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Alcoholics Anonymous and Twelve-Step Recovery: A Model Based on Social and Cognitive Neuroscience

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Background: In the course of achieving abstinence from alcohol, longstanding members of Alcoholics Anonymous (AA) typically experience a change in their addiction-related attitudes and behaviors. These changes are reflective of physiologically grounded mechanisms which can be investigated within the disciplines of social and cognitive neuroscience.
Objective: This article is designed to examine recent findings associated with these disciplines that may shed light on the mechanisms underlying this change.
Method: Literature review and hypothesis development.
Results: Pertinent aspects of the neural impact of drugs of abuse are summarized. After this, research regarding specific brain sites, elucidated primarily by imaging techniques, is reviewed relative to the following: Mirroring and mentalizing are described in relation to experimentally modeled studies on empathy and mutuality, which may parallel the experiences of social interaction and influence on AA members. Integration and retrieval of memories acquired in a setting like AA are described, and are related to studies on storytelling, models of self-schema development, and value formation. A model for ascription to a Higher Power is presented.
Conclusion: The phenomena associated with AA reflect greater complexity than the empirical studies on which this article is based, and certainly require further elucidation. Despite this substantial limitation in currently available findings, there is heuristic value in considering the relationship between the brain-based and clinical phenomena described here.
Scientific Significance: There are opportunities for the study of neuroscientific correlates of Twelve-Step-based recovery, and these can potentially enhance our understanding of related clinical phenomena. (Am J Addict 2013;XX:1–8)

INTRODUCTION

Addiction is a chronic illness subject to relapse. Because of this, providing long-term support for remission is a key element in how our society can address this major public health problem. At present, Twelve-Step fellowships provide such a resource and, importantly, place no requisite cost burden on government, insurers, or individual members. Alcoholics Anonymous (AA), which originated in 1935, is the source of this format for recovery, with some two million members' worldwide and 200,000 weekly meetings.[1] Narcotics Anonymous, which employs the same Twelve-Step format, reports over 58,000 meetings worldwide.[2]

This article is framed to suggest possible links to the way certain biologically grounded mechanisms, empirically derived, can play a role in the way that such fellowships achieve their effectiveness. For this, we will turn to a body of research of relatively recent origin which can be broadly subsumed under the rubric of social and cognitive neuroscience.[3] This discipline draws on basic biological mechanisms to explain the way both cognitive processes and social interaction underlie much of the behaviors observed in numerous species; hominids included.

We will begin with a brief summary of mechanisms directly associated with the disease of addiction, to distinguish the pathological process itself from a hypothesized model of the reparative process that can take place among AA members. We will then describe empirical findings related to the processes of mirroring and of mentalizing[4] which allow for understanding another person's experience as it relates to empathic encounter; these can be subsumed under a broader approach, termed Theory of the Mind. This then leads to an examination of how new memories that relate to the cognitive aspects of the Twelve-Step process can be laid down and integrated into broader schemas that represent perspectives on how the recovery process can be achieved. Finally, we will consider the way the aforesaid processes relate to the ritual of storytelling in AA, and the acceptance of a Higher Power by its established members.

To be clear, many of the biological processes described here have been studied with regard to stimuli and responses much less complex than those incorporated in an elaborate social structure like AA. Their applicability to AA itself may therefore draw on additional brain sites relevant to these broader issues.

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The brain mechanisms engaged in the AA context should indeed be subject to further investigation. The model presented here, however, can have heuristic value in developing a way to consider how the Twelve-Step process can be understood as grounded in bio-behavioral mechanisms. This explication can thereby provide clinicians with an approach to understanding a valuable resource they can employ in helping their patients, one whose underlying mechanisms are compatible with our current understanding of addiction as a biologically grounded process. This can be useful because many clinicians may hesitate to employ an adjunct to treatment until it is shown to draw on specific biological mechanisms. Such an explication may, as well, encourage members of the research community to pursue investigating further how AA's Twelve-Step process can be studied.

THE IMPACT OF DRUGS OF ABUSE ON THE BRAIN

In order to place the issue of long-term abstinence in context, it is useful to distinguish it from our current model of the disease of addiction, which is based on observations that relate primarily to acute drug effects and associated changes in neural function. This latter body of findings is illustrated by, but certainly not limited to, ones derived from imaging studies on the role of dopamine (DA) in the addictive process.

Research over this past decade ensues from initial observations of increases in the concentrations of synaptic DA that take place during drug intoxication. This relates to the vulnerability of succumbing to the addictive process; subjects addicted to a wide variety of drugs have been found to exhibit reductions in D2 DA receptor availability in the striatum during the resting state that persists for months after detoxification.[5] This is also relevant to drug craving, as illustrated by the fact that subjects who show lower DA increases in response to administered amphetamine are more likely to select cocaine over a monetary reinforcement.[6] Volkow et al.[7] pointed out that conditioning triggered by drugs enhances DA signaling, as observed when addicted subjects were exposed to drug-related conditioned cues. Furthermore, this process is likely associated with their deficits in DA activity and an acquired prefrontal and striatal dysregulation.[8] Altogether, it is posited that reward dysregulation consequent from protracted drug use is associated with the midbrain DA area and the structures to which they project, for example, the nucleus accumbens.[8] Much of this is now supported by studies on circuitry reflected in resting functional connectivity and long-term potentiation on memory, which can be predictive of subsequent behaviors.

Comparable neural mechanisms can be affected in a recovery process as well. In the clinical context, for example, smokers can be taught to use cognitive strategies to control craving. When studied in the course of such activity, they have been found to manifest activity in prefrontal areas previously associated with craving, and decreased activity in the limbic centers that are activated during drug use.[9] Such findings may be useful in understanding how to frame psychosocial interventions for addiction. Clearly, significant research on the role played by neurotransmitters other than DA, including glycine, adenosine, and norepinephrine, in addiction is ongoing and is expected to be productive as well. Investigations on the role of GABA receptor agonism in inhibiting alcohol-dependent persons' alcohol consumption,[10] as well as studies on other receptors, can be revealing in terms of relevant mechanisms.

SOCIAL AND COGNITIVE NEUROSCIENCE

The aforesaid findings on direct drug effects, however, cannot fully explain the processes associated with the impact of social and cognitive input embodied in experiences such as membership in a Twelve-Step program. Certainly, AA engages mechanisms that reflect symbolic thinking and affiliative processes that impinge on pathologic changes that may have resulted from chronic alcohol use. For example, we found that AA members' experience of alcohol craving was inversely proportional to the intensity of the affiliative experience in the fellowship.[11] Our purpose here is therefore to consider how involvement in such a social context can have an impact on the biologically grounded processes described above.

Over the course of engagement into membership in AA, addicted people acquire an understanding of their illness and means to cope with it based on the fellowship's precepts. Neural mechanisms which mediate this process can be considered from the perspective of social and cognitive neuroscience, disciplines which have emerged over the last two decades.[3] In recent years, this area of empirical research has been greatly enhanced by the availability of functional magnetic resonance imaging (fMRI), which allows for determining which brain regions are more active during specific psychological tasks. This technique offers the opportunity to localize brain sites associated with particular activities by detecting changes in blood flow, typically by means of blood-oxygenation-level-dependent contrast. Importantly, it is a non-invasive procedure, and therefore suitable for study on human subjects. It does not, however, necessarily address many of the mechanisms underlying the impact of AA, such as the role of social networks, coping, and self-efficacy.

MIRRORING AND MUTUALITY

Mutuality, rather than self-help, is central to the AA fellowship. This relates to psychological processes that underlie the building of relationships, namely, how a person entering into the AA context connects with other members. Each party in such relationships must be able to resonate in some way with the other's experience, and the ability to understand one's own mental state and its relation to that of another person has been termed mentalizing. This process has been described and explicated on a clinical level in the psychoanalytic literature as related to putative unconscious

mental processes.[12] It has also been applied to psychotherapeutic technique as well.[4]

A more basic neurophysiologic process that may underlie mentalization is the phenomenon of mirroring, which was first observed on a physiologic level in studies on monkeys: Electronic recordings were made of neurons that were activated when a monkey copied the behavior of a person picking up a piece of food.[13] Although the process is complex, and aspects of it are contested, the analogous circumstance has been observed in humans: fMRI imaging has illustrated activity in the inferior frontal cortex and parietal lobe sites when an experimental subject sees another person perform an action.[14] Such observations have been extended to a hypothesized neurobiologic model of self-awareness[15] and empathy, as well.[16]

Stated more fully, mentalizing refers to the ability to recognize one's own and others' mental states, and to see these mental states as separate from behavior. Lombardo et al.[17] undertook a study in which subjects were asked to surmise about either feelings (mentalizing) or physical traits (non-mentalizing) of others, offering the opportunity to bridge the relationship between motoric mirroring and mentalization in the research context. They ascertained multiple cortical sites associated with the process of mentalizing. They suggested that overlapping of such self-other representations is akin to experience sharing, and that this can contribute to a desire to help another person. This process is illustrated when experimental participants watch a person's experience of either pain[18] or reward[19] with engagement of neural structures associated with those states. The process can be predictive of later prosocial behavior. It suggests a way in which shared experience in a setting like an AA meeting can promote behavioral change in a positive direction.

Mutuality can therefore be understood as reflective of brain processes associated with three broad classes of psychological function which have grouped together in demonstrated neurobiologic correlates of empathic responsivity.[20] They are (a) mentalizing (understanding and experiencing another person's mental and emotional state); (b) sharing of self-other representations; and (c) being motivated to improve another person's experiences.

THEORY OF THE MIND AND EMPATHY

Speculation regarding the aforesaid process, often described broadly under a Theory of the Mind, has antecedents in the work of philosophers like Descartes, in dealing with the need to explain the nexus between the fact that the experience of identity and thinking is somehow embodied in the palpable body (i.e., the brain). It has most recently been subject to empirical physiologic studies in its primate antecedents,[21] and in humans it relates to the ability to attribute mental states, such as knowledge, feeling, and attitude, to oneself. Importantly—relative to mentalizing—it is essential to understand and appreciate those states in others, as well.[21,22]

Empathy is a characteristic that is important to a person's comfortable engagement with other AA members. It is essential to establishing a successful long-term relationship between sponsors and sponsees, and a key to a sponsors' guiding their newer members along the arduous passage through the Twelve-Steps, let alone supporting them in their struggle to maintain abstinence. Whereas Theory of the Mind embodies the capacity to take on the perspective of others, empathy connotes more of an emphasis on shared emotions, even a blurring of the line between self and others.

Two types of empathy have been differentiated in fMRI studies: emotional contagion and cognitive perspective taking, and they have been empirically determined to be associated with discretely different cortical sites.[19] There is an interesting evolutionary sequence to the emergence of these functions that reflects on their biological substrates. They emerge sequentially on an ontological level, that is, in the developmental sequence from empathy in the emotional contagion of the infant; then on to the addition of cognitively based empathy in the child. Phylogenically, they evolve from their role from lower species (affective reactivity absent conscious calculation) to the cognitively grounded empathy manifest in humans. Clearly, however, both types of empathy can operate at the same time. For instance, when a speaker at the podium at an AA meeting "qualifies," telling her experiences in the struggle for maintaining abstinence, the empathic listener experiences shared emotion with her. At the same time, the listener integrates the facts of the story into a pattern of recovery, consciously or non-consciously, detecting specific circumstances shared with that speaker. We will consider this further below.

Findings of individual imaging studies have been integrated in a three-dimensional manner by means of the meta-analytic technique of activation likelihood estimation in order to more effectively define the specific cortical sites activated during mentalizing.[23] This has been applied to demonstrate narratives associated with the autobiographical memory in a meta-analysis of imaging studies in which subjects performed either autobiographical or mentalizing tasks.[24] The salience of locating the sites of such functions is underlined by findings on patients with a focal lesion in a particular cortical area that results in impairment of autobiographical memory and in deficits in self-regulation. It has been pointed out that such skills therefore relate to the evolutionary adaptive value of inhibiting inappropriate actions that would compromise successful interactions with others.[25]

INTEGRATION OF MEMORIES

Exposure in the AA program to new information needs to be integrated into a coherent perspective on abstinence. The hippocampus plays a critical role in how such inferential reasoning takes place. Neuroimaging studies provide evidence for this role of the hippocampus in acquiring new memories and their integration, and for retrieval of information on memories of past experiences.[26] Along with hippocampal

activity, activation of the dorsolateral and medial prefrontal cortex has also been observed relative to retrieval of information in humans.[27] These regions may form an integrated network for judging the relationships between remembered but indirectly related stimuli.[28]

Recent findings also support the role of the hippocampus in acquisition of new memories and relational memory processing outside the realm of conscious awareness.[29] These findings suggest that non-conscious phenomena mediated in the hippocampus may ultimately be understood to play a role in the way certain memories are acquired and integrated in social contexts (like AA meetings) where distinct messages are conveyed to participants. These studies have been carried out only on simple stimuli, and other studies may show that response to more complex stimuli engage other or additional neural processes. Nonetheless, further research on mechanisms of integration of input may contribute to a better understanding of how schemas associated with abstinence, as discussed below, are generated.

Procedural memory refers to skills that are executed automatically and unconsciously, as is often the case in habit formation (as distinguished from memory that consists of consciously summed-up recollection). Imaging which is done while such memories are elicited suggests that procedural memory is mediated in the ventral striatum, where elevation of concomitant DA levels may come to bear.[30,31] Notably; learning, memory, and retrieval have been found to take place outside of the awareness of study participants. This has been shown on imaging, of sites associated stimuli involving facial recognition presented to subjects; there was a lack of clear distinctions as to whether recognition was consciously apparent or not consciously apparent.[29] This may relate to how aspects of the Twelve-Step ethos can be acquired in a setting such as an AA meeting by means of a process that takes place outside the awareness of a participant. In this regard, mere passive attendance at meetings, absent speaking with others, may contribute to effecting change.

The transmission of such information and perspectives raises the interesting issue of how such messages are conveyed and embedded in memory in social settings, where a pervasive ideologic orientation is maintained. Robert Lifton, in his discussion of the "brainwashing" of Korean War veterans, described how control over the context of communication under the circumstances of coercion can embed specific beliefs in an individual.[32] Transmission of ideology and integration into a person's memory for later retrieval, however, can also take place in settings where people participate voluntarily. We found this to be the case in religious retreats,[33] where a particular perspective is sustained by virtue of the predominance of believers in such group settings. Indeed, in our studies on Twelve-Step meetings,[11,34,35] we found that the overwhelming majority of participants in given meetings were long-standing, committed members. Such predominance of membership effectively, if tacitly, precludes dissent by participants early in their involvement, and sustains singularity of message.

SCHEMAS

Networks of memories related to thought and future action have been under consideration in the domain of cognitive psychology, going back to the early and mid-twentieth century. Tolman introduced the concept of a hypothesized "cognitive map;"[36] as a basis for inferential reasoning. Such maps were thought to constitute a substrate of mental processing composed of a series of psychological formations which an individual could store, code, and recall. The term "schema" was first applied by Piaget and Kegan[37] in framing a conception underlying such processes. He introduced this latter term in relation to children acquiring new knowledge and integrating it into coherent concepts. Bartlett applied the term schema to a hypothesized entity of past reactions and experiences that can be summed up, for example, in recalling a story.[38] One can surmise how this model of a schema may help to explain the format of recounting one's addiction-related experiences when one addresses a group of AA attendees (i.e., "qualifying," to use AA terminology).

The concept of a schema was carried further by social psychologists prior to the introduction of contemporary somatically grounded study techniques. Markus et al.[39] and Markus[40] considered the model of self-schemas, a network of associations which help define one's concept of one's self, implicitly constructed of generalizations derived from past experiences. They posited that such self-schemas allow for generating responses to social stimuli, and an internal system of knowledge, thought, and behavior that reflect the integration of generalities derived from such prior experiences. This theoretical model, although only early in its development through biological investigation, can be useful in illustrating how sensory input with subsequent memory integration can play a role in rectifying the self-concept of the alcoholic as an obligate drinker.

Once established in memory, schemata may be considered to provide a substrate for dealing with new stimuli and for serving as a basis for associated purposive thought and behavior.[41] While this conception can be used to explain the demonstrated role described empirically for memory integration on the hippocampus, it suggests that broader networks of neural substrate may be enlisted in embodying such schemas within the brain structure. Repeated exposure to perspectives presented in the AA context, validated by the stories characteristic of the practices of that fellowship, may serve to reshape members' self concept to one built around abstinence.

Arbib has referred to studies on neural models of schemas in animals, and there is an emerging body of interest in the role of the hippocampus in the formation of schemas.[42,43] Forbes and Grafman[44] described a related hypothesized model, the Structural Event Complex, in which the left prefrontal cortex serves as a site for integration of meaning between related events. They suggest specific regions in the prefrontal cortex derived from imaging data which underlie an implicit process of schema formation (and Theory of Mind, as well). Nonetheless an elaboration of this model in in vivo human

research awaits further study. The concept, though, may be an important one, because it suggests that there are neural networks in which a conception of the sober self, with associations embedded in it, derived from the AA experience, can play a role in stabilizing the abstinence of established AA members. This could apply, as well, to psychotherapy for addictions in a variety of different modalities. In any case, further insight may be derived from future research on schema theory on the way in which a sober identity is established.

STORYTELLING

We speak of mutuality and social support as key elements in the process of engagement of addicted people into Twelve-Step groups. This culture derives from a number of sources. Bill W, after many attempts at exhortation to turn recalcitrant alcoholics toward abstinence, concluded that the best way to approach them was by telling them his own story. The format of the book, "Alcoholics Anonymous: The Story of How Many Thousands of Men and Women Have Recovered from Alcoholism"[45] was derived from this experience largely as a series of first-person stories of people who found their way to recovery in AA. Sponsors are also encouraged to tell sponsees their own story in the course of engaging them, and for encouraging them to pursue working the Steps. Additionally, the most prominent format for AA meetings is to build the meeting experience around self-disclosure stories of speakers clarifying telling aspects of their recovery to those assembled, and a typology of such stories has been developed.[46] The role of stories in reinforcing meeting participants' acquisition of a shared identity as recovering alcoholics[47] reflects on the importance in shaping the (hypothesized) neuronally grounded personal schemas previously described. Are there central reinforcers for this behavior by storytellers themselves? Interestingly, self-disclosure is strongly associated with increased activation in brain regions in the mesolimbic DA system and, in experimental situations, subjects are willing to forego money in order to disclose about themselves.[48]

PERSONAL VALUES

The Twelve-Step approach to recovery is distinguished from professional, psychosocially grounded modalities like cognitive-behavioral therapy and motivational enhancement in one of its most prominent features: it espouses a system of values that extends beyond abstention from excessive substance use. This is embodied in expectations such as acknowledging the role one has played in problems that were previously ascribed to others (Step 4), and then making amends to those persons compromised by one's behavior (Step 9).

Studies have been undertaken that indicate brain loci associated with management of the social norms that sustain personal values, ones within the prefrontal cortex in particular. Forbes and Grafman[44] reviewed a number of studies in which vignettes involving moral dilemmas and social norms were presented to subjects undergoing brain imaging. They illustrated distinctions made between implicit (non-conscious) and explicit (consciously deliberated) cognitive processes mediated in different cortical areas, with the amygdala additionally involved in implicit processes. Both processes together, however, allow for attribution of meaning to an individual's own experiences and observations. In relation to establishing of Twelve-Step related values, these sites could be understood to contribute to shaping schemas that represent well-learned beliefs and attitudes. Compromise to such schemas is illustrated on a clinical level among brain-damaged patients who have damage in the ventromedial prefrontal cortex. They retain general intelligence and logical reasoning, but have diminished emotional responsivity and a lack in empathy that would otherwise be associated with concern over the interests of others.[49]

Other sites as well are associated with aspects of morally grounded attitudes, such as the concept of helping other alcoholics, with whom an AA member would identify, as in Step Twelve, "to carry this message to [other] alcoholics." One interesting study sheds light on AA members helping alcoholics with whom they identify, versus non-alcoholics toward whom they do not have the same level of commitment. Hein et al.[18] studied the differential in subjects' empathic concern for members of two teams, one for which subjects were fans, and the other members of the opposing team. Activation of the anterior insula was found to be predictive of greater likelihood to help an in-group member (i.e., favored team).[18]

THE ISSUE OF A HIGHER POWER

For many addicted people, AA's expectation of "a decision to turn our will and our lives over to God *as we understood Him*" (Step 3) is difficult to accept. Nonetheless, this conclusion, as it were, is apparently expected as part of the thinking of fully realized members in the fellowship, as we found in our surveys.[11,35] How does this come about?

This is a phenomenon achieved by AA members in different ways. For one way to understand this, however, we can turn to cognitive dissonance theory, which posits that people's attitudes can change when they find themselves adhering to two conflicting positions or sets of values.[50] This is the case for the alcoholics who have begun engagement in AA. They have seen themselves as having the capacity to drink at times, and to avoid drinking at other times. At the same time, they are now beginning to understand that they are "powerless over alcohol" (Step One). There is therefore a dissonance between presumption of self-control and powerlessness over alcohol. The social context of AA, wherein the context of communication is singularly maintained, provides a new construct that relieves this dissonance, namely, the acceptance of a Higher Power that governs and guides an AA member toward a reconstructed abstinent recovery. This acceptance thereby obviates living with two dissonant beliefs, control and lack of control.

Research on mechanisms underlying the theory of cognitive dissonance is now beginning to clarify both the brain sites involved in this clinically derived theory and the mechanisms

associated with it. Imaging studies on experimental subjects have revealed that the anterior cingulate cortex is activated in reconciling conflicting perceived stimuli.[51] This has been considered more broadly to pertain to issues of conflict and cognitive control in relation to brain mechanisms.[52] Furthermore, cognitive dissonance and activation of the anterior cingulate cortex and anterior insula have been associated with negative affect and autonomic arousal.[53] All these imaging-based findings pertain to attitudes generated in a laboratory setting rather than to ingrained dispositional attitudes (like self-image and worldview), but they do suggest the value of further examination of the adaption of a Higher Power as reported by AA members.

A SUMMARY OF THIS MODEL

For purposes of clarity, it is useful to summarize the model described here, admittedly extrapolating from existing findings, and delineating some of the active ingredients in Twelve-Step-based recovery. It is complemented by Table 1, which relates the studies cited to the clinically observed issues discussed. This is designed to show that specific neural phenomena may be considered together to illustrate how AA membership may promote an orientation toward abstinence in a given member; these phenomena relate to both social and cognitive functions. Social issues are reflected in the way mentalization promotes a member's self-awareness; it can also operate with regard to other members, partly reflective of an innate capacity for mirroring, and serving as a basis for sharing of self-other representations with other members. It also supports the development of both empathy and the motivation to help other alcoholics with similar problems. Issues related to cognition include the capacity to respond both consciously and unconsciously to the attitudes and values related to sobriety expressed in the AA social context. In part, this cognitive capacity is associated with the innately rewarding inclination of members toward storytelling about themselves. Memories associated with this cognitive input can be integrated for later retrieval, and this integration associated with focal brain sites serves as a basis for development of a system of values related to autobiographical memory and self-regulation. It also allows for development of a member's new abstinence-oriented self-schema, and the neurally grounded capacity for resolving cognitive dissonance, in this case, through acceptance of a governing Higher Power external to the members themselves.

LIMITATIONS

The circumstances observed among AA members on the clinical level are certainly complex, and deal with a variety of social interactions, attitudes, and mood states. For example, meeting attendees may be conflicted over social and class differences of members, which can impinge on their own ability to identify with the program; they may have to overcome ingrained attitudes that make acceptance of the addictive process as a disease, rather than a personal failing, quite difficult. Additionally, most people who sustain recovery from alcoholism worldwide achieve this without AA. These are just a few of the confounds that relate to such an explanatory model. Furthermore, the range of studies presented here represents only a survey of a number of mechanisms which may bear on the role of AA in stabilizing abstinence in long-term members. A focus on any one of the areas discussed would offer the opportunity to provide greater coherence.

The studies cited in this article only reflect in a limited way on the experiences associated with AA, as they typically employ experimental stimuli presented in laboratory settings where personal and social confounds are minimized. Additionally, many of the mechanisms described here, such as mirroring and mentalizing, operate in normal social interactions as well. Experimental settings cited here are far removed from the real-world situation of an AA meeting. This limitation is illustrated by studies cited here in relation to empathy, where the tasks presented to experimental subjects are based on photographs of facial expressions[19] or simple anecdotes[20]. The study cited here

TABLE 1. Neural sites noted relative to AA-related clinical/behavioral issues

Clinical/behavioral	Neural sites noted	Suggested refs.
Craving, relapse	Midbrain dopamine dysregulation	Volkow et al.[5]
Suppression of craving	Prefrontal activation	Kober et al.[9]
Mirroring	Inferior frontal cortex, parietal lobe	lacoboni et al.[14]
Mentalizing	Multiple cortical sites	Lombardo et al.[17]
Cognitive vs. emotional empathy	Differential cortical sites	Shamay-Tsoory et al.[19]
Memory acquisition, integration, and retrieval	Hippocampus, dorsolateral and medial prefrontal cortex	Zalesak and Heckers,[26] Acuna et al.,[27] DeVito et al.[28]
Unconscious learning	Hippocampus	Hannula and Greene[29]
Procedural memory	Hippocampal-striatal axis	Pennartz et al.[31]
Schema integration	Left prefrontal cortex	Forbes and Grafman[44]
Incentivising, storytelling	Mesolimbic dopamine system	Tamir[48]
Fellow member identification	Anterior insula	Hein et al.[18]
Resolving cognitive dissonance	Anterior cingulate	Kearns et al.,[51] van Veen et al.[52]

on responses to in- and out-group judgments employed attitudes toward a preferred sports team,[18] rather than to a heterogeneous group of unrelated individuals like those who the AA attendee may encounter. Memory tasks involving inference may rely on simple items presented, such as the differential recall of pairings of a human image (a face) and a non-human one (a house).[43] Cognitive dissonance was illustrated by subjects' responses to statements which may be consonant or non-consonant with their level of comfort during an imaging procedure[52], rather than ingrained attitudes reflecting their worldviews. Studies involving moral judgments[44] were typically conducted by presenting simple anecdotes, such as a standard dilemma in which a choice is made regarding differentially avoiding a certain, versus a possible, injury inflicted on others. Additionally, the behavioral and psychological issues related to Twelve-Step involvement for a given individual change over time; these issues may therefore be mediated by a different set of neural networks at different times.

Two groups of investigators[43,44] do suggest specific loci for schema formation based on imaging findings in the prefrontal cortex, indicating potential areas for future study on this complex concept. Nonetheless, the observation made by Arbib on schema-based modeling does apply here: It is only a theory, and can only be considered part of neuroscience when demonstrated in data from human brain mapping, studies on brain lesions, or neurophysiology.[42] We have only begun to meet such criteria, as evident in the fact that the imaging studies cited here have only emerged in the last several years.

GOING FORWARD

There are certainly opportunities to elaborate further on the neurophysiologic aspects of AA based recovery, and to develop a perspective based on research that more accurately reflects the richness of the AA experience. Some examples: studies could be conducted to differentiate longstanding AA members from addicted people who are not in recovery. One hypothesis to be tested is that activation during the presentation of alcohol (or drug) related stimuli to AA members would more likely encompass the brain sites associated with formation of normative values. Studies could also be undertaken on AA members alone. Imaging could be done while members recount or think through experiences associated with their recovery, in order to further define neural sites associated with the "storytelling" in AA. The paradigm applied by Hein et al.[18] on sites associated with empathy could be applied to distinguish the degree of AA members' empathic response to characters in an anecdote about a fellow alcoholic's need for help, as opposed to one on a non-alcoholic's difficulties with a personal problem.

CONCLUSION

In any case, despite the limitation cited, there is merit in considering recent findings of social and cognitive neuroscience like those reviewed here, in relation to the Twelve-Step process, for a number of reasons: To date, there has been little consideration of the neural underpinnings of the role of a spiritually oriented fellowship like AA in the recovery process. A review of biological models such as that presented here can be useful in promoting the development of protocols that better reflect how AA induction actually unfolds. The study of such processes may also have application in clarifying differential outcomes of addicted people treated with pharmacotherapy. For example, we need to better understand why certain opioid addicts successfully maintained on methadone maintenance relapse after discontinuation of their medication and others do not, or how the amethystic effectiveness of a medication such as naltrexone can best be incorporated into a long-term psychosocial regimen for recovery from alcoholism. These problems are well established in the addiction field. There can, however, be heuristic value in an undertaking such as the one outlined here, as it demonstrates that biological processes inherent in the experiential aspects of addiction recovery can have a place in empirically based biomedicine. At present, such value may have less impact on clinical practice than it may contribute to consideration of research options for improving treatment outcome.

Finally, there is value in considering that conceptual bridges can be built between two different communities of caregivers in the addiction field: those involved in empirically oriented addiction biopsychiatry and those who rely primarily on the Twelve-Step approach to recovery. Both groups may question if there are common mechanisms which underlie their respective fields, and the recognition of potential commonalities may yield improvements in the care provided by adherents to both of these respective orientations.

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