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Mind the dad–A review on the biopsychosocial influences of drug abuse on father-infant interaction ☆

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ABSTRACT

Substance use disorder (SUD) is an issue of concern that can have inter- generational impacts. Fathers affected by this disorder can exhibit atypical parenting that leaves pronounced, adverse consequences for the child, espe cially during a critical window for development, such as neonatal life and infancy. However, factors sustaining paternal drug use and its associated health outcomes remain elusive. The present review provides a systematic literature search of the scientific evidence published until February 2021 on PubMed Central, Scopus, PsycInfo, and PubMed databases. Adopting a biopsychosocial model, this review provides comprehensive insights into the issue, detailing: (i) the neurobiological correlates of paternal substance use and atypical parenting mechanisms, (ii) influence of drug consumption on paternal psychological state, and (iii) the social environment modulating the social dynamics central to fathers with SUD. Attention is also paid to the bidirectional relationships between paternal drug abuse and fatherhood, which has been severely neglected so far. Findings shed new light on the importance of paternal contributions to the father-child interaction, supporting the formulation of more targeted multidisciplinary interventions aimed at restoring such a crucial and overlooked relationship.

1. Introduction

Substance use disorder (SUD) is related to the uncontrolled and harmful use of psychoactive substances, which has been associated with an impairment in the inhibitory controls of social behaviors and relates to more risk-seeking actions (Association, 2020). These substances can be categorized as legal (e.g. nicotine from tobaccos), illegal (e.g. cocaine, heroin) or prescription/control drugs (McLellan, 2017), sometimes taken without clinical supervision (Corazza et al., 2019). Furthermore, according to the Diagnostic and Statistical Manual of Mental Disorders-5 (DSM-5), substances responsible for SUD are categorized into classes based on their phar macological and behavioural effects. These include (1) alcohol, (2) inhalants, (3) stimulants, (4) cannabis, (5) hallucinogens, (6) opioids, (7) sedatives, hypnotics or anxiolytics and (8) tobacco (American Psychiatric Association and others 2013). Of particular concern is also the use of novel psychoactive substances (NPS) and other emergent drugs, which have not been previously tested in humans (Corazza et al., 2013) and are particularly attractive to young male (Dores et al., 2021; Kuypers et al., 2021). These NHPS (e.g. synthetic cannabimimetics) led to a widespread consumption of herbal, pharmaceutical, or 'chemical' substances often labelled as 'legal' alternatives to the illicit counterparts (Corazza et al., 2013), leading to unwanted side-effects, hospital emergency admissions and sometimes fatalities. According to the United Nations, NPS are defined as "*substances of abuse, either in a pure form or a preparation, that are not controlled by the 1961 Single Convention on Narcotic Drugs or the 1971 Convention on Psychotropic Substances, but which may pose a public health threat*" (see United Nations Office on Drugs and Crime). According to data from the National Survey on Drug Use and Health (NSDUH), approximately 19.7 million American adults were diagnosed with SUD in 2017 (see American Addiction Center). Notably, sex differences in the prevalence and implications of drug abuse are well documented across literature. Men compared to women are 1.4 to 2 times more likely to engage in substance

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use (Somers et al., 2004), including the use of illicit drugs, and tend to start consumption at an earlier age compared to women (McHugh et al., 2018). Studies have also attempted to delineate the sex differences on SUD implications. In this case, females are more inclined to escalate drug use and relapse, wherein both human and animal studies, females tend towards a shift from a loss of voluntary control to compulsive drug use faster than males (Becker et al., 2017). This is supported by neurobiological data on sex differences in the brain addiction circuit, involving the nucleus accumbens and dorsal striatum. The former is responsible for modulating engagement in initially rewarding, non-pathological behaviours, while the latter in compulsive addictive behaviours. In those affected by addiction, dopamine activation is diminished in the nucleus accumbens but enhanced in the dorsal striatum that resultantly drives compulsive substance use. However, the sex differences are in part, explained by a comparatively smaller response in the nucleus accumbens and greater, more rapid response in the dorsal striatum to the initial substance stimulation in females, as opposed to males (Becker et al., 2017).Furthermore, sex differences in treatment and prognosis of SUD have been examined. No tably, in women attempting abstinence, they experience greater unpleasant symptoms of withdrawal, including effects on mood, heightened anxiety and stress. While collative evidence suggests similar treatment outcomes between genders once women overcome treatment barriers, they still face a greater propensity for relapse which are more sporadic or triggered by either negative affect or abuse (Becker et al., 2017). Notwithstanding this growing line of study, it is also of paramount importance to consider its implications on parenting. Thus far, perspectives on good parenting approaches can be culturally diverse as reported in a myriad of studies (Bornstein, 2012; Crippen and Brew, 2007; Yeh et al., 2010). Nonetheless, it has also been ubiquitously reported that parental SUD impoverishes parenting capacity such as exhibiting more parent-child conflict, less parental warmth, low levels of child supervision and more (Arria et al., 2012). Traditionally, the field of child development and parenting focuses heavily on maternal contributions. As both parental figures are central for a normal child development in facets of social, cognitive, physiological and psychological aspects, attention should also be given to father-infant interactions. Further given the greater prevalence for men to develop SUD, it should therefore be mandatory to scrutinize factors that sustain drug-abusing behaviors on father-child outcomes, which remain elusive. Tapping on advances in the scientific field, it seems imperative to employ a multisystem biopsychosocial approach to gain deeper insights on the mechanisms regulating these parent-infant interactions (Senese et al., 2019). This approach holds a comprehensive framework in forging a multilevel approach to functioning, encompassing the biological, psychological and social processes (Suls and Rothman, 2004). This is intuitive due to the embodiment of caregiving and parenting behaviours in interactions, regulated at said processes (Senese et al., 2019). Deficits in paternal caregiving due to substance use, especially during the critical window period where a child requires optical care, could leave profound, adverse consequences for the dyad across the three levels.

While the influence of drug abuse on mother-child interaction has been enunciated (Cataldo et al., 2019), its influence in father-child interaction remains scarce. There- fore, based on the existing state of knowledge, this review adopts the biopsy- chosocial approach in detailing the following: (i) the neurobiological correlates of paternal SUD and atypical parenting mechanisms, (ii) influence of SUD on paternal psychological state and (iii) the social environment modulating the social dynamics central to SUD fathers. This review will also entail the bidirectional influence between these addicted fathers and infants.

1.1. Biopsychosocial model of drug abuse and parenting

The biopsychosocial model has been widely applied to an array of physiological and psychological disorders alike, including drug abuse. It has been used to explain the comorbidity of SUD and social anxiety disorders (Skewes and Gonzalez, 2013), to examine predictors of substance use (Ishino et al., 2020), and in a related way, impacts of SUD on mother-child interaction (Cataldo et al., 2019). Mounting literature evidence has suggested the interaction of the biological, psychological and social factors as a core tenet that drives SUD.

At the core of the biological level, it focuses on the influence of genetics and neurobiological mechanisms. While varying degree of genetic contribution has been reported, depending on the type of substance use investigated, it appears unequivocal that there is a strong genetic component underlying the diathesis of SUD. Variability in the figures reported can be accounted for by the complexity of gene interaction through genetic heterogeneity (different genes that result in the same phenotype) and/or oligogenic inheritance (additive effects of risks genes) (Lachman, 2006). Further, neuroimaging studies have consistently reported changes in the neurocircuitry following substance use. While there is explicit emphasis on the mesolimbic dopaminergic reward system that entails the reinforcement of drug-abusing behaviours (Dom et al., 2005), other brain regions are also compromised. This includes alterations in the hypothalamic–pituitary–adrenal (HPA) axis involved in stress regulation (Miela et al., 2018), as well as the orbitofrontal cortex (OFC) involved in decision-making (Dom et al., 2005), among several other brain areas. At the psychological level, it primitively involves constructs of behaviour, emotion and cognition. Notably, at this level, operant conditioning can explain the recurring use of substances. It is a form of learning process that alters the frequency of a behavioural response through its consequences. In relation to addiction, substance intake creates a sense of euphoria as a form of positive reinforcement that increases the likelihood for future consumption. Likewise, as a maladaptive coping mechanism, it helps to relieve negative emotions in face of unpleasant events and to alleviate symptoms of withdrawal through a negative reinforcement (Skewes and Gonzalez, 2013), leading to the vicious cycle of consumption and relapse.

Finally, the social level pertains to the involvement of social networks. Engagement in substance use can be influenced by peer pressure and also the modeling of behaviours of an adult figure, as according to the social learning theory (Skewes and Gonzalez, 2013). The nature of one's social network can also influence SUD. For example, individuals with SUD tend to have a lower level of social resources and poor quality relationships can impede SUD recovery. On the other hand, maintaining quality and positive relationships can act as a protective factor against negative social influences and maintain sobriety (Pettersen et al., 2019).

While the above illustrates the biopsychosocial model of SUD, these are not necessarily distinctively restricted to drug abuse. Given that there are many shared neural pathways involved in both SUD and parenting, it would be unsurprising to find overlapping bio-psycho-social features between the two or the cascading consequences of substance use on parenting. Therefore, merging the two in the perspective of the biopsychosocial model would provide a broader, more comprehensive dynamics between SUD and parenting. Hence, this review would encapsulate the effects of illicit drug use on paternal parenting respective to father-infant interactions. Paternal responses to infant-related cues between fathers of non-clinical and addiction populations will also be contrasted.

1.1.1. The post-partum stage

While most studies focused heavily on maternal involvement in child development and interaction, in the recent decade, research has begun to shed light on the significance of paternal involvement as well. In an observational study conducted, it was found that paternal behavioural patterns during their first contact with newborns were identical to that of mothers. In a highly stereotypical manner, it begins with touching the extremities followed by the trunk of the infant, with increasing eye contact (Ro¨dholm and Larsson, 1979). This early father- infant contact is crucial in predicting more contact behaviours three months later (Ro¨dholm, 1981) and its significance can be supported by a more recent randomized controlled trial (RCT). Findings reported the early father-neonate contact to enhance attachment through means like facilitating

the role transition of an expectant father to instilling feelings of affection (Chen et al., 2017). Albeit some similarities between maternal and paternal interaction with infants, they are not entirely identical. To exemplify, mother-child interaction has been theorized to provide a calming relationship while father-child's to be an activation relationship. The former is aimed at calming the child during the time of stress while the latter is characterized by rough play that is said to encourage openness, risk- taking, competitiveness and more (Paquette, 2004). When exposed to infant-related stimuli, evidence from functional magnetic resonance imaging (fMRI) also documented sex differences in neural activation. In primary caregiving mothers, the limbic system was activated. Whereas, in primary caregiving fathers, both the limbic system and socio-cognitive regions were activated (Abraham et al., 2014). In sum, this would highlight a potentially unique and important parenting contributed by fathers.

As the role fathers play has been commended to be pivotal for child devel- opment, well-being and family functioning (Chen et al., 2017), consequences of dysfunctional paternal parenting should be discussed. Just as mothers can be susceptible to post-partum depression, fathers too can suffer from paternal postnatal depression (PPND), with a prevalence rate ranging from 4-25% (Kim and Swain, 2007). For both men and women, depression presents as a dysphoric mood with reduced activity. Men, however, reported a greater sense of irritability, fatigue and anger attacks. PPND often comorbids with anxiety and obsessive disorders (Kim and Swain, 2007), as well as increased susceptibility to alcohol abuse, heavy smoking and drug addiction (Northoff, 2014) as a result of depression.

Adversely, a depressed parent-infant negative interaction can hamper the infant's brain maturation, including OFC. Children of fathers with PPND were also more susceptible to a variety of mental and behavioural issues including hyperactivity and depression (Kim and Swain, 2007). Additionally, fathers engaging in substance use is associated with reduced cortisol reactivity in boys which in turn, is associated with increased risk for substance use later in adolescence (Marceau et al., 2020). It is evident that both paternal SUD and PPND tantamount to negative child functioning. This is likely due to the reduced parenting competence (Osborne and Berger, 2009) that is extremely crucial within the child's first year that serves as a window period for optimal development (Kim and Swain, 2007).

2. Methods and results

This review follows the PRISMA (Preferred Reporting Items for System- atic Reviews and Meta-Analyses) guideline with Boolean operators for the screening and reporting of the database (Moher et al., 2009). PubMed, PMC, PsycInfo and Scopus databases were screened papers on parenting and illicit drug abuse from inception to the end of February 2021. Keywords used for the search were as follow: (1) "drug abuse" AND "parenting", (2) "drug abuse" AND "parent-infant", (3) "drug abuse" AND "biopsychosocial" and (4) ("cocaine" OR "marijuana" OR "cannabis" OR "metamphetamine*" OR "opioid*") AND "father-infant". The preliminary search yielded 9249 records and was further shortlisted based on eligibility. As this review focused exclusively on illicit drugs and father-infant interactions, exclusion criteria applied were studies or publications focused on assessments of treatment program protocols effectiveness or outcomes, studies on adolescents, motherhood, papers dis- cussing ethical concerns and national policies regarding illicit substance use, recovery, comorbidity with other mental disorder, studies assessing caretakers' perceptions on impacts of SUD, HIV, BMI/obesity in offspring, non-father- infant interaction, neonatal abstinence syndrome, studies on solely alcohol and nicotine. Duplicates were also removed and the resultant 15 papers were used for qualitative analysis (See the PRISMA flowchart reported in Fig. 1 for the complete screening process). For the purpose of this review, the papers were filtered into three main areas of discussion: bio-physiological mechanisms of atypical paternal parenting, altered paternal psychological state from drug use and lastly, implications on father-infant social relationship/interaction. (See Table 1 for the papers included in the discussion).

2.1. Level 1– the neurobiological correlates of paternal SUD and atypical parenting mechanisms

As aforementioned, substance use can lead to alterations in the brain's neurocircuitry. Herein, the effects of substance use on the biophysiological mechanisms would be discussed in greater detail in tandem with fatherhood. However, it is important to highlight that most studies on substance use and parenting hinges on the maternal counterpart and animal studies. Therefore, while no studies specifically on fatherhood and illicit drug use were found during the screening at the biological level, this section here would draw on available evidence from current literature to explain the link and implications. Thus far, three main brain areas have been systematically identified to be involved in or affected by SUD that overlap with the neural circuits involved in modulating parenting behaviour. These include the reward, affiliative and stress system as mediated by dopamine (DA), oxytocin (OT) and glucocorticoids (GC) respectively (Rutherford et al., 2011; Strathearn et al., 2019). Primarily, the DA-associated reward pathway is involved in the regulation of decision making and motivation to pursue rewards; the OT-associated affiliative pathway mediates attachment cues and formation and together with the GC-associated stress pathway, are involved in stress regulation (Strathearn et al., 2019). Overall, a balanced neural circuit is imperative for the normal regulation of inhibitory controls of behaviours, stress regulation and motivation (Koob and Volkow, 2016). However, as evident from a large multitude of literature, substance use usurps this balance and engenders negative connotations to parenting (for a model, see Fig. 2).

In addiction, the nucleus accumbens (NAcc), ventral tegmental area (VTA) and prefrontal cortex (PFC) of the reward pathway becomes dysregulated (Rutherford et al., 2011) and is associated with an array of psychopathologies including depression (Strathearn et al., 2019). During the addiction process, repeated dopaminergic stimulation from recurrent drug misuse results in neuro-adaptations (Volkow et al., 2019) that leads to the rewiring of the reward circuitry. Prominently, addiction has been repeatedly associated with the diminished capacity to respond to non-drug associated reward cues (Volkow et al., 2019), including parenting. Parenting and attending to infant-related cues, as neuroimaging evidence suggests, are inherently rewarding, where it is this reward value that drives caregiving behaviours (Ferrey et al., 2016). For instance, exposure to infant-related cues such as vocalization was found to activate reward-associated brain regions, including VTA, in both parents of either sex and non-parents population (Rutherford and Mayes, 2019). Further, during the transition of both sex parents to parenthood, there is an apparent neurobiological reorganization to enhance saliency to infant cues (Ferrey et al., 2016). Additionally, in animal studies of biparental species like marmosets, the density of PFC was higher in fathers compared to non-fathers. Congruently in human fathers, there is greater gray matter volume in neural regions underlying parental motivation, including the lateral PFC (Kim et al., 2014). Despite this, the reward pathway that is integral to support caregiving behaviours may be co-opted to support addictive behaviours instead (Kim et al., 2017; Rutherford et al., 2011). In addiction, the reward system is recruited to maintain the habitual substance-using behaviours to relieve negative affect at the expense of attenuating the saliency of natural rewards (Rutherford et al., 2011). Because of the similar and conserved brain regions involved in SUD and parenting, fathers who engage in illicit drug use can be expected to have attenuated reward pathways that adversely compromise their infant-care behaviours and responses to attachment cues.

Stress has also been linked to increased vulnerability to addiction. Apart from the less rewarding experience with the infant interaction, addicted adults also reported more stress (Rutherford et al., 2015). Because brain functions are intricately intertwined, there is futility in attributing

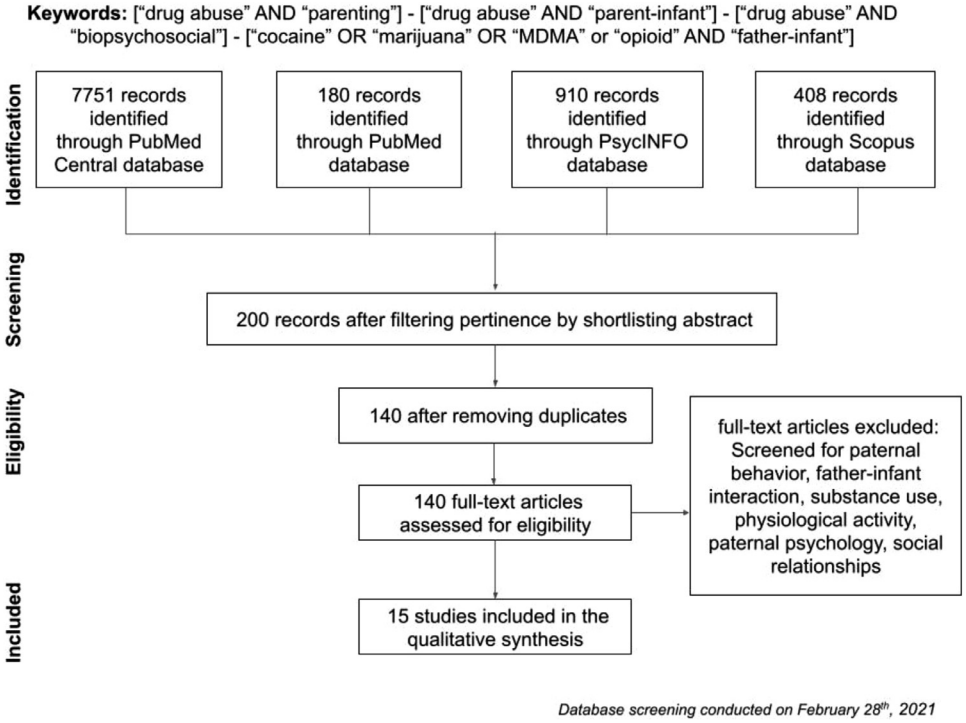

Fig. 1. PRISMA flowchart for search criteria and papers eligibility.

Table 1
List of papers included in the review.

n	Article	Type	*N*	ChildAge	Drug
1	Eskandari N. et al, 2019	empirical	572	0-12mo	ns
2	DybaJ, et al, 2019	qualitative	8	0-5yo	met
3	Smith Stover C. & Coates E., 2016	empirical	24	<7yo	ns
4	Smith Stover C. & Kiselica A., 2016	empirical	79	3 yo	cann, coc, hal
5	Smith Stover C. & Kiselica A., 2014	empirical	132	2-6 yo	cann, coc, opi, hal, inh, amph
6	Herland M.D. et al, 2014	qualitative	15	<18(ns)	ns
7	Smith Stover C. et al, 2013	empirical	86	2-6yo	cann,coc
8	Smith Stover C. et al, 2012a	empirical	126	<18(ns)	cann,coc,opi
9	Smith Stover C. et al, 2012b	empirical	87	<18(ns)	cann,coc,opi
10	Smith Stover C.& Spink A. 2012	qualitative	40	2-6yo	cann,coc,opi,pcp
11	Brown J.A. & Teichman M., 2012	qualitative	3	8mo-17yo	met
12	Garrusi S. et al., 2011	qualitative	35	2yo	opi
13	Harvey E. et al., 2011	empirical	126	3-4yo	ns
14	Rhodes T. et al., 2010	qualitative	14	6mo-18yo	coc,opi
15	McMahon T.J. et al., 2007	empirical	50	<18(ns)	cann,coc,opi

LEGEND: ***N*** = number of fathers involved in the study; **mo** = months old; **yo** = years old; **ns** = non specified; **amph** = amphetamines; **cann** = cannabis; **coc** = cocaine; **hal** = hallocinogens; **inh** = inhalants; **met** = metamphetamines; **opi** = opiates; **pcp** = phencyclidine.

consequences of SUD to parenting to any brain pathways in isolation. Indeed, both stress and reward circuitry do interact and dysregulation impedes optimal parenting (Rutherford and Mayes, 2017). In addiction, the reward pathway activation underscores the use of drugs. Meanwhile, the stress pathway underscores the drug withdrawal associated distress and a bidirectional relationship exists between stress-related symptomatology and substance use. For instance, cocaine use, as motivated by the reward pathway, acutely activates the hypothalamic-pituitary-adrenal (HPA) axis of the stress regulatory system. Changes in the VTA activity and DA release from NAcc, induced by cocaine consumption, are dependent on the stress hormones, corticotrophin-releasing factor and corticosterone, which modulates NAcc sensitivity to DA. In acute withdrawal, however, HPA reactivity becomes elevated and persists even during protracted abstinence (Rutherford et al., 2011). On the arrival of newborns and parenting, both are associated with a certain level of stress that is irrespective of the clinical and non-clinical populations of SUD of either sex. However, studies on mothers found such stress to be significantly enhanced in substance abusers which may suggest a maladaptive allosteric stress regulation that amplifies stress cues (Rutherford et al., 2011). Simultaneously, neuroimaging evidence has documented an appreciable overlap in the neural correlates of stress and drug cues within the corticostriatal limbic system (Sinha and Li, 2007). Taken together, this is insidious in perpetuating the vicious cycle for sustained substance use and relapse as an overlap in stress activation circuits with drug-craving cues facilitate relapse. Nonetheless, while no empirical studies have been conducted on the effects of SUD on fatherhood according to our search, variations departing from motherhood due to an attenuated stress system should be expected. This is due to the presence of sex differences in the drug-related stress system such as a significantly elevated HPA reactivity found in cocaine-dependent males compared to females (Fox and Sinha, 2009).

Finally, the oxytocinergic affiliative pathway is involved in the processing of social cues including attachment but also interacts with NAcc of the reward pathway directly for increasing the perception of incen-

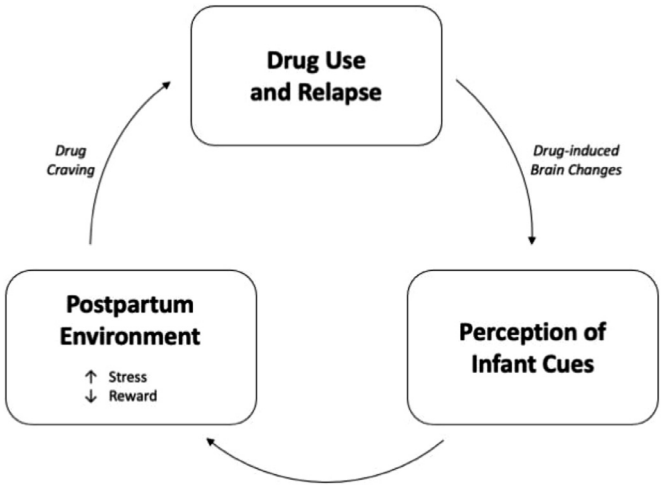

Fig. 2. Model of the relationship between addiction and parenting adapted from Rutherford et al. (2011) as presented in Cataldo et al. (2019). In this model, addiction represents the dysregulation of stress and reward systems, both of which are adapted to support parenting. In the case of addiction, we propose that drug-induced brain changes result in the attenuation of the reward value of infant cues, which are replaced by a more stressful neurophysiological response. This stress response to infant cues may increase craving for drugs and promote drug-seeking and relapse in abstinent fathers, thus perpetuating a cycle of neglect.

tive values to infant cues (Ferrey et al., 2016). Generally, the presence of a low functioning OT receptor allele is linked to a lower postpartum maternal sensitivity. However, cocaine consumption too, during pregnancy, can depress OT level that is tied to higher stress perception (Rutherford et al., 2011) and social deficits (Strathearn et al., 2019). Subsequently, this impedes the development of secure parent-child attachment and hampers the synchronous, sensitive and/ or responsive aspects of caregiving that in turn, also blunts the salivary OT levels in infants. Overall, SUD has been significantly associated with an insecure parent-infant attachment which is also unsurprising due to the inadequate caregiving provided by these parents (Strathearn et al., 2019). Within father-infant interaction, fathers too, have OT levels that are comparable to mothers within the first few months of parenthood. Furthermore, OT administration was found to enhance neural activation of the reward pathways when fathers viewed images of their biological child (Witte et al., 2019). Within a sampled population of both males and females that are ketamine-dependent, depreciable levels of OT were found compared to healthy controls (Huang et al., 2018). Likewise, while there is a gap in literature relating to fatherhood, a potential link can be drawn here from the studies above. That is, oxytocin is equally important for modulating father-infant but drug use can dysregulate this affiliative pathway that thereby becomes detrimental.

Beyond the neurobiological approach, genetics also present a substantial risk factor that can be cross-generational which applies to both men and women. Genetic studies on SUD found drug addiction to be one of the most heritable psychiatric disorders. For instance, the heritability estimates of cocaine in both men and women are 79% and 65% respectively (Pierce et al., 2018). Although the specific genes that underlie this variance may remain elusive since genome-wide association studies (GWASs) require a large sample size for statistical power, some candidate single nucleotide polymorphisms (SNPs) in genes like dopamine β–hydroxylase have been identified. Besides the heritability of these SUD-vulnerable genes, repeated substance use in fathers can instigate changes to the sperm epigenome that produce intergenerational effects. To investigate the effects of paternal cocaine consumption on offspring, murine models of addiction have been used, providing unanimous support that paternal SUD influences offspring's reward processing ability, cognitive processes and proclivity to seek drugs (Pierce et al., 2018).

2.2. Level 2–influence of SUD on paternal psychological state

The psychological level would encompass the discussion of the emotional, behavioural and cognitive aspects of the impacts of SUD on fathering. Through the screening, 14 articles were found to fit the requirements that could explain the psychological states of drug-abusing fathers. General themes uncovered were the dysfunctional emotional expressivity, compromised mental states/ cognition and abuse/neglect.

Cognitively, while fathers expressed their desires to fulfil their parental roles and remain attached to their child, their efforts are often compromised by substance use (Gilchrist et al., 2012; Herland et al., 2015; Stover et al., 2012b). One such was established in a methamphetamine use study where a father expressed sadness and the desire to reconnect with his child whom he is no longer in contact with (Dyba et al., 2019). For first-time fathers especially, paternal adaptation is essential for facilitating the assumption of parental responsibilities and perception of parental development, which is disrupted in the case of substance use (Eskandari et al., 2019). This is unsurprising due to the attenuated OT-associated affiliative pathway that is imperative for attachment formation and caregiving behaviours as discussed. In opioid-dependent fathers, they have limited conceptions of their parental roles and hold poorer views on their fathering practices. For these fathers who are concerned about their fatherhood, they experienced greater symptoms of depression than fathers at similar severity for drug abuse, who remained unperturbed (Stover et al., 2012b). Similarly, even when these fathers are aware of the potential impacts of their substance use on their child, they may rationalize their addiction as within the norms and having provided sufficient parenting support. This is evident from a qualitative account of a heroin-addicted father who claimed was able to maintain an outward appearance of normalcy and having covered the child's basic needs (Rhodes et al., 2010). Nonetheless, it is critical to highlight that a child's welfare is more than ensuring the coverage of one's basic needs like food but also entails the availability of parental presence for support. More generally, paternal substance use is associated with greater self-reported lax parenting practices (Harvey et al., 2011) since the cognitive capacity to think and care for the child is undermined (Gilchrist et al., 2012). While they feel guilt, this perceived guilt is not necessarily related to their substance abusing behaviours but tended towards failing their role as a strong provider for their child. Additionally, they hold misguided parenting practices that are biased towards anger and hostility (Gilchrist et al., 2012) that is in part, a consequence of emotional dysregulation. This is accompanied by the high rates of co-occurrence with intimate partner violence (IPV) ranging between 40-50% (Stover et al., 2013). Relatedly, IPV-SUD co-occurrence increases the risk for harsher parenting practices like intrusion and this relationship is mediated by the addict's degree of hostility. That is, a higher hostility level increases the likelihood to engage in substance use that perpetuates as a risk for both IPV and poorer parenting practices (Stover and Kiselica, 2015).

For substance-abusing fathers, numerous studies have detailed the profound emotional dysregulation that proves detrimental to parenting outcomes. For these fathers, they struggle to regulate their negative affect which is instead, often heightened and may interfere with problem-solving processes that lead to maladaptive strategies (Gilchrist et al., 2012). Often than not, alexithymia is common among drug abusers, characterized by deficits in identifying and expressing emotions (Gilchrist et al., 2012). Indeed, this has been reported in some that substance-abusing fathers experienced difficulties in expressing and communicating their emotions across to their family counterparts (Eskandari et al., 2019; Garrusi et al., 2011). Despite so, some fathers may attempt to shield their children away from their negative affect like striving to contain their angry feelings or stay away from the children (Gilchrist et al., 2012). Relatedly, reflective functioning (RF), the abil-

ity to understand the mental state of self and others, has been identified in maternal studies to be vital for developing healthy attachment and interpersonal relationships with the child (Stover and Kiselica, 2014). Within non-clinical populations, mothers in general tend to score higher on RF while approximately half the fathers examined displayed deficient RF ability (Stover and Kiselica, 2014). However, substance use can impair RF due to the emotional dysregulation that impedes perception of other's mental states. Contrary to maternal studies, RF was not predictive of paternal parenting behaviours, both self-reported or observed (Stover and Coates, 2016; Stover and Kiselica, 2014), suggesting father's RF capacity to be less critical for modulating parenting behaviours.

Of fathers abusing drugs, their psychological states are also subparred compared to healthy controls. While healthy fathers generally perceive providing parental care as rewarding, SUD fathers experience greater parenting stress and lower satisfaction (Gilchrist et al., 2012; Stover et al., 2012b). This is in light due to the attenuated stress response system that enhances stress perception as explained at the biological level. The stress, combined with maladaptive coping strategies, instigate the perpetuating use of drugs to mitigate stress and negative affect. Furthermore, substance use often comorbid with depression and/ or polysubstance dependence (Stover et al., 2012b). The hostility and negativity directed towards a child as a result of substance abuse can be mediated by the presence of a depressive psychological state (Stover et al., 2012a) whereby the depressive symptoms increase risk for these negative father-infant interactions (Harvey et al., 2011), congruent to findings on the maternal counterpart.

2.3. Level 3–the social environment modulating the social dynamics central to SUD fathers

In accordance with the gene by environment contrive, aside from the genetic influence as highlighted at the biological level, the environment (including social environment) is also essential in accounting for the risk and onset of SUD. The social implications are important as most men engaging in substance use, including IPV, are father figures who also continued to maintain relationship with their wife and child (Stover and Coates, 2016). Herein, the perspective of men engaging in substance use on their fatherhood and relationship with their parents will also be documented.

Traditionally, fathers were notion to be breadwinners while mothers as primary caretakers for the family. However, such conceptions have long been shifted and fathers are expected to be equally involved in nurturing the child (Herland et al., 2015). Regardless, evidence construed on the involvement of both parents on child development and outcome as significant and enduring. Of current fathers engaging in substance use, their risks for SUD are partly related to the social vulnerabilities experienced during their childhood and most were indicted for crimes. In support, when substance-abusing fathers share their experience of fatherhood, their recount is often diverted to their emotionally unsettled, difficult relationships with their parents during childhood (Herland et al., 2015). For most, while the relationship with their biological mothers was positive, their biological fathers were often described as alcoholic and relationships were generally impaired. Many drug-abusing fathers also confirmed a history of experiencing child abuse and neglect by their biological fathers (McMahon et al., 2007). Furthermore, the biological fathers who co-engaged in drug abuse and IPV significantly perpetuated this pattern of behaviours in men (Stover et al., 2013). In a manner of rippling effects from childhood experiences to adult parenting skills, experience of child security is connected to confidence in parenting skills while severe adjustment issues create parenting uncertainty (Herland et al., 2015).

Even after controlling for psychiatric comorbidities, substance use presented a unique contribution to maladaptive parenting practices, even in fathers (Harvey et al., 2011). Often, substance use is associated with less child engagement (Eskandari et al., 2019; Gilchrist et al., 2012), lower father-child interaction quality (i.e hostility, aggressiveness and neglect) (Harvey et al., 2011; Stover and Kiselica, 2015), reduced family cohesion (Stover et al., 2013) and more dyadic tension (Stover and Coates, 2016). Estrangement with the family can be due to the difficulties in expressing emotions by addicted fathers. Furthermore, marital satisfaction that is critical for predicting paternal adaptation is often dampened by acts of substance use and can adversely affect the father-infant attachment (Eskandari et al., 2019). However, while a link between paternal attachment and RF was suggested, one study found that RF was not predictive of the attachment style in both parent-child and romantic dyads, with a caveat that some items derived from the attachment scale of the parenting relationship questionnaire (PRQ) can be simultaneously associated to both high and low RF (Stover and Kiselica, 2014).

Furthermore, co-occurrence of IPV is a common social consequence of substance use (Stover et al., 2013) which is also linked to the increased risk for child maltreatment (Stover and Kiselica, 2015). Reasons perpetuating engagement in IPV is partly due to the misguided worries for the child that is deflected towards the intimate partner verbally and physically (Gilchrist et al., 2012). Additionally, a subgroup of IPV was associated to having an avoidant attachment style with their romantic partners and mediated the effects on the negative parenting practices (Stover et al., 2013). Despite the abuse, women tend to remain in or resume the violent relationship upon leaving shelters for domestic violence (Stover and Coates, 2016). Nonetheless, on the impact of child development, there is substantial evidence supporting the deleterious effects of substance use and IPV. The co-occurrence is tied to poorer coparenting practices and more hostile parenting approaches compared to fathers with substance use alone (Gilchrist et al., 2012). This is mediated by hostility levels to engage in confrontational coping styles to resolve interpersonal conflicts (Stover and Kiselica, 2015), as well as displaying avoidant attachment behaviours and difficulties in regulating affect (Gilchrist et al., 2012). Notably, the severity of both IPV and substance use can result in the child's withdrawal from interacting with the fathers. This may underlie a defense mechanism to avoid being a target for the father's violent tendencies and uncertainties about the triggers for such aggression (Stover and Coates, 2016).

Despite complications in the familial relationships as described above, SUD fathers reported attempts to limit the damage of their substance use on family via efforts to maintain normalcy, prevent disruption and create a safety net of support for the family (e.g. transfer of legal guardianship) (Rhodes et al., 2010). Despite the ongoing substance use, most fathers were present at the time of childbirth, attempted to provide financial support (McMahon et al., 2007) and viewed distancing themselves from their child as a solution (Herland et al., 2015). In addition, regardless of their aggression status, the time spent with their children was not significantly different (Gilchrist et al., 2012). While fatherhood in relation to SUD is generally characterized as negative, it appears that the fathering capacity is not entirely incapacitated as evident from the discourse of some SUD fathers. For example, one identified his fatherhood to be extensively supported by the wife's efforts in caring and protecting the child which, albeit limited paternal achievements, enabled him to continue to provide for the family. In another discourse, while the father was unable to provide care regularly, he remained emotionally involved with his child (Herland et al., 2015). Therefore, unconventional parenting or co-parenting methods can rescue the fragility of these familial social relationships, that are potentially impaired in SUD, to a certain extent.

3. Bidirectional effects of paternal SUD and infants

Thus far, the consequences of SUD on fatherhood interactions with infants have been discussed with reference to the biopsychosocial model. However, the above portrayed mainly a unidirectional effect of paternal SUD on the infants where in essence, it is also paramount to highlight the bidirectionality between the two. Within the purview of paternal SUD on infant outcomes, it is ubiquitously known that paternal

SUD is generally damaging. However, the associated consequences on a child's psychosocial development remain understudied and data are often extrapolated from existing literature on paternal alcohol dependence (McMahon, 2013). This warrants some caution as there are important differences between alcohol and drug use that may be overlooked, in line with the argument as posited by Hogan (1998).

Nonetheless, child maltreatment is a particular area of concern for parents with SUD. This is unsurprising given that children of parents with drug abuse issues are three times more likely to be abused or neglected (Lander et al., 2013). Moreover, men who engage in substance use are far more likely to marry earlier and to spouse with psychiatric problems, including SUD (McMahon, 2013) or even, introduce substance use to the spouse, where women then have the tendency for uncontrolled escalation of use (Guterman and Lee, 2005). This is aggravating given the association of paternal substance use to maternal's, both of which contribute to the risk for child maltreatment (Guterman and Lee, 2005). Generally, research posits that children exposed to abuse and neglect are more likely to manifest externalizing disorders (e.g. impulsivity) and internalizing disorders (e.g. social withdrawal) respectively, as well as heightened risk for engaging in substance use themselves. In more severe cases, the child could be taken into custody or the transfer of guardianship for protection (Lander et al., 2013).

Additionally, paternal substance use places the family at risk for dysfunc tion, precipitating IPV, marital dissatisfaction, compromised co-parenting practices and more (Gruber and Taylor, 2006, McMahon, 2013). In compromised family settings where marital conflicts are common, men tend to withdraw from children (McMahon, 2013) which reduces father-infant/child interactions. Paternal unavailability is also marked by their drug-associated incapacitation, serving jail term or in treatment (Gruber and Taylor, 2006). Together with a neurophysiologically attenuated system in SUD fathers, it impedes the healthy development of a child's attachment style. According to the classical and renowned attachment theory, attachment is developed within the infant's first years (Bowlby, 1973; Egeland and Sroufe, 1981). The early caregiver-child attachment styles developed has enduring influences across one's entire life-span, ranging from subsequent relationship patterns (Banse, 2004; Kane et al., 2007) to perception of self (Lee and Hankin, 2009; Park et al., 2004) to vulnerabilities for a host of physiological and psychological disorders (Feeney, 2000; Mikulincer and Shaver, 2012). Briefly, a quality parent-child interaction paves the development for healthy, secure attachment or otherwise insecure attachment (anxious/ avoidant) under sub-optimal caregiving environment. Because the attachment system is intricately built on the reciprocal parent-infant dyad interactions, paternal unavailability can infringe on the development of a healthy, secure attachment (Lander et al., 2013), thereby placing the child on a higher prospect for insecure attachment-associated adversity (e.g. depression, low self-worth, maladaptive role expectations).

Conversely, infants can influence the status of paternal SUD. Indirectly, although fatherhood is generally perceived as rewarding, the period of expectant for incoming newborns and postnatally are usually stressful, especially for first-time fathers. The transition to fatherhood represents a significant source of stress which entails taking up new responsibilities as a fatherly figure, experiencing changes in family patterns with existing members and balancing activities. More critically, time management was a critical factor for most first-time fathers, wherein they have to reprioritize and make trade-offs between family, work, personal relationships and activities. Notably, the first 12 weeks postpartum is most challenging where newborns require round-the-clock care, have irregular biological clock, along with frequent, incessant infant cries. Yet, there may be reduced maternal support from mothers recovering from parturition, accompanied by inept paternal care for new, inexperienced fathers (St John et al., 2005). Nonetheless, in non-clinical population of fathers, the pattern of distress declines steadily by the fourth month post-partum, where fatherhood concerns begin to resolve. However, those failing to adjust due to underestimation about their expected role and infant care, remain distressed (Buist et al., 2003) which serves as a precipitant for SUD onset or relapse (Gruber and Taylor, 2006).

However, a silver lining for fatherhood is the powerful motivation for drug abstinence in the best interest of the child (S¨oderstr¨om and MED, 2013), where most parents reflect on the undue harm on the child and engage in damage limiting strategies (Rhodes et al., 2010). Of note, children of age 6 to 11 were notion to be particularly incentive for parental drug abstinence in women due to their role expectations of a "good mother". Similarly, findings from a paternal study too reported children as a reason for withdrawing from drug use and persevering abstinence (Garrusi et al., 2011). Moreover, the role of fatherhood may uniquely influence SUD severity where a higher degree of father-child involvement was associated with lower addiction severity (Stover et al., 2012a). How infants can influence paternal SUD can be exemplified in one discourse by an addicted father as follows: "When you get money and the first things you think of is buying diapers and toilet paper, and not how many doses you can get..." (S¨oderstr¨om and MED, 2013). While these present a window for positive change, many addicted parents lack the schematic contrive of a good parenting model and are further challenged by the need to learn to regulate their mental state and affect without reliance on substances (Gruber and Taylor, 2006; S¨oderstr¨om and MED, 2013). Therefore, motivations itself may be inadequate for change which could explain the ongoing substance use in most SUD parenthood desiring change, thereby necessitating specific interventions to overcome inadequacies.

4. Discussion and conclusion

SUD is a crippling disorder that is strongly influenced by the complex biopsychosocial interactions between the pharmacological effects of illicit drugs, individual vulnerability for SUD (e.g. genetics) and other socio-environmental contributing factors (Volkow et al., 2019), having significant negative repercussions on the self and family. In this context, the intersection of SUD and parenting behaviours, through shared pathways, is gaining increasing attention. For instance, a recent review on illicit drug use on motherhood (Cataldo et al., 2019) highlighted the severity of maternal SUD on infant outcomes at the biological, psychological and social level. However, fathers too, play a critical and unique role in child development and the present review articulated for the first time the effects of illicit drug use on the paternal interactions with infants according to a biopsychosocial model.

Firstly, it was found that there are overlapping neurobiological pathways involved in the maintenance of addiction and parenting, mainly central to the reward, affiliative and stress regulatory brain areas. Current evidence is mainly synthesized from maternal and animal studies but available evidence from paternal counterparts suggest some shared similarities and unique differences with SUD motherhood. On the psychological level, paternal substance use impairs fathers' emotional regulation, generates vulnerable mental states that contribute to the negative parenting practices. Finally, while these fathers expressed their desire to fulfil the role of a good father, most experienced childhood adversity or attenuated brain systems from their current substance use that undermined caregiving efforts. In turn, the father-child interaction is characterized more by withdrawal and aggression with high co-occurrence rates for child maltreatment and IPV.

While the implications of paternal SUD and fatherhood from the current state of the art has been synthesized to provide more comprehensive insights, some noteworthy caveats about the existing literature should be highlighted. Foremost, the term "parenting" commonly refers to the mother-child dyad. However, this is an obsolete perspective that undermines the paternal contributions. This is more so when assessed in conjunction with the topic on SUD where evidently, only 15 articles that fitted the requirements of this review screening were found, thereby communicating that the perspective on father- hood has been woefully neglected thus far. Most data were extrapolated and generalized from

maternal studies or studies of paternal alcohol dependence. However, one should be cautioned of the issue of overgeneralization. For one, fathering practices have certain dissimilar properties to that of mothering and the important alcohol-drug differences may be overlooked. Additionally, most studies on paternal SUD were qualitative in nature. Secondly, the transition to fatherhood can be equally stressful, especially during the first year from postpartum. Fathers too can experience PPND and is becoming an increasing phenomenon that can serve as a potential trigger for the onset or relapse of substance use in the vulnerable population of fathers. Yet, there were less emphasis in research on men compared to women where the entity of research on postpartum syndrome was focused almost exclusively on mothers. Lastly, it is possible that polydrug use could constitute a more severe case of SUD that results in more grievous consequences for the parent-child dyad. However, exploration of the influence of polydrug consumption remains limited.

In retrospect, SUD is a disorder that has intergenerational consequences and can impair the optimal development of the child through three constructs: biological, psychological and social. The following factors discussed could potentially better inform the formulation of interventions and therapies targeted to rescue or restore dysfunctional father-infant dyad relationships. While the current state of knowledge on paternal SUD and fatherhood has been reflected here, it also captured the prominent gaps in the literature. This necessitates the collective efforts of researchers/authors to shed light on this issue and bring more focus towards paternal contributions.

Finally, the potential use of new emerging substances and their interaction with other compounds make this scenario even more alarming.

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CRediT authorship contribution statement

Jovin Jie Ning Lee: Investigation, Writing – original draft, Writing – review & editing. **Ilaria Cataldo:** Conceptualization, Methodology, Investigation, Writing – review & editing, Visualization. **Aurora Coppola:** Conceptualization, Writing – review & editing. **Ornella Corazza:** Supervision, Writing – review & editing. **Gianluca Esposito:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

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