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The Effects of Social Contact on Drug Use: Behavioral Mechanisms Controlling Drug Intake

Justin C. Strickland and **Mark A. Smith**
Department of Psychology and Program in Neuroscience, Davidson College

Abstract

The social environment plays a critical role in determining the likelihood that an individual will use drugs or will develop a drug use disorder. Recent evidence obtained from preclinical studies reveals that proximal social factors (i.e., those factors that are immediately present at the time of drug exposure) exert a particularly strong influence on both drug-seeking and drug-taking behavior. These studies are advancing our understanding of the role of the social environment in drug use by showing that the rewarding and reinforcing effects of drugs depend on (1) whether other individuals are immediately present and (2) whether those individuals are also using drugs. Furthermore, the preclinical literature examining the role of social learning in behavior maintained by nondrug reinforcers reveals a number of behavioral mechanisms by which social contact may influence drug use, as well as potential ways the social environment may be modified to prevent or reduce drug use. Additional research is needed to determine potential age and sex differences in the effects of social contact on drug use, to determine the generality of the current findings across different pharmacological classes of drugs, and to determine the role of social contact on drug intake during different transitional stages of drug use disorders; however, enough evidence now exists to begin implementing social interventions in clinical and at-risk populations.

Keywords

conditioned place preference; self-administration; social; social learning; drug use

Drug use is mediated by both genetic and environmental factors, and the interplay of these factors determines the likelihood that a person will develop a drug use disorder. Twin and adoption studies have revealed an especially important role for the individual's environment, with some studies reporting that up to the 88% of the variance in drug use can be explained by post-gestational environmental influences (see review by Hopfer, Crowley, & Hewitt, 2003). A number of these influences may be found in an individual's social environment, and these influences may increase or decrease the risk that an individual will use drugs and/or develop a drug use disorder. For instance, social isolation and social ridicule are associated with higher rates of drug use (Aloise-Young & Kaeppner, 2005; Pearson et al., 2006; Rusby, Forrester, Biglan, & Metzler, 2005), whereas social competence and strong familial ties are associated with lower rates of use (Barnes & Farrell, 1992; Barnes, Reifman, Farrell, & Dintcheff, 2000; Dorius, Bahr, Hoffman, & Harmon, 2004; Pandina,

Corresponding Author: Mark A. Smith, Ph.D., Department of Psychology, Box 7037, Davidson College, Davidson, NC 28035-7037, Phone: 704-894-2470, Fax: 704-894-2512, masmith@davidson.edu.

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Labouvie, Johnson, & White, 1990; Scheier, Botvin, Diaz, & Griffin, 1999). Thus, at the broadest level, the social environment serves as the context in which drug use occurs, providing the antecedent conditions under which drug use is established and maintained.

In recent years, there has been a rapid increase in the number of studies that have examined the role of the social environment in drug use. Several comprehensive literature reviews have recently been published, and those reviews explore the role of social context in drug use (Badiani, 2013), the epidemiology of drug use across different populations (Merikangas & McClair, 2012), preclinical models of drug use and the social environment (Neisewander, Peartree, & Pentkowski, 2012), and the neurobiological mechanisms that mediate the effects of the social environment on drug use (Bardo, Neisewander, & Kelly, 2013). The primary objective of this review is to explore the behavioral mechanisms by which social contact may influence drug use by carefully examining the effects of social learning on behaviors related to drug use.

The Role of Proximal Social Contact in Drug Use

Some of the most convincing evidence for the role of social factors in drug use may be gleaned from epidemiological studies examining the concordance rate of drug use among members of peer groups. These studies have consistently revealed that one of the most reliable predictors of whether an adolescent or young adult will use drugs is whether his or her friends use drugs (Bahr, Hoffmann, & Yang, 2005; Simons-Morton & Chen, 2006; Walden, McGue, Iacono, Burt, & Elkins, 2004). Such findings suggest that proximal social factors (i.e., factors that are immediately present at the time of drug use) may be as important, and possibly more important, than distal social factors (i.e., factors that are present in an individual's broader social environment, but may not be immediately present when drug use occurs) in determining whether an individual will use and abuse a particular drug. In adolescents, for example, social pressure exerted by an individual's friend who is offering drugs at a party (a proximal influence) may be a much stronger determinant of drug use than parental advice or community outreach initiatives that emphasize social engagement in the context of an abstinence-based lifestyle (distal influences).

Social learning models of behavior (also known as socialization models) posit that attitudes and behaviors held by a social group are actively transmitted and diffused among its individual members (see reviews by Andrews & Hops, 2010; Kandel, 1986; Pandina, Johnson, & White, 2010). Specifically, members of a group model group-accepted behaviors, leading other members of the group to imitate those behaviors. Additionally, behaviors adhering to group norms are selectively reinforced, whereas those that deviate from these standards are punished. Thus, according to these models, drug use is established through the imitation of peer-modeled drug use and then maintained by social reinforcement from peers; in contrast, abstinence-related behaviors are punished or otherwise extinguished (Akers, 1977).

Research examining the role of social learning in drug use is limited. Ethical constraints limit the degree to which drug use, particularly illicit drug use, can be modeled and reinforced in human participants. Animal studies have historically focused on the role of distal social factors on measures of drug self-administration and drug-seeking behavior. These models have typically shown good concordance with human epidemiological studies, reporting that social stress and isolation reliably increase drug intake whereas social enrichment reliably decreases drug intake (see reviews by Miczek, Yap, & Covington, 2008; Stairs & Bardo, 2009). The primary limitation of these models is that animals are typically removed from the social environment during behavioral testing, and thus the social manipulation is not immediately present at the time of drug exposure.

Recently, researchers have begun developing preclinical models by which proximal social factors may be examined under controlled laboratory conditions. These studies represent some of the first studies to manipulate social factors that are immediately present at the time of drug exposure and/or drug intake. Most of these models have used either the conditioned place preference procedure or the drug self-administration procedure to determine the effects that these factors have on measures of drug-seeking and drug-taking behavior, respectively. These studies are advancing our understanding of the role of social contact in drug use by showing that the rewarding and reinforcing effects of drugs depend on (1) whether other individuals are immediately present and (2) whether those individuals are also using drugs.

Social Contact and Drug-Seeking Behavior: Conditioned Place Preference

The conditioned place preference (CPP) procedure measures the positive affective states produced by a stimulus and is often used to measure drug-seeking behavior in pharmacological research. In this procedure, a Pavlovian association is formed between a stimulus (e.g., an interoceptive drug cue, a social peer) and a distinctive environmental context (e.g., one compartment of a two-compartment test chamber). Conditioning trials consist of exposing an experimental animal to the stimulus in one context, and withholding the stimulus in a second context. After conditioning, the subject is given free access to both contexts under stimulus-free conditions, and the time spent in each context is measured. If the subject expresses a preference for the stimulus-paired environment over the control environment, then the stimulus is assumed to have produced a positive affective state in the animal. In the context of drug research, a drug-induced CPP is suggestive of a drug's rewarding effects and hence its abuse potential (see reviews by Bardo & Bevins, 2000; Tzchentke, 2007).

Multiple studies have demonstrated the rewarding effects of peer-peer interactions as assessed by the CPP procedure, and several of these studies are summarized in Table 1. For instance, rats housed in isolation develop a CPP to an environment paired with an active social partner; however, this effect is abolished if the partner is rendered unresponsive by injections of scopolamine (Calcagnetti & Schechter, 1992). These effects are observed in both males and females, and in both adolescents and adults, with the most robust effects observed in adolescent males (Douglas, Varlinskaya, & Spear, 2004). These effects are also apparent in golden hamsters, with the greatest effects seen when socially dominant hamsters are conditioned with a subordinate partner (Gil, Nguyen, McDonald, & Albers, 2013). Similar to the dose-dependent effects of drugs in the CPP procedure, there is also a "dose-dependent" effect of social contact in this procedure. For example, only two conditioning sessions were required to establish a CPP when rats were given full access to a social partner; however, eight conditioning sessions were required if they were given only limited access to the partner through a mesh barrier (Peartree et al., 2012). Similarly, a robust CPP was established when rats were separated from their partners by steel bars, but a CPP failed to be established if social contact was prevented by a glass partition, or when only olfactory cues were present during conditioning (Kummer et al., 2011). Collectively, these studies suggest that the rewarding effects of social contact increase proportionally with the degree of social contact, with greater degrees of contact engendering greater levels of preference.

Recently, investigators have used the CPP procedure to investigate the interactions between the rewarding effects of drugs and social contact, and several of these studies are summarized in Table 2. In one of the first studies to examine these interactions, Thiel, Okun, and Neisewander (2008) reported that a low dose of cocaine (2 mg/kg) and a low number of social pairings (two sessions) failed to produce a CPP when each was conditioned alone; however, a robust CPP was observed when the two stimuli were conditioned together, and similar findings were reported in a follow-up study using nicotine (Thiel, Sanabria, &

Neisewander, 2009). Mice conditioned with a social partner developed a more robust CPP to methamphetamine (Watanabe, 2011) and morphine (Cole, Hofford, Evert, Wellman, & Eitan, 2013; Watanabe, 2013), but strain differences are occasionally noted (e.g., Kennedy, Panksepp, Runckel, & Lahvis, 2012). Interestingly, the enhancement observed with methamphetamine was only apparent when the social partner was also treated with methamphetamine; if the partner was treated with saline, only a small CPP was observed. Collectively, these studies reveal that drug and social rewards can interact in an additive fashion when the two stimuli are conditioned together, suggesting that drug use is more rewarding in the presence of peers compared to when drugs are used alone.

In contrast to that observed when drugs and social partners are conditioned together, competing effects may be observed if they are conditioned separately (also summarized in Table 2). In these types of studies, an interoceptive drug cue is conditioned in one context, whereas a social partner is conditioned in a second context. Under these conditions, individually housed adolescent rats develop a CPP to a social partner when the alternative is amphetamine; however, these effects are not apparent in socially housed adolescents or adults (Yates, Beckmann, Meyer, & Bardo, 2013). Recent studies have also revealed that conditioning with a social partner can reverse a previously established CPP to cocaine (Fritz et al., 2011a; Fritz, Klement, El Rawas, Saria, & Zernig, 2011b), and these effects may be observed in as little as two conditioning sessions (Fritz et al., 2011a). Furthermore, conditioning with a social partner during a series of cocaine extinction sessions can prevent the later reinstatement of a cocaine-induced CPP (Fritz et al., 2011a, El Rawas et al., 2012), a model of drug-induced relapse in the CPP procedure. These findings suggest that the rewarding effects of social contact may “outweigh” the rewarding effects of drug use, especially if the two behaviors occur under mutually exclusive conditions and must compete with one another for expression (Fritz et al., 2011a; 2011b).

Social Contact and Drug-Taking Behavior: Drug Self-Administration

The drug self-administration procedure is the most common method by which the reinforcing effects of drugs are examined in the laboratory. In this procedure, drug administration is contingent on an operant response (e.g., pressing a response lever, licking a drinking spout). A drug functions as a positive reinforcer if it maintains responding to a greater degree than the drug’s vehicle (e.g., saline, water). The drug self-administration procedure possesses both face and predictive validity, and drugs that are self-administered by experimental animals also tend to be self-administered by humans (see reviews by O’Brien & Gardner, 2005; O’Connor, Chapman, Butler, & Mead, 2011).

Some of the first studies examining proximal social influences on drug self-administration examined the oral consumption of morphine. Hadaway, Alexander, Coambs, and Beyerstein (1979) reported that isolated rats consumed more of a palatable morphine-sucrose solution during a 24-hr/day two-bottle choice procedure than socially housed rats, and this effect was observed in both males and females. These findings were confirmed in follow-up studies, in which isolated rats drank more of a morphine solution than socially housed rats, but did not drink more of a control solution (Alexander, Beyerstein, Hadaway, & Coambs, 1981; Raz & Berger, 2010). These studies suggest that social contact decreases the self-administration of morphine without altering other types of consummatory behaviors.

Recent studies have revisited the role of proximal social contact on measures of drug self-administration, and several of these studies have reported that social contact increases drug intake, at least under some conditions. Table 3 summarizes many of the studies that have examined the effects of social contact on drug self-administration. Newman, Perry, and Carroll (2007) examined the oral consumption of phencyclidine (PCP) in pairs of rhesus

monkeys housed side-by-side in modular cages that permitted either no social contact (via a solid partition) or limited social contact (via a grid partition). Monkeys self-administered significantly more PCP on both fixed ratio and progressive ratio schedules of reinforcement when permitted limited social contact with their partner during the daily self-administration sessions. Gipson et al. (2011) reported similar findings in one of the few studies examining the effects of social contact on intravenous drug self-administration. In that study, rats self-administering amphetamine were presented with an unfamiliar rat without access to the drug behind a clear partition. Presentation of the unfamiliar rat increased responding maintained by a high dose of amphetamine; however, this effect dissipated with repeated pairings and was not observed with a lower dose of amphetamine. Similar effects have also been reported for nicotine, with social contact both facilitating the acquisition of nicotine self-administration and increasing subsequent nicotine intake (Chen, Sharp, Matta, & Wu, 2011).

The majority of research examining proximal social influences on drug self-administration has examined ethanol, and several of these studies have also reported that social contact increases ethanol intake. Table 4 summarizes studies that have examined the effects of social contact on ethanol self-administration. In a classical conditioning procedure during which an ethanol sipper (the conditioned stimulus, CS) predicted social contact with a same-sex peer (the unconditioned stimulus, US), more ethanol was consumed when the sipper was paired with social contact than when the sipper was presented alone (Tomie, Uveges, Burger, Patterson-Buckendahl, & Pohorecky, 2004b). These effects could not be attributed to nonspecific increases in consummatory behavior, because these effects were not replicated when water served as the CS. These findings were replicated and extended in a second study, which showed that the effect was dose-dependent, with greater increases in ethanol consumption occurring at higher concentrations of ethanol (Tomie, Burger, Di Poce, & Pohorecky, 2004a). Increases in ethanol consumption were also observed in previously isolated rats that were transferred to social housing conditions, and these increases developed in as little as eight days after transfer (Weisinger, Denton, & Osborne, 1989). It is important to note that not all studies have reported elevations in ethanol intake in socially housed animals, with some studies reporting suppression of intake in socially housed animals (Deatherage, 1972; Ehlers, Walker, Pian, Roth, & Slawecki, 2007) or variable effects depending on the duration of the housing manipulation (McKenzie-Quirk & Miczek, 2008) and social rank of the subject (Pohorecky, 2006, 2008).

A series of studies have examined the effects of social contact with an ethanol-exposed peer on subsequent ethanol seeking and ethanol self-administration. For instance, social contact with an intoxicated same-sex sibling increased subsequent ethanol self-administration in male and female rats, and this effect increased with greater exposure to the sibling (Hunt, Holloway, & Scordalakes, 2001; Hunt, Lant, & Carroll, 2000). Similarly, Honey, Varley, and Galef (2004) reported that rats housed with an ethanol-consuming partner consumed more ethanol in a two-bottle choice test (ethanol vs. water) than rats housed with a partner that consumed only water. It is important to note that mere exposure to an ethanol cue is not sufficient to increase ethanol consumption. Fernandez-Vidal and Molina (2004) exposed rats to an active intoxicated peer, an anesthetized intoxicated peer, or an ethanol-scented cotton surrogate, and then later tested their preference in a two-scent olfactory test (ethanol vs. vanilla). They reported that the tendency to prefer vanilla was only reduced when the rats were exposed to an intoxicated active peer, suggesting that social interaction with an intoxicated peer, as opposed to merely the presence of an intoxicated peer, is critical in determining what effects social contact will have on subsequent preference for ethanol.

Prairie voles are unique laboratory subjects because they are socially monogamous rodents that form long-lasting pair bonds with either same-sex or opposite-sex conspecifics. Using this species, Anacker, Loftis, Kaur, and Ryabinin (2011a) measured ethanol consumption in

same-sex siblings during a 24-hr, unlimited access two-bottle choice test (ethanol vs. water). Siblings housed together exhibited greater preference for ethanol over water than siblings housed separately. Moreover, ethanol consumption was highly correlated between siblings when they were housed together but not when they were housed separately. In a follow-up study, Anacker, Loftis, and Ryabinin (2011b) examined imitation-like behavior in pair-housed prairie voles in a two-bottle choice test (ethanol vs. water). In that study, baseline-drinking levels were used to assign subjects a housing partner with either similar or dissimilar levels of ethanol intake. When high-drinking voles were assigned to a high-drinking partner, their ethanol intake and ethanol preference remained high; however, when they were assigned to a low-drinking partner, their ethanol intake and ethanol preference decreased to match that of their partner. These findings suggest that the behavior of a peer, as opposed to merely the presence of a peer, is the critical factor determining how social housing will influence ethanol self-administration.

The importance of a peer's behavior on drug intake was recently demonstrated by Smith (2012) in pair-housed rats self-administering cocaine. In that study, pair-housed rats were tested in custom-built, operant conditioning chambers that allowed two rats to self-administer cocaine in the same chamber, separated only by a grid partition. For some pairs of rats, both rats had simultaneous access to cocaine; for other pairs of rats, only one member of the pair had access to cocaine. Relative to isolated control rats, cocaine self-administration was facilitated in rats paired with a self-administering companion, but cocaine self-administration was inhibited in rats paired with a companion without access to cocaine. Interestingly, in rats without access to cocaine, responding on an inactive lever mimicked the pattern of responding by their self-administering companion. Collectively, these data suggest that a partner's behavior (i.e., whether or not they are also self-administering a drug) determines whether drug self-administration will be facilitated or inhibited by social contact.

Behavioral Mechanisms Controlling Drug Intake

The preclinical literature examining social learning in animals is extensive, and many of the seminal studies in the field were conducted well over 50 years ago. The majority of this research has focused on the acquisition of behavior maintained by nondrug reinforcers; however, a careful examination of this literature reveals several behavioral mechanisms by which social contact may influence drug-seeking and drug-taking behavior. These behavioral mechanisms are not mutually exclusive of one another, and all likely contribute to the transmission of drug use behaviors within groups. These mechanisms are listed and described in Table 5.

Imitation and Modeling

Although there is continuing debate over how to define true imitation (see reviews by Heyes, 1994; Kymissis & Poulson, 1990), most descriptions of imitative behavior are characterized by repeating a novel behavior for which there is no instinctive drive (Thorpe, 1963). In the laboratory, imitation is often demonstrated when a subject acquires a novel response at a faster rate after viewing an experienced model. For instance, naïve cats learn a series of food-reinforced responses (e.g., pushing a lever, rotating a turntable) at a faster rate if they are first allowed to observe an experienced model, and the magnitude of this effect increases as the number of viewing opportunities increases (Herbert & Harsh, 1944). These effects are not limited to positively reinforced behaviors, because similar effects are observed in cats learning a shock-avoidance task (John, Chesler, Bartlett, & Victor, 1968) and rats learning a candle-flame avoidance task (Bunch & Zentall, 1980). Under conditions in which the response topography is preserved between the model and observer, as is typically the case in drug use, other types of learning phenomena (e.g., social facilitation,

stimulus enhancement) may be ruled out (Akins & Zentall, 1996). For example, adolescents and young adults often imitate the drug use behavior of their peers, mimicking not only the selection of a particular drug, but also mimicking the response topographies demonstrated by other group members (Harocopos, Goldsamt, Kobrak, Jost, & Clatts, 2009).

Social Reinforcement

Once established, a number of mechanisms may serve to maintain drug use within a peer group. Social reinforcement includes the primary reinforcing effects of social contact, but also includes various words and actions that are directed from one individual to another in the form of attention, praise, and nonverbal gestures. It is well established that animals will learn an operant response that is reinforced only by the opportunity to interact with another animal. For instance, rats will learn a novel lever-pressing response that produces access to a social partner but no other maintaining event (Angermeier, 1960). These effects are observed even if responding produces only the visual stimulus of another rat and physical contact is prevented, suggesting that the mere presence of another animal is sufficient to produce reinforcing effects. Moreover, when the reinforcing effects of social contact are compared with the reinforcing effects of food, no significant differences are observed if the stimuli are tested under similar conditions of deprivation and reinforcer duration (Evans et al., 1994). Thus, if participation within a group is contingent on using a drug, then the social contact provided by that group may be sufficient to maintain drug use as long as the group remains functionally intact. Under these conditions, the drug use of individual group members may be particularly resistant to treatment, especially if using drugs is also reinforced by praise and other positive actions by the group.

Social Facilitation

Under some conditions, drug use may be increased by the mere presence of others, especially if they are also using drugs. It is well established that the presence of a social partner can increase arousal and thereby increase activity and contact with environmental contingencies, a phenomenon known as social facilitation. For instance, dogs tested in the presence of other dogs display increased activity and are faster to open a goal box containing a food reward than dogs tested in isolation (Vogel, Scott, & Marston, 1950). Similarly, rats tested in the presence of another rat show increased locomotor activity and higher rates of food-reinforced lever pressing than rats tested in isolation (Gardner & Engel, 1971). It is believed that social facilitation selectively increases the rate of high-probability behaviors at the expense of low-probability behaviors (Zajonc, 1965), and several pieces of evidence support this hypothesis. For instance, rates of lever pressing are facilitated by social contact in well-trained, water-deprived rats in which lever pressing (maintained by water presentation) is a high-probability behavior (Levine & Zentall, 1974); however, acquisition of the same lever-pressing response is inhibited if social contact occurs at the start of training (before rats have learned the operant contingencies) when lever pressing is a low-probability behavior (Zentall & Levine, 1972). Of particular relevance to drug use is evidence that social facilitation is enhanced if both individuals are performing the same behavior. For instance, food-reinforced key pecking in pigeons is suppressed in the presence of a stimulus that signals the delivery of an electric shock. This suppression is eliminated (i.e., key pecking is facilitated) in the presence of another pigeon if that pigeon is performing the same key-pecking response, but not if that pigeon is performing a dissimilar response (Hake & Laws, 1967). Taken collectively, these data suggest that drug use is facilitated in individuals with an established history of drug use (i.e., when it's a high-probability response) when they are in the presence of others, and this facilitation is likely to be further enhanced if those other individuals are also using drugs.

Local Enhancement

In any social group, experienced drug users may draw attention to places and locales in which drug use is likely to be rewarded through a process called local enhancement. In this process, an experienced demonstrator draws a subject's attention to a location where operant responding is likely to be reinforced. For instance, ducks learn to escape through a hole in their pen by observing other ducks only when they are in close physical proximity to the escaping ducks, suggesting that nearness to the hole is responsible for the learned response (Lorenz, 1937). Social groups that tend to meet at bars, pubs, and similar locations may facilitate drug use among their individual members by placing them in close physical proximity to places in which drug use is a high-probability event that is likely to be reinforced.

Stimulus Enhancement

Whereas local enhancement refers to increased attention to a general location, stimulus enhancement refers to increased attention to a particular object. For example, marmosets that observe a demonstrator open an artificial fruit later manipulate the artificial fruit to a greater extent than marmosets that do not observe the demonstration or that observe only a partial demonstration (Caldwell & Whiten, 2004). Similarly, hand-raised goslings that observe a human tutor open a box are more likely to learn the task and make more contacts with the lid latch than goslings that do not observe a tutor (Fritz, Bisenberger, & Kotrschal, 2000). In the context of drug use, it is well established that drugs and the stimuli associated with their use acquire increased salience and induce subjective states of craving in drug-experienced individuals (Carter & Tiffany, 1999; Zhao et al., 2012). In fact, exposure to drug-related cues is often used to reinstate drug-seeking behavior after a period of abstinence in animal models of drug use (Epstein, Preston, Stewart, & Shaham, 2006; Shaham, Shalev, Lu, De Wit, & Stewart, 2003). In social groups where drug use is common, individual group members who repeatedly use drugs may increase the salience of drug-related cues (i.e., they draw attention to drug-related cues and increase the stimulus control exerted by those cues) for other group members, thereby contributing to further drug use and an increased likelihood of relapse in vulnerable individuals.

Emulation

An additional mechanism by which drug use may be transmitted within a group is through emulation, a process in which individuals learn operant contingencies by observing others, but in which they develop novel behavioral strategies to produce similar consequences. In goal emulation, an individual observes the action of a demonstrator, but uses a different sequence of responses to produce the same result. For instance, nonhuman primates will often use tools after seeing other primates successfully use tools, but they will use the tools in novel ways to obtain the same goal (Call, Carpenter, & Tomasello, 2005; Nagell, Olguin, & Tomasello, 1993; Tomasello, Davis-Dasilva, Camak, & Bard, 1987). In much the same way, human drug users may develop novel methods of drug administration after observing the consequences of drug administration in their peers. This may explain why members of some peer groups may all prefer a similar drug (e.g., cocaine), but individual members of the group may develop their own preferred route of administration (e.g., snorting vs. smoking vs. injecting).

Peers as Discriminative Stimuli

If the social environment serves as the context in which drug use occurs, then individuals from that environment may serve as discriminative stimuli signaling that drug use will be reinforced. Studies have shown that rats will run to a food-baited platform faster when tested in the presence of a social partner signaling the availability of food than when tested alone

(Holder, 1958). These effects cannot be explained by merely the presence of another rat, because rats run slower to a platform in the presence of a social partner signaling the absence of food (i.e., extinction). Furthermore, the behavior of the social partner can also function as a discriminative stimulus. For instance, pigeons can learn a follow-the-leader task in which reinforcement is contingent on one bird (i.e., the follower) repeating a sequence of actions performed by the other bird (i.e., the leader). In this scenario, key pecking exhibited by the leader serves as the discriminative stimulus that controls the key pecking exhibited by the follower (Skinner, 1962). Similarly, chain pulls by one monkey can serve as a discriminative stimulus signaling the availability of food for another monkey, and manipulations that decrease the rate of responding by the demonstrator produce corresponding decreases in the rate of responding by the observer (Danson & Creed, 1970). In regard to drug use, these data suggest that manipulations that increase or decrease drug use in some group members will likely produce corresponding increases or decreases in the drug use of other members.

Peers as Conditioned Reinforcers

If some individuals are consistently present during episodes of drug use, then those individuals may become conditioned (or secondary) reinforcers because of their association with the unconditioned (or primary) reinforcing effects of drugs. For instance, rats trained to associate one group of social partners with food, and another group of social partners with the absence of food, respond more rapidly when lever pressing produces social contact with the rats associated with food than those associated with the absence of food (Holder, 1958). In other words, establishing an association between food and a social partner increases the reinforcing strength of social contact with that partner. In much the same way, associations between the unconditioned effects of drugs and the individuals present at the time of drug administration may increase the reinforcing strength of social contact with those individuals. Once this occurs, an individual may seek the presence of those social partners in much the same way that he or she seeks the effects produced by drugs.

Reinforcement Enhancement

A final mechanism by which drug use may be maintained within a peer group is by reinforcement enhancement. It is well established that in addition to their primary reinforcing effects, many drugs can increase or enhance the reinforcing effects of other stimuli. For instance, nicotine increases responding maintained by an audiovisual stimulus, and this effect is observed whether nicotine is administered contingently or noncontingently (Donny et al., 2003). This reinforcement enhancing effect is observed with many drugs of abuse (see review by Phillips & Fibiger, 1990), and may extend to the reinforcing effects of social contact as well. In this scenario, the reinforcing effects of social contact would be amplified by concurrent drug use, which would preferentially increase involvement in groups where drug use is common. This effect may also be bidirectional. In other words, social contact may also increase the primary reinforcing effects of some drugs. This may explain why some drugs are abused in human populations but are not self-administered in the laboratory when subjects are tested in isolation (e.g., LSD, psilocybin).

Translational Implications

The preclinical literature provides ample evidence that proximal social factors related to social contact directly impact drug-seeking and drug-taking behaviors. Additionally, studies examining social learning in laboratory animals provide a number of behavioral mechanisms by which drug use may be established, maintained, and transmitted within peer groups. For example, experienced group members may model drug-use behavior and less experienced group members may then imitate these behaviors. If drug use is normative for a group,

individual members may then reinforce this behavior in the form of social contact or through explicit praise. For groups in which drug use is already common (i.e., a high-probability event), social facilitation may exacerbate drug-seeking and drug-taking behaviors within individual members. Group participation may also bring individuals into contact with locations in which drug use is both a high probability event and likely to be reinforced. Similarly, social contact with individuals that use drugs enhances the salience of drugs and drug-related stimuli, which increases the probability of use and the likelihood of relapse in recovering individuals. When individuals observe other members reacting positively to the effects of a drug, they may emulate those effects through novel behaviors that are likely to achieve similar results. If drug use is repeatedly and consistently reinforced in the presence of some group members, then those members may become discriminative stimuli signaling that drug use will lead to positive consequences, which will serve to increase drug use in other group members. Moreover, these same individuals that are present during episodes of drug use may become conditioned reinforcers through their association with drugs, which serves to further increase social contact with these individuals. Finally, the primary reinforcing effects of both drug use and social contact may be mutually enhanced when drugs are used in the presence of others, which serves to both increase drug use by individual members and to strengthen social contact with the group.

On a more promising note, a careful examination of the preclinical literature also reveals ways in which the social environment may be changed to reduce drug use and prevent drug abuse. For instance, social peers could be recruited to model abstinence-related behaviors, reinforce these behaviors in other individuals, and punish drug-use behaviors (see Lerman & Vorndran, 2002, for a discussion of the use of punishment in applied situations). Supporting this possibility are studies showing that age-matched, social-peer role models are better than older adults at changing attitudes and behaviors regarding drug use in adolescent and young adult populations (Campbell et al., 2008; Cuijpers, 2002; Tobler et al., 2000). Additionally, the introduction of new members to a group who abstain from drug use could inhibit drug use and dampen the impact of social facilitation by other group members that actively use drugs.

Social groups could also be encouraged, possibility by direct invitation, to meet at locations and participate in programs that are incompatible with drug use, such as community centers, religious institutions, and after-school programs. Participation in such programs would also reduce exposure to drug-using individuals, thereby reducing the salience of drugs and removing many of the cues that are predictive of relapse to drug use. Such programs would also provide nondrug social activities and a rewarding alternative to drug use that would compete with drug use for behavioral expression. In fact, many studies have shown that participation in community, religious, and after-school activities is associated with lower rates of drug use in adolescent and young adult populations (Brown, Parks, Zimmerman, & Phillips, 2001; D'Amico et al., 2012; Mellor & Freeborn, 2011; St. Pierre, Kaltreider, Mark, & Aikin, 1992; Tebes et al., 2007).

Exposure to individuals who participate in activities that are incompatible with drug use (e.g., academics, sports) may also encourage the development of novel behaviors that are incompatible with drug use but are nonetheless rewarding. These individuals would also serve as discriminative stimuli to signal that drug use will not be reinforced through social praise or social engagement (in behavioral terms, these individuals would function as an S^{Δ}, a discriminative stimulus signaling extinction and the absence of response-contingent reinforcement). Furthermore, as long as abstinent-related behaviors were reinforced in the presence of these individuals, they would also become conditioned inhibitors of drug use. Finally, these individuals may enhance the primarily reinforcing effects of behaviors that are incompatible with drug use. Indeed, individuals are more likely to engage in physical

activity, participate in religious organizations, and attend self-help groups targeting drug use (e.g., Alcoholics Anonymous, Narcotics Anonymous), if they do so with a friend or social peer (Gunnoe & Moore, 2002; Kelly, Myers, & Brown, 2005; Salvy et al., 2009; Whitehead & Biddle, 2008). We emphasize that many of these translational implications are speculative; however, enough epidemiological data now exist to begin testing specific hypotheses addressing the behavioral mechanisms responsible for the effects of social contact on drug use.

Future Directions

The literature examining the role of proximal social factors in drug use is limited, and additional preclinical research will be needed to guide the development of clinical interventions. For instance, very few studies have examined the effects of social contact on drugs other than alcohol and psychomotor stimulants. Cannabis is the most widely used illicit drug in Europe and North America, yet we know of no studies that have examined how social contact influences the intake of its primary psychoactive component (delta-9-tentrahydrocannibinol) in traditional measures of drug self-administration. Likewise, very little data exist on how social contact influences the self-administration of many emerging drugs of abuse, such as mephedrone, methylenedioxypyrovalerone (MDPV), and the synthetic cannabinoids (i.e., “K2”, “spice”). Given that social patterns of drug use vary across different drugs (Hanson, Venturelli, & Fleckenstein, 2011), it is likely that that the effects of social contact on measures of drug self-administration will also vary across pharmacological classes.

Similarly, few studies have examined how age and sex influence the effects of social contact on measures of drug self-administration, but the data that exist suggest there may be relevant differences across populations. For instance, it is well established that adolescents exhibit a more robust CPP for social interaction than adults (Douglas et al., 2004; Van den Berg et al., 1999), and it was recently reported that only adolescents preferred a compartment paired with social interaction over a compartment paired with amphetamine (Yates et al., 2013). At least one study reported that males show a more pronounced CPP for social interaction than females under similar conditions (Douglas et al., 2004), but females are more sensitive than males to the facilitatory effects of social interaction on voluntary ethanol consumption (Maldonado, Finkbeiner, & Kirstein, 2008). This latter finding is particularly relevant in light of studies showing that females have higher rates of drug self-administration than males (Lynch & Taylor, 2004; Roth & Carroll, 2004). Sex differences in drug self-administration are often attributed to gonadal hormones and frequently vary as a function of the estrous cycle (see review by Evans & Foltin, 2010), but we do not know how hormones modulate the effects of social contact on drug self-administration. Furthermore, almost all of the studies conducted to date have used same-sex dyads when examining the effects of social contact on measures of drug self-administration. The one study that did examine opposite-sex dyads reported that the facilitatory effects of social interaction on ethanol consumption depended on the sex of the social partner (Hostetler, Anacker, Loftis, & Ryabinin, 2012). Given the commonality of male-female dyads in human populations, particularly in smaller and more intimate social groups, further research is needed on how social contact with opposite-sex partners influences measures of drug intake.

Finally, most studies examining the effects of social contact on measures of drug self-administration have only examined the maintenance of stable patterns of drug intake. This limits the translational appeal of this literature because it fails to take into account the dynamic changes in drug intake that occur during different transitional stages in the development of, and recovery from, drug use disorders. Investigators are now using the drug self-administration procedure to model the initiation of drug use, the escalation of drug use

over time, the compulsive patterns of drug use that occur during an extended binge, and the reinstatement of drug use after a period of abstinence (see review by Smith & Lynch, 2012). To date, it is unknown how social contact might influence drug use during each of these transitional stages; however, this knowledge will be necessary in order to develop effective social interventions to prevent or reduce drug use in human populations.

Conclusion

Preclinical studies now indicate that social contact can influence the likelihood that an individual will use a particular drug. Multiple studies using both the conditioned place preference procedure and the drug self-administration procedure reveal that proximal social factors (i.e., those factors that are immediately present at the time of drug exposure) modulate both the drug-seeking and drug-taking behavior of laboratory animals. These studies indicate that the presence of other individuals, and the behavior of those individuals (i.e., whether or not they are also using drugs), determine whether drug use will increase or decrease by social contact. Moreover, studies using nondrug reinforcers reveal a number of behavioral mechanisms by which drug use may be established, maintained, and transmitted between members of a social group. Notably, these same studies also reveal potential ways in which social interventions may be used to reduce drug use and the resulting harm. Further research will be necessary to determine the effects of social contact on drug intake for drugs other than alcohol and stimulants, in populations that differ in age and sex, and during different transitional stages of drug use disorders; however, enough is now known to begin the process of designing and implementing social interventions in clinical and at-risk populations.

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Table 1

Effects of Social Contact on Peer Conditioned Place Preference

Study	Subjects	Social Manipulation	Peer CPP Outcome
Calcagnetti & Schechter 1992	Wistar rats (M & F; adol)	Partner awake vs. anesthetized	CPP only with awake partner
Douglas et al. 2004	SD rats (M & F; adol & adult)	Housing condition	CPP most robust in isolated, M, & adol subjects
Kummer et al. 2011	SD rats (M; adult)	Partition type	CPP with steel bars or no partition only
Peartree et al. 2012	SD rats (M; adol)	Partition type & # of pairings	More peer access needed fewer pairings
Gil et al. 2013	Golden hamsters (M; adult)	Social rank	CPP greatest in dominant subject paired with subordinate partner

Note. M = male subject; F = female subject; SD = Sprague-Dawley; adol = adolescent subject.

Table 2

Effects of Social Contact on Drug Conditioned Place

Study	Subjects	Drug Dose	Pairings	Drug CPP Outcome
Concurrent Pairings				
Thiel et al. 2008	SD rats (adol)	COC 2 mg/kg (ip)	2	Enhanced
Thiel et al. 2009	SD rats (adol)	NIC 0.1 mg/kg (ip)	2	Enhanced
Kennedy et al. 2012	BALB/cJ & C57/BL6 mice (adol)	MORP 0.25–5 mg/kg (sc)	4	Enhanced (C57); inhibited (BALB)
Watanabe 2011	C57/BL6 mice (adult)	METH 2 mg/kg (ip)	3	Enhanced (w/drug-treated partner)
Cole et al. 2013	C57/BL6 mice (adol)	MORP 10–40 mg/kg (sc)	6	Enhanced (w/drug-treated partner)
Watanabe 2013	C57/BL6 mice (adult)	MORP 0.1–3 mg/kg (ip)	3	Enhanced
Competing Pairings				
Fritz et al. 2011a	SD rats (adult)	COC 15 mg/kg (ip)	4	Prevented reinstatement & reversed
Fritz et al. 2011b	SD rats (adult)	COC 15 mg/kg (ip)	4	Reversed
El Rawas et al. 2012	SD rats (adult)	COC 15 mg/kg (ip)	4	Prevented reinstatement
Yates et al. 2013	SD rats (adol & adult)	AMP 1 mg/kg (sc)	4	Inhibited (in adol)

Note. CPP = conditioned place preference; SD = Sprague-Dawley; adol = Adolescent subject; ip = intraperitoneal; sc = subcutaneous; COC = cocaine; NIC = nicotine; MORP = morphine; METH = methamphetamine; AMP = amphetamine; Concurrent Pairings = social contact in same environment as drug administration; Competing Pairings = social conditioning in different environment than drug administration. All subjects were male. All outcomes for CPP are for the indicated conditioned drug.

Table 3

Effects of Social Contact on Drug Self-Administration

Study	Subjects	Drug Dose	Test	Social Manipulation	Drug Intake Outcome
Hadaway et al. 1979	Wistar Rats (M & F, adult)	MORP 0.15–0.5 mg/ml (oral)	24-hr two bottle choice	Housing condition	Decreased intake in socially housed
Alexander et al. 1981	Wistar Rats (M & F, adult)	MORP 0.15–1.0 mg/ml (oral)	24-hr two bottle choice	Housing condition	Decreased intake in socially housed
Raz & Berger 2010	Wistar Rats (M & F, adol)	MORP 0.5 mg/ml (oral)	24-hr two bottle choice	Housing condition	Decreased intake in socially housed
Newman et al. 2007	Rhesus Monkeys (M & F, adult)	PCP 0.125–1.0 mg/ml (oral)	Concurrent FR16 & PR	Social v isolated self-administration	Increased intake during social sessions
Chen et al. 2011	SD Rats (M & F, adol)	NIC 15–30 μg/ml (iv)	FR10 & PR	Peer use behind Plexiglas partition	Increased acquisition & intake with peer present
Gipson et al. 2011	SD Rats (M, adult)	AMPH 0.01–0.1 mg/ml (iv)	FR5	Peer nonuse behind Plexiglas partition	Increased intake with peer present (high dose)
Smith 2012	LE Rats (M, adult)	COC 0.03–1.0 mg/kg (iv)	FR1 & PR	Self-administration behavior of peer	Increased (peer use) or decreased (peer nonuse)

Note. M = male subject; F = female subject; SD = Sprague-Dawley; LE = Long-Evans; adol = adolescent subject; MOR = morphine; PCP = phencyclidine; NIC = nicotine; AMPH = amphetamine; ETOH = ethanol; COC = cocaine; iv = intravenous; FR = fixed ratio; PR = progressive ratio.

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Table 4

Effects of Social Contact on Ethanol Self-Administration

Study	Subjects	Dose (Oral)	Partner Manipulation	ETOH Intake
Deatherage 1972	LE rats (M, adult)	10–20% v/v	Housing condition	Highest in isolated subjects
Weisinger et al. 1989	SD rats (M, adult)	10% v/v	Housing condition	Highest in socially housed subjects
Hunt et al. 2000; 2001	SD rats (M & F, adol)	5.6% v/v	Intoxication of partner	Increased with intoxicated partner
Fernandez-Vidal & Molina 2004	Wistar rats (M, adol)	Ethanol Cue	Intoxication of partner	Increased with intoxicated partner
Honey et al. 2004	LE rats (M & F, adol)	8% v/v	Ethanol use of partner	Increased with partner use
Tomie et al. 2004a,b	LE rats (M, adult)	3–16% v/v	Partner paired with ETOH CS	Increased with partner pairing
Pohorecky 2006; 2008	LE rats (M, adult)	6–10% v/v	Social rank & housing	Highest in socially housed subordinates
Ehlers et al. 2007	Indiana P & NP Rats (M, adult)	10% v/v	Housing condition	Highest in isolated subjects
McKenzie-Qurik & Miczek 2008	Squirrel monkeys (M & F, adult)	2% w/v	Social rank & housing	Highest in socially housed subordinates
Anacker et al. 2011a	Prairie voles (M & F, adult)	10% v/v	Housing condition	Highest in socially housed subjects
Anacker et al. 2011b	Prairie voles (M & F, adult)	10% v/v	Consumption level	Social pairs matched consumption

Note. M = male subject; F = female subject; SD = Sprague-Dawley; LE = Long-Evans; adol = adolescent subject; ETOH = ethanol; CS = conditioned stimulus.

Table 5

Behavioral Mechanisms Underlying the Effects of Social Contact on Drug Use

Behavioral Mechanism	Influence on Drug Use
Imitation & Modeling	Initiation of drug use by mimicking others; mimicking drug-use topographies of others
Social Reinforcement	Participation in group is dependent on drug use; social attention or praise encourages drug use
Social Facilitation	Increase in high-probability drug-use behaviors in the presence of others using drugs
Local Enhancement	Increase in time spent in environments where drug use is common and likely to be reinforced
Stimulus Enhancement	Increase attention paid to drugs, drug-related paraphernalia, and drug-associated stimuli
Emulation	Novel drug-use behaviors are acquired to achieve similar states of intoxication of others
Peer as Discriminative Stimuli	Peers provide a signal that drugs are available and that drug use will be reinforced
Peers as Conditioned Reinforcers	Peers act as secondary reinforcers to strengthen social contact with groups that use drugs
Reinforcement Enhancement	Bidirectional increase in the reinforcing efficacy of social contact and drug use