Published in final edited form as:
Addict Behav. 2014 November ; 39(11): 1573–1579. doi:10.1016/j.addbeh.2013.10.033.

Sex differences in impulsive action and impulsive choice

Jessica Weafer, PhD and **Harriet de Wit, PhD***
Department of Psychiatry and Behavioral Neuroscience, University of Chicago, 5841 S. Maryland Ave., Chicago, IL, 60637

Abstract

Here, we review the evidence for sex differences in behavioral measures of impulsivity for both humans and laboratory animals. We focus on two specific components of impulsivity: impulsive action (i.e., difficulty inhibiting a prepotent response) and impulsive choice (i.e., difficulty delaying gratification). Sex differences appear to exist on these measures, but the direction and magnitude of the differences vary. In laboratory animals, impulsive action is typically greater in males than females, whereas impulsive choice is typically greater in females. In humans, women discount more steeply than men, but sex differences on measures of impulsive action depend on tasks and subject samples. We discuss implications of these findings as they relate to drug addiction. We also point out the major gaps in this research to date, including the lack of studies designed specifically to examine sex differences in behavioral impulsivity, and the lack of consideration of menstrual or estrous phase or sex hormone levels in the studies.

Keywords

sex differences; impulsive action; impulsive choice; laboratory animals; humans

1. Introduction

Here we review the literature regarding sex differences in behavioral measures of impulsivity, within the broader context of how these differences might relate to drug abuse. Men are generally thought to be more impulsive and men also exhibit higher rates of drug use and abuse. However, the evidence for sex differences in impulsivity using objective behavioral measures is mixed. We first briefly review the evidence for sex differences in substance abuse, as well as associations between impulsivity and drug abuse and the

*Corresponding author: Harriet de Wit, Department of Psychiatry and Behavioral Neuroscience, MC 3077, University of Chicago, 5841 S. Maryland Ave., Chicago, IL 60637, Phone: 773-702-1537, Fax: 773-834-7698, hdew@uchicago.edu.

Contributors
Jessica Weafer conducted the literature review and wrote the first draft of the manuscript. Both authors contributed to and have approved the final version of the manuscript.

Conflict of Interest Jessica Weafer declares no conflict of interest. Harriet de Wit has received support from Unilever for a project unrelated to this study.

potential modulating effects of sex hormones. We define the specific behavioral components of impulsivity (i.e., impulsive action and impulsive choice) that will be the focus of this review, as well as how these are measured in both laboratory animals and humans. We then review the literature on sex differences in impulsive action and impulsive choice. Within each impulsivity component, we report evidence from laboratory animals and humans. For human studies we report findings from both behavioral and neuroimaging studies, and in healthy individuals as well as substance abusers. Finally, we summarize the findings to date and discuss how these fit within existing theoretical framework regarding impulsivity and sex differences, as well as speculate on potential links between sex differences in impulsivity and sex differences in drug abuse. We then point out the gaps in the literature, as well as propose directions for future research.

2. Sex differences in drug abuse

Men and women differ in several indices of drug abuse, but the differences are sometimes conflicting. Men report higher levels of alcohol, tobacco, and illicit drug use including marijuana, cocaine, and hallucinogens than women (SAMHSA, 2011), and men are twice as likely as women to meet criteria for abuse and dependence. Yet, women progress faster from initiation of drinking to problem drinking and dependence (Piazza, Vrbka, & Yeager, 1989; Randall et al., 1999; although see Alvanzo et al., 2011; Keyes, Martins, Blanco, & Hasin, 2010). In laboratory animals, females acquire drug self-administration more rapidly than males, and exhibit more binge patterns and greater reinstatement of drug-seeking (Becker & Hu, 2008; Carroll & Anker, 2010; Lynch, Roth, & Carroll, 2002). There are numerous potential explanations for observed sex differences in drug abuse, including sex differences in pre-existing risk factors for abuse. One such risk factor is impulsivity, described below.

3. Impulsivity and drug abuse

Impulsivity, broadly defined as a tendency to act without thinking and without consideration of future consequences, is strongly implicated in drug abuse (de Wit, 2009; Perry & Carroll, 2008). Greater impulsivity is thought to increase risk for drug abuse, and conversely, drugs of abuse produce acute and chronic changes in impulsivity. Behavioral impulsivity is thought to consist of two distinct components: impulsive action and impulsive choice. Impulsive action (also known as behavioral inhibition) involves difficulty inhibiting or controlling behavior, whereas impulsive choice refers to the tendency to prefer smaller, immediate rewards to larger, delayed rewards. Both of these components have been shown to predict different aspects of drug abuse, and acute or chronic use of a drug can alter both types of behavior (Perry & Carroll, 2008).

4. Role of sex hormones

Sex differences may be due to organizing factors at critical phases during development, as hormones present during development may permanently affect both vulnerability to drug abuse and impulsive behavior. Sex differences may also be attributable to circulating levels of sex hormones, as circulating levels of testosterone, estrogen or progesterone may affect these behaviors at any point in life. In laboratory animals, there is some evidence that circulating levels of the ovarian hormone estrogen affect the reinforcing effects of drugs.

Estrogen modulates dopaminergic function by enhancing dopamine release and increasing D2 receptor densities (Bazzett & Becker, 1994; Dazzi et al., 2007; Di Paolo, 1994; Xiao & Becker, 1994) and dopamine is thought to be the primary mechanism through which drugs exert their acute rewarding effects (e.g., Di Chiara et al., 2004; Koob & Volkow, 2010). Both impulsive action and impulsive choice are also linked to the dopamine system (Cardinal, Pennicott, Sugathapala, Robbins, & Everitt, 2001; Dalley et al., 2007; Del Campo, Chamberlain, Sahakian, & Robbins, 2011; Diergaarde, et al., 2008), and this suggests a potential mechanism through which sex hormones could modulate impulsivity as well.

5. Behavioral measures of impulsive action and impulsive choice

In humans and laboratory animals, impulsive action, or the ability to inhibit inappropriate responses, is typically assessed with stop signal and go/no-go tasks (Logan, Schachar, & Tannock, 1997; Newman, Widom, & Nathan, 1985). These measures involve a reaction time task in which subjects must respond as quickly as possible to ‘go’ stimuli, while inhibiting responses when no-go targets are presented or when a stop signal (e.g., an auditory tone) occasionally occurs. The major dependent measures derived from these tasks include number of commission (i.e., inhibitory) errors, and stop signal reaction time (SSRT), an estimate of the time necessary to inhibit a response. More commission errors and longer SSRTs are indicative of greater impulsive action. Another procedure commonly used in laboratory animals is the 5-choice serial reaction time test (5-CSRTT; Robbins, 2002) in which animals are trained to respond when ‘go’ signals are presented, and to inhibit such responses when ‘go’ signals are not presented. Responses that are made before the ‘go’ signal are considered premature responses, or inhibitory errors, and these are indicative of greater impulsive action.

Impulsive choice is typically assessed in both humans and laboratory animals using discounting tasks in which subjects make choices between small rewards delivered immediately or with 100% certainty, or larger rewards delivered after a delay or with less than 100% certainty (Richards, Zhang, Mitchell, & de Wit, 1999; Thiebot, Le Bihan, Soubrie, & Simon, 1985). A curve is plotted based on the subject’s points of indifference between immediate and delayed rewards, and steeper discounting curves indicate greater impulsive choice. Human subjects perform these tasks for either real reward, usually money, in which they have a chance to actually receive one of their choices or for hypothetical monetary rewards. In laboratory animals, animals respond on one lever for a small, immediate reward (e.g., a food pellet), and respond on a different lever for a large, delayed reward (e.g., several food pellets after 30 sec). Discounting curves are plotted, or the reward delay is adjusted and the mean adjusted delay (MAD) is calculated. In both humans and nonhumans, steeper discounting curves and shorter MAD are indicative of greater impulsive choice, or greater discounting of delayed reward.

6. Sex differences in impulsive action

6.1 Laboratory animals

There is mixed evidence for sex differences in impulsive action in laboratory animals (see Table 1 for a summary). Papaleo, Erickson, Liu, Chen, and Weinberger (2012) found no sex differences in mice on 5-CSRTT acquisition or performance during the challenging task condition (although males learned to perform less impulsively than did females over repeated testing). However, when mice were no longer food-restricted or exposed to a mild stressor, males displayed greater premature responses than females. Using a simpler version of the task (the 2-CSRTT), Burton and Fletcher (2012) found no sex differences in either young or adult rats in task acquisition, but adult females made more premature errors than did adult males in the challenging task condition. Finally, Anker, Gliddon, and Carroll (2008) found no sex differences in premature responding for a food reward on a go/no-go task, but reported that female rats made more premature responses when responding for a cocaine drug reward. Thus, the direction of sex differences in impulsive action depends in part on the species studied (mice vs. rats), the task used (5-CSRTT vs. 2-CSRTT), and the reinforcer (food vs. drug).

Studies that have taken sex hormones into account provide more consistent evidence of greater impulsive action in male laboratory animals compared to females. Jentsch and Taylor (2003) examined sex differences in normal and gonadectomized rats on a modified version of the 5-CSRTT. In intact animals, males made more premature responses both during task acquisition and in a challenging task condition (i.e., longer inter-trial intervals). Gonadectomy decreased impulsive action in males, suggesting that the difference was related to circulating levels of testosterone, but ovariectomy increased impulsive action in females, suggesting that ovarian hormones also play a role. Bayless, Darling, Stout, and Daniel (2012) compared 5-CSRTT performance of male to female rats tested only in the proestrous phase of the estrous cycle (when estradiol levels are high, as verified by vaginal smears). In this study, male rats committed more premature responses in the challenging task condition, indicating greater impulsive action. In sum, males show greater impulsive action in studies that take sex hormones into account, whereas studies that do not account for hormones provide mixed evidence regarding the presence and direction of sex differences. This suggests that circulating hormones contribute to the greater impulsivity observed in males, and emphasizes the importance of taking sex hormones into account when assessing sex differences in impulsive action in laboratory animals.

6.2 Humans

Investigations of sex differences in impulsive action in humans have produced mixed results (see Table 1). On go/no-go tasks males commit more inhibitory errors than females in samples of both adults (Saunders et al., 2008) and children (Liu, Xiao, & Shi, 2013). Similarly, a meta-analysis of 8 studies using the continuous performance task (CPT, in which impulsive action is assessed by errors of commission) in children and adolescents with ADHD showed greater commission errors in boys than girls (Hasson & Fine, 2012). By contrast, using a modified version of the stop task, Morgan, Grey, and Snowden (2011) found that adult women had a higher percentage of inhibitory failures than men. Similarly,

in a large sample (n=14388) of children and adolescents, a significant effect of sex on SSRT was found, as well as an interaction between sex and age. Specifically, females had longer SSRTs than males, and this sex difference was more pronounced in younger children (Crosbie et al., 2013). Other studies have reported no sex differences on stop signal and go/no-go tasks (e.g., Fernie, Cole, Goudie, & Field, 2010; Reynolds, Ortengren, Richards, & de Wit, 2006). Taken together, human studies of impulsive action have provided inconsistent evidence for sex differences. When sex differences are observed, the direction of the difference depends in part on the task administered (i.e., men display poorer control on go/no-go and CPT tasks, whereas women display poorer control on stop tasks).

Very little research has examined the effects of circulating sex hormones in impulsive action. Colzato, Hertsig, van den Wildenberg, and Hommel (2010) examined stop signal performance in women across three phases of the menstrual cycle (i.e., the follicular phase, luteal phase, and menstruation proper), and also in men. Women in the follicular phase (when estrogen levels are highest) exhibited greater impulsive action, as evidenced by longer SSRT's than women in the luteal phase and during menstruation. Further, women in the follicular phase had longer SSRT's than men, but these differences were not apparent in the luteal phase or during menstruation. Moreover, SSRT was positively correlated with salivary estradiol, such that higher estradiol levels were associated with greater impulsive action. Although these findings will need to be replicated in larger samples, this study provides initial support for the role of estrogen in impulsive action.

6.2.1. Neuroimaging—Sex differences in impulsive behaviors have also been studied using brain imaging techniques. These studies typically examine brain activation during task performance, in participants whose behavioral performance is matched. For instance, Li, Huang, Constable, and Sinha (2006) found that whereas men and women performed similarly on the stop signal task, men showed greater activation of several brain regions (e.g., bilateral medial frontal cortex and cingulate cortex, globus pallidus, thalamus, and parahippocampal gyrus) during the task, compared to women. The authors concluded that men needed more 'neural resources' to perform comparably to women, suggesting greater impulsivity in men. In a follow-up study, the authors tested 20 additional participants and examined sex differences in the combined sample (Li et al., 2009). In this analysis, men showed greater regional brain activation during inhibitory successes compared to inhibitory errors whereas women showed greater activation during inhibitory errors compared to successes. This latter pattern may reflect greater performance monitoring and affective response to error in females. Huster, Westerhausen, and Herrmann (2011) used fMRI and electrophysiology to assess brain activity in men and women while they performed a tactile stop signal task. Although there were no differences in performance, men displayed greater functional lateralization compared to females. The authors conclude that men experience a greater need for interhemispheric interaction, resulting in a 'degradation of information'. This might represent a neuroanatomical factor contributing to greater inhibitory difficulty in men compared to women. In a re-analysis of data taken from five previous studies, Garavan, Hester, Murphy, Fassbender, and Kelly (2006) compared brain activation in men and women during performance of a go/no-go task. Here, greater activation during the task was observed in women, in 14 clusters located bilaterally in the middle frontal gyrus, inferior

parietal lobule, right superior, middle, and inferior temporal gyri, thalamus, lentiform, and cerebellum. In sum, there do appear to be sex differences in neural activation during performance of behavioral control tasks, but specific brain regions and the direction of the differences are mixed. As with the behavioral studies, there again seems to be an influence of task. Here, men show greater neural activation while performing stop signal tasks, while women show greater activation on a go/no-go task.

6.2.2 Substance abusers—Several studies have examined impulsive action specifically in male and female substance users and abusers. These studies typically match men and women on severity of drug use, although studies with drinkers report greater alcohol consumption in heavy drinking men compared to heavy drinking women. Even so, among heavy drinkers, women exhibit poorer inhibitory control than men. For instance, in a stop signal task, female heavy drinkers exhibited longer SSRTs compared to both heavy drinking males and light drinkers of both sexes (Nederkoorn, Baltus, Guerrieri, & Wiers, 2009). Similarly, Townshend and Duka (2005) observed an interaction between sex and binge drinker status on the CPT. Here, female binge drinkers committed more inhibitory failures compared to both male binge drinkers and male or female non-binge drinkers. A similar pattern has been observed in adolescent smokers. Specifically, Fields, Collins, Leraas, and Reynolds (2009) found a significant interaction between sex and smoker status in stop signal performance: female smokers were more impulsive than male smokers, whereas among nonsmokers, males were more impulsive than females. The same study found that males committed more errors of commission on the CPT, but this was unrelated to smoking status. Reynolds et al. (2007) also examined impulsive action on a modified stop task in adolescent smokers. In this study, male smokers were less impulsive than male non-smokers, but no significant sex differences were observed. The authors suggest that smokers may have been less impulsive on the stop task due to the facilitative effects of nicotine on behavioral control. Smoking prior to the study was not regulated, and a significant negative association was observed between breath carbon monoxide levels (an indicator of recent nicotine consumption) and SSRT, such that more recent nicotine consumption predicted less impulsive action. Finally, van der Plas, Crone, van den Wildenberg, Tranel, and Bechara (2009) found no sex differences in stop task performance in alcohol, cocaine, and methamphetamine abusing adults and controls. Taken together, these studies suggest that among heavy drinkers and smokers, women exhibit greater impulsive action than do men; whereas among non-substance abusers, men tend to be more impulsive.

7. Summary

Overall, the evidence for sex differences in impulsive action is mixed. In laboratory animals, males tend to be more impulsive than females, especially when sex hormones are taken into account. In humans, the differences vary depending on the task. In CPT and go/no-go tasks, when impulsive action is measured as absolute number of inhibitory failures, men show greater impulsivity. By contrast, on stop signal tasks, when stimulus presentation is adjusted to maintain a 50% inhibition rate, women require more time to inhibit a prepotent response. In neuroimaging studies, in which task performance is matched between men and women, greater brain activation is observed in women on go/no-go tasks, whereas greater activation

in men is observed on stop-signal tasks. Finally, among substance abusers, women show greater impulsive action, regardless of the type of task administered.

7. Sex differences in impulsive choice

7.1 Laboratory animals

Few preclinical studies have directly compared male and female laboratory animals on measures of delay discounting (see Table 2). Koot, van den Bos, Adriani, and Laviola (2009) assessed delay discounting in mice under mild food restriction (i.e., 90% ad libitum body weight), and divided the sample into 'steep' and 'flat' discounters based on a median split of the discounting curve. Among the 'steep' discounters, females showed a lower preference for delayed rewards compared to males, suggesting greater impulsive choice in females. In an earlier study using rats, van Haaren, van Hest, and van de Poll (1988) also showed that females were more impulsive on a delay discounting task than males. Perry, Nelson, Anderson, Morgan, and Carroll (2007) compared male and female rats bred for high saccharin intake (HiS) and low saccharin intake (LoS) in discounting for both food and cocaine reward. In the food reward condition, LoS females were more impulsive than LoS males, but in the cocaine reward condition males and females did not differ. The authors suggest that this could be due to pharmacological effects of cocaine administration on impulsivity. A second study by this group examined impulsive choice in relation to different stages of cocaine seeking and self-administration in rats (Perry, Nelson, & Carroll, 2008). Here, no sex differences were observed in impulsive choice for food rewards, or in the association between impulsive choice and acquisition of cocaine self-administration. However, high impulsive females showed greater cocaine reinstatement compared to both high impulsive males and all low impulsive animals. Taken together, these studies provide evidence for greater impulsive choice in female laboratory animals, and initial evidence that impulsive choice is associated with greater reinstatement of cocaine seeking in females.

7.2 Humans

Information regarding sex differences in impulsive choice in humans has come almost exclusively from post hoc analyses. Although results have been somewhat inconsistent, the majority of these studies suggest greater impulsive choice in women (see Table 2). Using hypothetical delay discounting measures, studies have found steeper discounting in women (Beck & Triplett, 2009; Smith & Hantula, 2008). Similarly, women discounted more steeply on a procedure in which it was possible to receive one of their choices, based on the roll of a die (Reynolds et al., 2006). By contrast, Kirby and Marakovic (1995) reported no sex differences on a hypothetical discounting task, but slightly steeper discounting in men on a task involving real money (although the sex difference was not significant). A second study showed that when participants were told they would be entered into a lottery and could potentially win money based on their choices, men discounted more steeply, especially at higher reward values (Kirby & Marakovic, 1996). Sex differences have been examined for discounting of other types of rewards as well. Logue and Anderson (2001) investigated discounting of rewards related to university administration (i.e., departmental funds), in university administrators at three different levels of experience (i.e., new fellows, experienced fellows, and provosts). Across the three groups, women discounted at a

significantly higher rate than men. Kirby et al. (2002) found that in a sample of Tsimane' Amerindians of the Bolivian rain forest, women discounted slightly more steeply (although not statistically significant) for both money and candy. In sum, human studies of impulsive choice suggest that women show greater impulsive choice for hypothetical rewards, whereas men may show greater impulsive choice for actual rewards.

7.2.1 Neuroimaging—Little is known regarding sex difference in brain activity related to impulsive choice. Peper et al. (2013) used tract-based diffusion tensor imaging and magnetization transfer imaging to examine the quality of frontostriatal white matter tracts as a predictor of delay discounting of hypothetical rewards. Sex hormones (testosterone and estradiol) were also examined as predictors of both functional connectivity and impulsive choice. Results showed greater discounting in men compared to women. Sex hormones were not associated with delay discounting performance in either sex (although testosterone levels were associated with greater diffusion of the frontostriatal tract in men only). In sum, this study provides evidence for greater discounting of hypothetical rewards in males (in contrast to previous studies), but no evidence for a direct link between sex hormones and impulsive choice in either men or women.

7.2.2. Substance abusers—A few studies have examined sex differences in impulsive choice in substance using populations. For instance, Heyman and Gibb (2006) assessed delay discounting for actual and hypothetical rewards in smokers, chippers, and non-smokers. Overall, women tended to discount more on the hypothetical task, and this was true across smoking groups. By contrast, men discounted more in the real money task, but this difference was not significant, and it did not differ by smoking group. Two studies found no sex differences in delay and probability discounting in adolescent and adult smokers (Reynolds, Karraker, Horn, & Richards, 2003; Reynolds, Richards, Horn, & Karraker, 2004). Finally, in a study examining individuals at risk for alcohol dependence (i.e., family history positive; FHP), Petry, Kirby, and Kranzler (2002) found that FHP women discounted more steeply than family history negative (FHN) women, whereas FHP and FHN men did not differ. Overall, sex differences in impulsive choice do not appear to differ between smokers and non-smokers. By contrast, greater impulsive choice might be associated with increased genetic risk for alcoholism specifically in women.

8. Summary

Evidence for sex differences in impulsive choice generally points towards greater impulsivity in females. In laboratory animals, studies consistently show greater delay discounting in females. In humans, the direction of sex difference often depends on whether the discounted reward is hypothetical (greater discounting in women) or real money (greater discounting in men.

8. Potential explanations for observed sex differences

In sum, sex differences in behavioral measures of impulsivity vary depending on both the construct assessed and the task used. These sex differences can be interpreted in terms of several psychological theories regarding sexual differentiation. In an excellent recent

review, Cross, Copping, and Campbell (2011) discuss the major theoretical predictions for sex differences across three components of impulsivity: reward sensitivity, punishment insensitivity, and effortful control. They consider these processes in terms of evolutionary theory (Daly & Wilson, 1983), three-factor theories (Cloninger, 1987), and reinforcement sensitivity theories (Gray, 1970), and find that all three theories predict greater reward sensitivity and punishment insensitivity in men, and greater effortful control in women. For instance, evolutionary theory predicts that men will exhibit greater reward sensitivity because their reproductive success depends on dominance, competition for mates, and ability to hunt. By contrast, it predicts that women will be more sensitive to punishment and exhibit greater effortful control because their reproductive success depends on avoiding harm to themselves and their children, and on controlling their impulses in favor of the needs of their offspring. Three-factor and reinforcement sensitivity theories make similar predictions based on associations between impulsivity components and psychiatric disorders. That is, greater reward sensitivity and punishment insensitivity are observed in psychopathy (a disorder most often seen in men), whereas greater sensitivity to punishment is observed in anxiety disorders (predominately female disorders).

Task-specific sex differences in the behavioral measures reviewed here (i.e., greater impulsive action in men on go/no-go tasks but not stop tasks, and steeper discounting in men for real rewards but not hypothetical rewards) can be considered in terms of these three components. For instance, greater reward sensitivity in men could explain their steeper discounting for real rewards. By contrast, discounting tasks using hypothetical rewards might be less sensitive measures. Additionally, greater inhibitory errors on go/no-go tasks in men could be due to insensitivity to punishment from such errors. By contrast, punishment sensitivity is less relevant to stop task performance, as the task is programmed to maintain error rates around 50% and participants are typically instructed that inhibitory errors will be frequent. Finally, effortful control differs between go/no-go and stop tasks. In go/no-go tasks, effortful control must be exerted to postpone response execution until after the stimulus has been processed as go or no-go. By contrast, all stimuli in stop signal tasks are go signals, and thus effortful control is needed only if and when the stop signal is presented. As such, women may be better able to exert effortful control over the processing of stimuli in go/no-go tasks, but less able to exert control to heed a stop signal presented after a go response has already been initiated.

8. Implications for drug abuse

The studies reviewed here suggest that impulsivity might be a stronger predictor of drug abuse in females than in males. In laboratory animals, females show greater impulsive action when responding for cocaine (Anker et al., 2008), and impulsive choice is a stronger predictor of cocaine reinstatement in females (Perry et al., 2008). As such, greater impulsivity could be a contributing factor to the greater vulnerability to drug abuse observed in female laboratory animals. In human substance users, women tend to be higher in impulsive action than men. This could suggest that impulsive action is a stronger predictor of drug abuse for women than men, or alternately it could be that women are more sensitive to the chronic effects of drugs on impulsive action. Indeed, cortical thickness is greater and brain activation is lower in frontal regions of adolescent female binge drinkers compared to

males, and both of these are associated with deficits in cognitive performance (Squeglia, Schweinsburg, Pulido, & Tapert, 2011; Squeglia et al., 2012). Although these studies do not allow for causal inferences, it is possible that women might be more sensitive to the long-term adverse consequences of heavy drinking, including impairments in behavioral inhibition (i.e., greater impulsive action). This could contribute to the telescoping phenomenon observed in women. That is, greater vulnerability of inhibitory control to chronic drug abuse in women could result in a faster progression to 'loss of control' over drug intake.

9. Limitations and future research

There are several clear gaps in the literature to date regarding sex differences in impulsivity. Most notably, only a handful of studies have directly compared males and females in either impulsive action or impulsive choice. As such, the majority of comparisons are made post hoc, with unequal numbers of males and females, and no attempts to equate the sexes on other demographic variables, including age, education, or race. Further, very few studies consider the role of sex hormones. There is some evidence to suggest hormones are influential in sex differences in impulsive action (Bayless et al., 2012; Colzato et al., 2010; Jentsch & Taylor, 2003), and these preliminary studies emphasize the importance of more fully probing the role of sex hormones in impulsivity in both males and females.

More direct assessments are also needed to test for sex differences in the association between impulsivity and drug abuse. Initial evidence from both laboratory animals and humans suggests that this association might be stronger in females than in males. However, longitudinal studies of associations between externalizing disorders (characterized by deficits in behavioral inhibition) in childhood and alcohol use in early adolescence suggest a stronger association in boys compared to girls (Hicks et al., 2007; King, Iacono, & McGue, 2004; McGue, Iacono, Legrand, Malone, & Elkins, 2001). By contrast, in a sample of 43,093 adults, Dawson, Goldstein, Moss, Li, and Grant (2010) observed a stronger association between externalizing psychopathology and alcohol dependence in women. It will be important to conduct longitudinal studies examining sex differences in behavioral measures of impulsivity (i.e., below the threshold criteria for diagnosable disorders) as predictors of drug abuse. This could help to provide a better understanding of such prospective relationships and to clarify conflicting findings. Further, longitudinal studies will also be needed to determine the degree to which greater impulsive action observed in female substance abusers is a cause or consequence (or both) of drug use.

In sum, the current knowledge regarding sex differences in impulsivity and associations between impulsivity and drug abuse is lacking. Well-controlled, adequately powered studies are necessary to gain a more complete picture of the degree to which males and females differ in behavioral components of impulsivity. This will provide much needed information regarding the degree to which men and women might differ in specific risk factors for drug abuse and dependence, thus allowing for more specific prevention and treatment efforts for both sexes.

Acknowledgments

Role of funding sources

This research was supported by National Institute on Drug Abuse Grants DA002812 and DA032015 (HdW) and F32 DA033756 (JW). NIDA had no role in the study design, interpretation, writing the manuscript, or the decision to submit the paper for publication.

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Highlights

- In laboratory animals and humans, females tend to discount more steeply than males.
- In laboratory animals, males tend to show greater impulsive action than females.
- In humans, sex differences in impulsive action depend on tasks and subject samples.
- Among heavy drinkers and smokers, women show greater impulsive action than males.

Table 1

Sex differences in behavioral measures of impulsive action

Subjects (M:F)	Measures	Results	Reference
Laboratory Animals			
Rats (24:24)	5-CSRTT	M>F	Jentsch & Taylor (2003)
Rats (10:10)	Go/no-go		Anker et al. (2008)
	(food reward)	-	
(23:19)	(cocaine reward)	F>M	
Rats (10:9)	5-CSRTT	M>F	Bayless et al. (2012)
Rats (11:12)	2-CSRTT		Burton & Fletcher (2012)
	(long ITI)	F>M	
Mice (27:27)	5-CSRTT		Papaleo et al. (2012)
	(long ITI)	-	
	(stress)	M>F	
	(food ad lib)	M>F	
Humans			
Healthy adults (97:133)	Go/no-go	M>F	Saunders et al. (2008)
Healthy adults (30:50)	Stop task	F>M	Morgan et al. (2011)
Healthy adults (16:16)	Stop task	F>M (in follicular phase only)	Colzato et al. (2010)
Healthy adults (51:48)	Go/no-go	-	Reynolds et al. (2006)
	Stop task	-	
Healthy adults (18:50)	Go/no-go	-	Fernie et al. (2010)
	Stop task	-	
Binge drinkers (23:15)	CPT	F>M	Townshend & Duka (2005)
Non-binge drinkers (13:21)	CPT	-	
Heavy drinkers (16:15)	Stop task	F>M	Neederkoorn et al. (2009)
Light drinkers (15:15)	Stop task	-	
Substance dependent and healthy adults (60:74)	Stop task	-	van der Plas et al. (2009)
Adolescent smokers (17:33)	Stop Task	F>M	Fields et al. (2009)
Adolescent non-smokers (17:33)		M>F	
Adolescent smokers and non-smokers (34:66)	CPT	M>F	
Adolescent smokers and non-smokers (25:26)	Stop Task	-	Reynolds et al. (2007)
Healthy children (14:18)	Go/no-go	M>F	Liu et al. (2013)
Healthy children and adolescents (7176:7212)	Stop task	F>M	Crosbie et al. (2013)
Children w/ADHD (772:325)	CPT	M>F	Hasson & Fine (2012)

M>F=males more impulsive than females; F>M=females more impulsive than males; - =no sex difference. 5-CSRTT=5-choice serial reaction time task; 2-CSRTT=2-choice serial reaction time task; CPT=continuous performance task

Table 2

Sex differences in behavioral measures of impulsive choice

Subjects (M:F)	Measures	Results	Reference
Laboratory Animals			
Rats (8:8)	DD (food)	F>M	van Haaren et al. (1988)
Rats (HiS) (9:10)	DD (food)	-	Perry et al. (2007)
Rats (LoS) (10:10)		F>M	
Rats (23:24)	DD (cocaine)	-	
Rats (81:88)	DD (food)	-	Perry et al. (2008)
Mice (12:12)	DD (food)	F>M	Koot et al. (2009)
Humans			
Healthy adults (95:121)	DD (hypothetical money)	F>M	Beck & Triplett (2009)
Healthy adults (23:31)	DD (hypothetical money)	F>M	Smith & Hantula (2008)
Healthy adults (51:48)	DD (chance for real money)	F>M	Reynolds et al. (2006)
Healthy adults (11:10)	DD (hypothetical money)	-	Kirby & Marakovic (1995)
(10:8)	DD (real money)	M>F (ns)	
Healthy adults (303:318)	DD (chance for real money)	M>F	Kirby & Marakovic (1996)
University administrators (50:27)	DD (hypothetical departmental funds)	F>M	Logue & Anderson (2001)
Tsimane' Amerindians (73:74)	DD (real money)	F>M (ns)	Kirby et al. (2002)
	DD (real candy)	F>M (ns)	
Adult smokers and non-smokers (37:34)	DD (hypothetical money)	F>M [a]	Heymann & Gibb (2006)
	DD (real money)	M>F (ns)	
Adult smokers and non-smokers (29:25)	DD (real money)	-	Reynolds et al. (2004)
	PD (real money)		
Adolescent smokers and non-smokers (27:28)	DD (real money)	-	Reynolds et al. (2003)
	PD (real money)		

M>F=males more impulsive than females; F>M=females more impulsive than males; - =no sex difference. DD=delay discounting, PD=probability discounting, HiS=high saccharin intake, LoS=low saccharin intake; ns=non-significant;

[a]=p-value of .06