SharedWar Reality: Transforming Negative Images and Enhancing Coping Resources. International Journal of Environmental Research and Public Health, 17(2287), 1–13.

Sinha Rajita. (2007). The role of stress in addiction relapse. Current Psychiatry Reports, 9 (5), 388–395. [PubMed: 17915078]

Sinha R, & Li CS (2007). Imaging stress-and cue-induced drug and alcohol craving: association with relapse and clinical implications. Drug & Alcohol Review, 26(1), 25–31. [PubMed: 17364833]

Stewart JL, Khalsa SS, Kuplicki R, Puhl M, T1000 investigators, Paulus MP (2019). Interoceptive attention in opioid and stimulant use disorder. Addiction Biology, e12831. 10.1111/adb.12831 [PubMed: 31617639]

Strack F, & Deutsch R (2004). Reflective and impulsive determinants of social behavior. Personality and Social Psychology Review, 8, 220–247. [PubMed: 15454347]

Strekalova Y, & Krieger J (2017). A picture really is worth a thousand words: Public engagement with cancer information on social media. Journal of Cancer Education : the Official Journal of the American Association for Cancer Education, 32(1), 155–157. [PubMed: 26351003]

Substance Abuse and Mental Health Services Administration. (2019). Key substance use and mental health indicators in the United States: Results from the 2018 National Survey on Drug Use and Health (HHS Publication No. PEP19-5068, NSDUH Series H-54). Rockville, MD: Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration. Retrieved from https://www.samhsa.gov/data/

Sugie NF, & Lens MC (2017). Daytime locations in spatial mismatch: Job accessibility and employment at reentry from prison. Demography, 54, 775–800. [PubMed: 28224468]

Tofighi B, Abrantes A, & Stein M (2018). The Role of Technology-Based Interventions for Substance Use Disorders in Primary Care: A Review of the Literature. The Medical Clinics of North America, 102(4), 715–731. [PubMed: 29933825]

Uhart M, & Wand GS (2008). Stress, alcohol and drug interaction: an update of human research. Addiction Biology, 14, 43–64. [PubMed: 18855803]

U.S. Department of Health and Human Services (HHS), Office of the Surgeon General, Facing Addiction in America: The Surgeon General's Report on Alcohol, Drugs, and Health. Washington, DC: HHS, 11 2016.

U.S. Department of Health and Human Services, SAMHSA, 1999 National Household Survey on Drug Abuse, Rockville, MD: US DHHS, 2000.

Verdejo-Garcia A, Chong TT-J, Stout JC, Yucel M, & London ED (2018). Stages of dysfunctional decision-making in addiction. Pharmacology, Biochemistry and Behavior, 164, 99–105.

Volkow ND, Koob GF & McLellan AT Neurobiologic Advances from the Brain Disease Model of Addiction. N. Engl. J. Med 374, 363–371 (2016). [PubMed: 26816013]